The development and testing of a classroom-based intervention targeting working memory, attention and language skills in 4-5 year old children from areas of social disadvantage: a cluster randomised feasibility trial

Volume 1 (of 2)

by

Anita Rowe

BSc. Speech and Language Therapy, University of Ulster, 1995
MSc. Interprofessional Health and Social Care Management, Queen's University Belfast, 2011

Faculty of Life and Health Sciences of

ULSTER UNIVERSITY

Thesis submitted for the degree of

DOCTOR OF PHILOSOPHY

May 2020

I confirm that the word count for this thesis is less than 40,000 words (excluding papers)

Table of Contents

List of Figures x

List of Tables xii

Acknowledgements xiii

Dedication xv

Abstract xvii

Operational Definitions xix

Abbreviations xxii

Chapter 1 - Introduction: study rationale and thesis structure 1

1.1 Introduction 1

1.2 Current issues, policy and practice 2

1.2.1 The prevalence and impact of speech, language and communication needs in children 2

1.2.2 The links between social disadvantage and language disorder 3

1.2.3 National strategy and policy 4

1.2.4 Current models of service provision for children at risk of language disorder 4

1.3 The Northern Ireland context 7

1.3.1 Northern Ireland policy 7

1.3.2 The Regional Integrated Support for Education (RISE) Teams 8

1.3.3 Transdisciplinary teamwork 8

1.3.4 The prevalence of attention difficulties in the classroom for children from areas of social disadvantage and current practice to address them 12

1.4 Factors contributing to attention difficulties in the classroom 13

1.4.1 The importance of working memory ... 15

1.5 Rationale for the current study ... 17

1.6 Aims ... 18

1.6.1 Objectives ... 18

1.7 Study design and methods ... 19

1.8 Structure of thesis ... 19

Chapter 2 - Setting the scene: an overview of working memory, attention and language ... 26

2.1 Introduction ... 26

2.2 Understanding working memory ... 26

2.2.1 Defining working memory ... 26

2.2.2 The Working Memory Model ... 28

2.2.3 Measuring working memory ... 30

2.3 Working memory and attention ... 33

2.3.1 Working memory and attention in the classroom ... 34

2.4 Working memory and language ... 36

2.4.1 Working memory supports language learning and processing ... 37

2.4.2 Language supports working memory ... 38

2.4.3 Working memory and DLD ... 38

2.4.4 The symbiotic relationship between WM, attention and language and implications for practice and research ... 41

2.5 Working memory training and transfer: current evidence and gaps in knowledge ... 42

2.5.1 The effectiveness and feasibility of WM interventions applied in children's everyday contexts ... 43

2.5.2 Underlying mechanisms of transfer 44

2.5.3 Children under 7 years and population sub-groups 47

2.5.4 Features of WM training 48

2.5.5 Summary and implications 49

2.6 Conclusions and gaps in the evidence base 49

Chapter 3 - Design and methods 51

3.1 Introduction 51

3.2 Theoretical frameworks 51

3.2.1 The realist paradigm 51

3.2.2 Complexity theory and the ecological perspective 53

3.2.3 Rationale for the theoretical framework 55

3.3. Study Design 56

3.3.1 Overview of study design 56

3.3.2 Rationale for using a mixed methods, multi-phase design 59

3.3.3 Rationale for using the 6SQuID model (Wight *et al.* 2016) 60

3.4 6SQuID Step 1. Define and understand the problem and its causes 62

3.5 6SQuID Step 2. Clarify which causal or contextual factors are malleable and have the greatest scope for change 63

3.5.1 Systematic review 63

3.5.2 Qualitative study 65

3.5.2.1 Rationale for the qualitative study 66

3.5.2.2 Focus groups 66

3.5.2.3 Thematic analysis 67

3.5.2.4 Trustworthiness 69

3.5.2.5 The socio-ecological model (McLeroy *et al.* 1988) 69

3.6 6SQuID Step 3. Identify how to bring about change: the change mechanism 71

3.6.1 Logic modelling 72

3.7 6SQuID Step 4. Identify how to deliver the change mechanism 75

3.7.1 Co-production 75

3.8 6SQuID Step 5. Test and refine on small scale 77

3.9 6SQuID Step 6. Collect sufficient evidence to justify rigorous evaluation/implementation.. 77

3.9.1 Process evaluation 79

3.10 Integration of mixed methods evidence and data triangulation 81

3.11 Ethical considerations and approval 82

3.12 Limitations 84

3.13 Conclusion 85

Chapter 4 - Systematic review 86

4.1 Introduction 86

4.2 Interventions targeting working memory in 4–11 year olds within their everyday contexts: a systematic review (Paper 1) 87

4.3 Summary of implications for intervention development 88

Chapter 5 - Qualitative Study 90

5.1 Introduction 90

5.2 An exploration of health professionals' and teachers' knowledge, perceptions and practice in relation to working memory when delivering services to children in the classroom (Paper 2) 91

5.3 Summary of implications for intervention development and testing 92

Chapter 6 - Identifying the change mechanism 93

6.1 Introduction 93

6.2 Rationale for developing a theory of change 93

6.3 Aims 96

6.4 Aim 1a. To identify the individual theory of change 97

6.4.1 Methods 97

6.4.2 Results 98

6.4.3 Conclusion – the proposed individual theory of change 99

6.5 Aim 1b. To develop the systems theory of change 100

6.5.1 Methods 100

6.5.2. Results 101

6.5.3 Conclusion – the proposed systems theory of change 107

6.6 The proposed intervention theory of change 108

6.7 Aim 2. To select the executive-loaded intervention components 109

6.7.1 Methods 109

6.7.2 Results 110

6.7.3 Selected components: definitions, theory and evidence 113

6.7.3.1 Direct executive-loaded working memory training 113

6.7.3.2 Phoneme awareness training 116

6.7.3.3 Fantastical play 117

6.8 Aim 3. To develop an initial intervention logic model 118

6.8.1 Methods 118

6.8.2 Results 119

6.9 Limitations 121

6.10 Conclusions 122

Chapter 7 - Intervention co-production 123

7.1 Introduction 123

7.2 6SQuID Step 4. Identify how to deliver the change mechanism 124

7.3 Aims and objectives 126

7.4 Study design 127

7.5 Methods 127

7.5.1 Participants 127

7.5.1.1 Eligibility criteria 127

7.5.1.2 Recruitment and consent 128

7.5.1.3 Sample 129

7.5.2 Data collection 130

7.5.2.1 Workshop schedule 130

7.5.3 Data analysis and interpretation 133

7.6. Ethical approval and considerations 134

7.7 Results: the co-produced classroom-based intervention 135

7.7.1 Overview of classroom-based intervention 135

7.7.2 Structure of RECALL sessions 136

7.7.3 The intervention manual 137

7.7.4 Content, task progression and dosage of directly trained tasks 138

7.7.4.1 Listening recall 138

7.7.4.2 Odd one out 140

7.7.4.3 Phoneme awareness training........ 143

7.8 Refining the intervention logic model 147

7.9. Benefits and limitations of co-production........ 149

7.10 6SQuID Step 5. Test and refine on small scale 151

7.10.1 Aim 151

7.10.2 Methods 152

7.10.3 Results........ 152

7.11 Conclusions........ 153

Chapter 8 - Study protocol for feasibility trial........ 155

8.1 Introduction........ 155

8.2 A classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): study protocol for a cluster randomised feasibility trial (Paper 3)........ 156

Chapter 9 - Findings from feasibility trial 157

9.1 Introduction........ 157

9.2 Findings from a classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): a cluster randomised feasibility trial (Paper 4)........ 157

9.3 Conclusions and implications for RECALL........ 159

9.3.1 Modifying the intervention 159

9.3.2 Proceeding to a full-scale trial 162

Chapter 10 - Conclusions and recommendations........ 165

10.1 Introduction 165
10.2 Unique contributions of this thesis to knowledge, theory and practice 166
10.2.1 Study design and methods 166
10.2.2 The systematic review (Chapter 4) 168
10.2.3 Qualitative study (Chapter 5) 170
10.2.4 Intervention co-production (Chapter 7) 172
10.2.5 Recall to Enhance Children's Attention, Language and Learning 173
10.2.6 Feasibility study (Chapters 8 and 9) 174
10.3 Strengths and limitations of the study 176
10.3.1 Strengths 176
10.3.2 Limitations 178
10.4 Recommendations 180
10.4.1 Recommendations for research 180
10.4.2 Recommendations for policy 182
10.4.3 Recommendations for practice 182
10.5 Dissemination of the findings from the doctoral thesis 183
10.5.1 Written publications 183
10.5.2 Conference presentations 183
10.5.3 Strategic meetings 185
10.5.4 Future dissemination 186
10.6 Conclusion 186
References 188
Appendix A - Confirmation of ethical approval: focus groups and co-production work 236

Appendix B - Confirmation of ethical approval: feasibility study 237

Appendix C - Participant Information Sheet: focus groups (Chapter 5) 238

Appendix D - Participant Information Sheet: co-production work (Chapter 7) 243

Appendix E - Participant Information Sheet: feasibility study - health professionals................ 247

Appendix F - Participant Information Sheet: feasibility study - teachers.................................. 251

Appendix G - Participant Information Sheet: feasibility study - parents and children............... 255

Appendix H - Research Information Leaflet: feasibility study - parents................................... 259

Appendix I - Systematic review supplementary materials 261

Appendix J - TIDIER checklist (Hoffman *et al.* 2014) 278

List of Figures

Figure 1-1 Typical tiered model of SLT service provision (Gascoigne 2006) 5

Figure 1-2 Model of multidisciplinary teamwork (Gascoigne 2006) 10

Figure 1-3 Model of transdisciplinary teamwork (Gascoigne 2006) 10

Figure 2-1 Operational definitions of four aspects of WM 32

Figure 2-2 Task examples for each aspect of WM and the corresponding component of the WM Model (Baddeley and Hitch 1974, Baddeley 2000, 2007) 32

Figure 2-3 Causal pathway required in WM research to demonstrate transfer effects 44

Figure 3-1 Representation of Context-Mechanism-Outcomes (CMO) Framework (Pawson and Tilley 1997) 52

Figure 3-2 Study design based on the Six Steps in Quality Intervention Development model (Wight *et al.* 2016) 58

Figure 3-3 The socio-ecological model (McLeroy *et al.* 1988) 70

Figure 3-4 Template for a basic theory of change logic model 73

Figure 3-5 Template for the theory logic model linking the theory of change to the intervention activities and outcomes 74

Figure 6-1 Context-Mechanism-Outcomes Configuration for the to-be-developed intervention 94

Figure 6-2 The proposed individual theory of change 100

Figure 6-3 Key system factors influencing decision making and service delivery at each level of the socio-ecological model (McLeroy *et al.* 1988) 102

Figure 6-4 The proposed systems theory of change 107

Figure 6-5 The proposed theory of change underpinning the intervention development 108

Figure 6-6 Example of odd one out task with one to-be-remembered location.......................... 115

Figure 7-1 Recruitment and consent process for co-production workshops.............................. 129

Figure 7-2 Cyclical process of co-production workshops 130

Figure 7-3 Structure of RECALL sessions 136

Figure 9-1 Updated CMO framework for RECALL 160

Figure 10-1 Model of the factors impacting on dosage in classroom-based interventions 175

List of Tables

Table 1-1 Thesis Volume 1: structure and relationship of chapters to the 6SQuID model (Wight *et al.* 2016) 20

Table 2-1 Theories of transfer (based on Gathercole *et al.* 2019) 46

Table 3-1 Intervention development approaches (O'Cathain *et al.* 2019a) 61

Table 6-1 Evidential and conceptual statements informing the individual theory of change 98

Table 6-2 The barriers and facilitators to the intervention development and testing and their implications 104

Table 6-3 Potential intervention components and rationale for their inclusion/exclusion 111

Table 6-4 Initial intervention logic model for the to-be-developed intervention (WK Kellogg Foundation 2014) 120

Table 7-1 Overview of co-production workshops 132

Table 7-2 Early, middle and late developing phonemes (Shriberg 1993) 145

Table 7-3 Interim intervention logic model for RECALL (WK Kellogg Foundation 2014) 148

Table 7-4 Alterations made to the RECALL intervention following expert and practitioner review 153

Table 9-1 Refined intervention logic model to inform a full-scale trial of RECALL (WK Kellogg Foundation 2014) 164

Acknowledgements

I would like to express my deep gratitude to my supervisors, Dr Laurence Taggart and Dr Jill Titterington, for their support and encouragement at every step along the way of my PhD journey, both academically and personally. It was a privilege to work with them.

I am indebted to the Research and Development Division of the Public Health Agency Northern Ireland for the doctoral fellowship award that enabled me to complete this study. I am extremely grateful for the opportunity. I would also like to thank the Belfast Health and Social Care Trust for seconding me from my clinical role for the duration of the fellowship. In particular, my thanks go to Felicity Dickson for supporting my secondment.

I am very grateful to Professor Lucy Henry and Dr Joni Holmes for generously sharing their knowledge and expertise with me and for co-authoring two of the papers included in this thesis. Their contributions and insights significantly enriched and enhanced my learning and were very much valued and appreciated. My thanks also go to Professor Mike Clarke and Professor Brendan Bunting for their advice regarding the design and analysis of the feasibility study respectively.

My sincere thanks go to all of the participants in the focus groups, co-production work and feasibility trial aspects of the research. Without their willingness, this study would not have been possible. I am also grateful to the members of the Research Advisory Group who gave freely of their time to support this study, including: Mrs Lisa Montgomery; Mrs Brenda Brown; Miss Joy Irwin; Mr Mark Morgan; Mrs Sarah Denvir; and Professor Tony Cassidy.

I would like to thank the staff of Ulster University, especially those in the Institute of Nursing and Health Research (INHR) and the Doctoral College. I am very grateful to all who provided practical support and assistance over the past three years. My particular thanks go to Julie Cummins, Paul Henry, Lorraine Brownlie and Roger Theis for their administrative support and prompt responses to my emails and queries. My thanks also go to Terry Curran for his help with designing posters for conferences.

Finally, I would like to thank my fellow PhD Researchers within the INHR for sharing the highs and lows of PhD life: Alison Little, Anne Fee, Deirdre Harkin, Nikki Daniels, Rosie Kelly, Beverly Turtle and Zillah Huddleston.

Dedication

I dedicate this thesis to my mother, Edith, who worked hard to ensure I had every opportunity to reach my potential and never doubted my ability to do so. I also dedicate it to my husband, Jonathan, for his love, prayers, support and patience over the past three years.

Abstract

Background: In areas of social disadvantage (SD), high proportions of children have impoverished language skills and poor attention. There is international debate around how best to support this population. Targeting working memory (WM) as an underlying skill may improve these real-world skills.

Aims: To develop and test a classroom-based intervention targeting working memory to enhance attention and language skills in 4-5 year olds from areas of SD.

Methods: A mixed methods, multi-phase study including: 1) A systematic review of WM interventions applied in children's everyday contexts; 2) A qualitative study that explored health professionals' (HPs) (*n*= 13) and teachers' (*n*= 10) perceptions of WM; 3) Co-production work with HPs (*n*= 5), teachers (*n*= 2) and parents (*n*= 2) of 4-5 year olds; and 4) A cluster randomised feasibility trial of the novel intervention.

Findings: Evidence from the systematic review and the qualitative study, synthesised with the experience of HPs, teachers and parents led to the co-production of 'Recall to Enhance Children's Attention, Language and Learning' (RECALL). It is a 6-week intervention that includes direct executive-loaded WM tasks, phoneme awareness training and fantastical play and is delivered to whole classes of children by HPs and teachers. The feasibility trial indicated that the trial processes could be scaled-up into a definitive trial but there were mixed findings about the acceptability of the intervention. In the whole class setting, large group sizes reduced the dose (number of practice items) accessed by individual children, particularly those who may benefit most from RECALL.

Outcomes: RECALL should be optimised as a small group intervention (for children at risk of low WM) and tested in a full-scale trial. Teachers require training on the theoretical underpinning of classroom-based interventions. Policy-makers and practitioners in school-based services should reflect on the effectiveness of whole-class interventions, considering the potential dilution of the potency of interventions in this setting.

.

Operational Definitions

Attention

- **Divided attention:** the ability to split attention across more than one task (Baddeley 2007).
- **Selective attention:** the ability to apply *"goal-directed focus on one aspect of the environment, while ignoring irrelevant aspects*" (Gazzaley and Nobre 2012, p. 129).
- **Sustained attention:** the ability to attend continuously to input so that information in the input can be processed (Leclercq 2002).

Context: The particular geographical, cultural and social environment and the organisational and political systems in which an intervention takes place (Petticrew *et al.* 2013 p. 1233).

Co-production: *"the collaborative generation of knowledge by academics working alongside stakeholders from other sectors*" (Greenhalgh *et al.* 2016, p. 393).

Developmental Language Disorder (DLD): a language disorder that results in functional impairment in everyday life, is likely to have a poor prognosis and is not associated with a known biomedical condition. DLD can occur with other neurodevelopmental disorders including difficulties in the areas of: attention (e.g., ADHD); motor skills (e.g., dyspraxia, dysarthria); literacy; speech; executive function; behaviour problems; auditory processing; and intellectual disability. DLD does not require a mismatch between verbal and nonverbal ability (Bishop *et al.* 2016).

Dosage

- **Cumulative intervention intensity:** the product of dose x dose frequency x total intervention duration (Warren *et al.* 2007).

- **Dose:** the number of properly administrated teaching episodes (trials or practice items) during a single intervention session (Warren *et al.* 2007).
- **Dose form:** the typical task or activity within which teaching episodes are delivered (Warren *et al.* 2007).
- **Dose frequency:** the number of times a dose of intervention is provided per day/per week (Warren *et al.* 2007).

Executive functions (EFs): a set of high-level cognitive processes that enable individuals to control and regulate behaviour during goal-directed tasks (Friedman and Miyake 2017). It is generally accepted that there are three core EFs that are viewed as separable but related skills: working memory, inhibition and cognitive flexibility (Diamond 2013, Miyake *et al.* 2000).

Setting: the environment in which implementation occurs e.g. a school, hospital.

Transdisciplinary: a model of teamwork within which practitioners have shared goals and deliver interventions interchangeably, sharing expertise and engaging in 'role release' (Gascoigne 2008, p. 143).

Transfer effects

- **Transfer:** when a set of skills acquired in one domain generalise to other domains (Sala and Gobet 2017).
- **Near-transfer:** the transfer of skills between strictly related domains (Sala and Gobet 2017). This refers to the transfer of effects from trained WM tasks to similar but untrained WM tasks e.g., improvements on a visuospatial WM task following training on a verbal WM task (Melby-Lervåg and Hulme 2013).

- **Far-transfer effects:** the transfer of skills between source and target domains that are weakly related to each other (Sala and Gobet 2017). This refers to the transfer of effects from trained WM tasks to tasks quite different from those trained e.g., to 'real world' tasks such as attention in the classroom and language skills (Melby-Lervåg and Hulme 2013).

Working memory: the ability to hold in mind and mentally manipulate information over short periods in the face of distraction (Allen *et al.* 2009, Baddeley and Hitch 1974, Cowan 2008). Working memory is used in this thesis as an umbrella term to describe all memory tasks i.e., short-term memory tasks and executive-loaded working memory tasks.

Executive loaded working memory (ELWM): the ability to store and process information concurrently, thereby requiring attentional resources under executive control (Henry 2012).

- **Verbal executive-loaded working memory (VELWM):** the concurrent storage and processing of verbal information (Henry 2012).

- **Visuospatial executive-loaded working memory (VSELWM):** the concurrent storage and processing of visual and spatial information (Henry 2012).

Short-term memory (STM): the simple recall or recognition of information in the form in which it was presented (storage-only) (Holmes *et al.* 2015).

- **Verbal short-term memory (VSTM):** the ability to repeat a short list of verbally presented items immediately in the correct order (Henry and Botting 2017).

- **Visuospatial short-term memory (VSSTM):** the ability to hold in mind and report back immediately spatial or visual information/details (Henry and Botting 2017).

Abbreviations

ADHD	Attention Deficit Hyperactivity Disorder
AHP	Allied Health Professionals
ALP	Attention and Listening Programme
CA	Classroom Assistant
CONSORT	Consolidated Standards of Reporting Trials
EF(s)	Executive Function(s)
ELWM	Executive-loaded Working Memory
EBP	Evidence-based practice
CRT	Cluster Randomised Trial
DLD	Developmental Language Disorder
GRADE	Grading of Recommendations, Assessment, Development and Evaluations
HPs	Health Professionals
HSCT	Health and Social Care Trust
MMR	Mixed Methods Research
MRC	Medical Research Council
NI	Northern Ireland
OT	Occupational Therapist
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
PRISMA-P	Preferred Reporting Items for Protocols of Systematic reviews and Meta-Analyses - Protocols
PROSPERO	International Prospective Register of Ongoing Systematic Reviews
PT	Physiotherapist
RA	Research Assistant
RCT	Randomised Control Trial
RECALL	Recall to Enhance Children's Attention Language and Learning
RISE	Regional Integrated Support for Education
SD	Social Disadvantage
SEB	Social Emotional and Behaviour Specialist

SLI	Specific Language Impairment
SLT	Speech and Language Therapist
SPIRIT	Standard Protocol Items: Recommendations for Intervention Trials
STM	Short-term memory
TSC	Trial Steering Committee
UK	United Kingdom
VELWM	Verbal Executive-Loaded Working Memory
VSELWM	Visuospatial Executive-Loaded Working Memory
VSTM	Verbal Short-Term Memory
VSSTM	Visuospatial Short-Term Memory
WM	Working memory

Chapter 1 - Introduction: study rationale and thesis structure

1.1 Introduction

This doctoral thesis covers the development and testing of a complex intervention for working memory designed to enhance attention and language skills in 4-5 year olds from areas of social disadvantage. This chapter introduces the doctoral thesis. It commences with the background to the study regarding the prevalence of speech, language and communication needs in children and the personal and societal impact of this. Definitions of language disorder are then provided and the association between language disorder and social disadvantage are explained. This is followed by an outline of current national policy and practice in the UK that aim to address these issues. The chapter progresses to a specific focus on policy and practice in Northern Ireland (NI); the context for this doctoral study. The Regional Integrated Support for Education (RISE) Teams and the transdisciplinary model of teamwork they employ are then introduced, and the high incidence of attention and language difficulties in NI schools is identified. This leads to an overview of the factors that may contribute to attention difficulties in the classroom for 4-5 year old children from areas of social disadvantage. Working memory is identified as a cognitive skill that is associated with both attention and language skills and the broad rationale for why it is the focus of this thesis is outlined. The aims of this doctoral study are then laid out. The chapter concludes with a brief overview of each of the chapters within the thesis.

1.2 Current issues, policy and practice

1.2.1 The prevalence and impact of speech, language and communication needs in children

Worldwide, the prevalence and impact of speech, language and communication needs (SLCN) in children has come to light in recent years. In the United Kingdom (UK), more than 1.4 million children and young people have SLCN that are likely to have a lasting impact on their: educational outcomes (Conti-Ramsden *et al.* 2018); employment prospects (Johnson *et al.* 2010, Law *et al*. 2009); relationships (Conti-Ramsden *et al.* 2013); emotional wellbeing; and mental health (Botting *et al.* 2016, Conti-Ramsden and Botting 2008, Conti-Ramsden *et al.* 2016, Lyons and Roulstone 2018, St Clair *et al.* 2019). Early language skills are a strong predictor of educational underachievement (Save the Children 2016) and it is estimated that the severe problems associated with underachievement could cost the UK economy more than £16 billion per year (Chowdry and Oppenheim 2015).

Speech and Language Therapists (SLTs) have unique knowledge and skills and should play a pivotal role, within integrated children's services, to address this problem (ICAN/RCSLT 2018). However, there has been international debate around the optimal models of service provision for children with language difficulties whose risk of underachievement is higher than average (Ebbels *et al.* 2019, Law 2019, Murphy 2019, Schmitt *et al.* 2017). This debate has raised questions about the prioritisation of SLT services. Answering these questions requires an understanding of: which children need and will benefit most from SLT services; how services are designed and delivered; and what is the evidence base for their effectiveness.

1.2.2 The links between social disadvantage and language disorder

The term 'language disorder' refers to "*a profile of language difficulties that causes functional impairment in everyday life and is associated with poor prognosis*" (Bishop *et al.* 2017, p. 1068). It includes language difficulties that are associated with other conditions such as autism spectrum disorder, hearing impairment or intellectual disability. It also includes language difficulties that are not associated with a known biomedical aetiology, for which the internationally recommended term is now 'developmental language disorder' (DLD) (Bishop *et al.* 2016). Recent epidemiological studies estimate that nearly 10% of children in the UK have language disorder, with 7.58% starting school with DLD (Norbury *et al.* 2016). However, in areas of social disadvantage (SD), upwards of 50% of children commence school with impoverished language skills (Law *et al.* 2011, Locke *et al.* 2002). Oral language skills are a foundation for literacy development and the ability to access the education curriculum (Snowling and Hulme 2012). Children who present with low language skills at age five perform significantly more poorly on assessments of English and maths than their typically developing peers at the end of primary school and at GCSE level (Spencer *et al.* 2017, Save the Children 2016).

The mechanisms by which poverty influences children's language acquisition are not fully understood (Perkins *et al.* 2013, Spencer *et al.* 2017). However, it is clear that children raised in poverty are at greater risk of experiencing a language disorder than those from other backgrounds (Fisher 2017). They start their formal education at a lower point than their more-advantaged peers and their subsequent experiences exacerbate this disadvantage (Law *et al.* 2009). The unequal distribution of language disorder in childhood and its personal and societal impact has resulted in its identification as a public health concern, which should be reflected in public policy and the design of SLT services (Law *et al.* 2013, Law *et al.* 2017a).

1.2.3 National strategy and policy

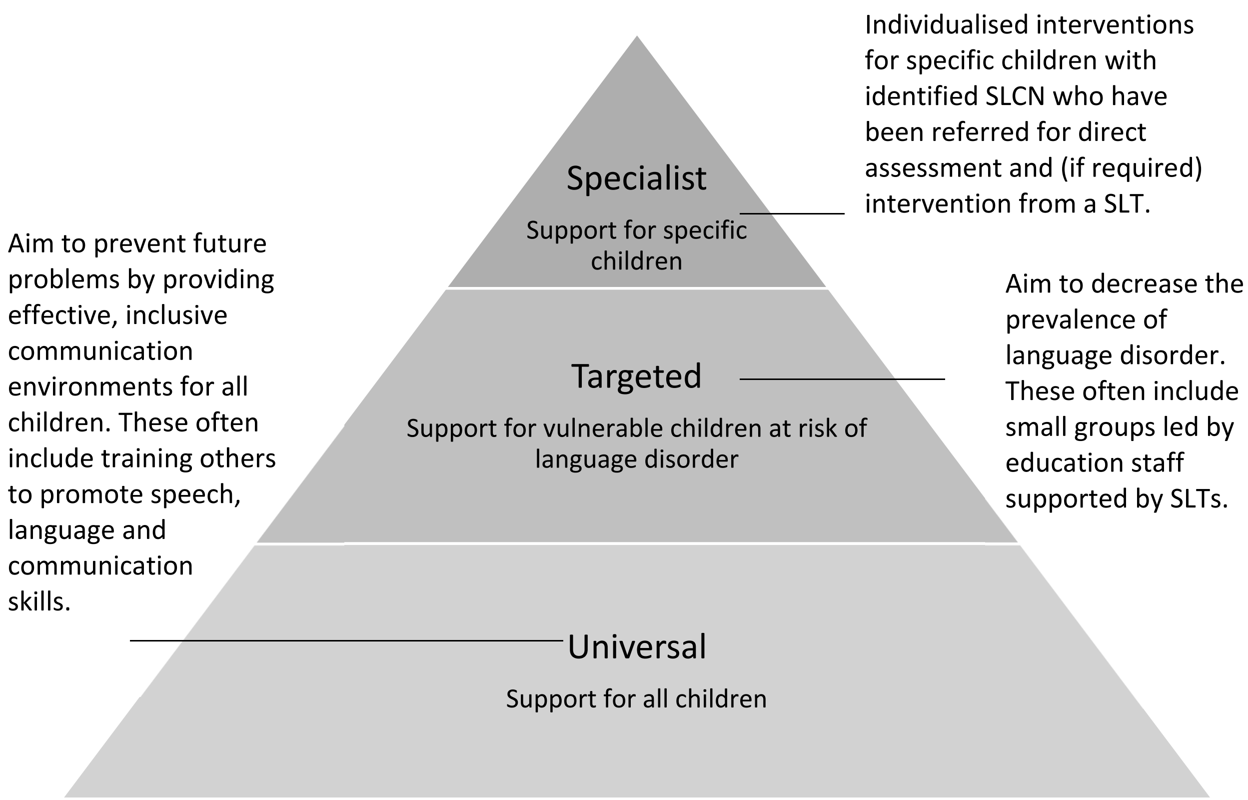
Education policy in the UK stresses the need to narrow the achievement gap between children from areas of social disadvantage and their more-advantaged peers (DFE 2017). Good early years education, with a focus on language and literacy skills, is viewed as the cornerstone to breaking cycles of disadvantage and underachievement and ensuring that *all* children can learn, thrive and achieve their potential (DfES 2003, DFE 2017). To achieve this, early intervention and integrated children's services are viewed as essential strategies. Alongside this, the Royal College of Speech and Language Therapists (RCLST) advocates collaborative practice between SLT services and schools to prevent the development and exacerbation of speech, language and communication difficulties (RCSLT 2018).

1.2.4 Current models of service provision for children at risk of language disorder

In tandem with the public health perspective of DLD and education policy in the UK, SLT services should encompass prevention activities, not just provide individual support for children with identified SLCN (Law *et al.* 2013, Law *et al.* 2017a). In recent years, provision of SLT services in mainstream schools has been seen as increasingly valuable and ecologically valid (Bercow 2008). In many cases, the development of services within educational settings has taken place without the allocation of additional funding or where SLT department budgets have actually been cut (ICAN/RCSTL 2018). This has inevitably resulted in the development of new, hierarchical models of service provision that incorporate more indirect roles for SLTs (Pring *et al.* 2012).

Tiered models of service provision are now used commonly across the UK with the aim of maximising the use of limited resources (Ebbels *et al.* 2019, Parsons 2019, ICAN/RCSLT 2018). The labels used to delineate the tiers within these models are applied inconsistently, both in the literature and by SLTs in practice (Ebbels *et al.* 2019, Ferguson and Spence 2012). However, typically they incorporate three tiers: universal support, targeted support and specialist support (Ebbels *et al.* 2019). Figure 1-1 presents an overview of a typical three-tiered model along with a description of each tier.

Figure 1-1 Typical tiered model of SLT service provision (Gascoigne 2006)



SLT services employing tiered models of service delivery face a significant challenge because recent reviews have revealed that there is a lack of robust, research-based evidence to support the use of universal and targeted interventions (Archibald 2017a, Cirrin *et al.* 2010, Ebbels *et al.* 2019). The most recent comprehensive review of SLT services reinforced this, suggesting that current service models are based on policy and needs, rather than on evidence-based research, particularly in relation to school-based provision (ICAN/RCSLT 2018). The lack of evidence for universal and targeted interventions has sparked international debate around the best models of service provision for children at risk of language disorder and whether current classroom-based support is a waste of valuable resources (Ebbels *et al.* 2019, Law 2019, Murphy 2019, Schmitt *et al.* 2017). Furthermore, there is uncertainty about the optimal levels of dosage for interventions in the area of child language and development (Justice 2018), and very little is known about the theoretical underpinning of the interventions used by SLTs (Roulstone 2015). Research into the effectiveness of current practice is clearly required. Moreover, the urgent need for novel, creative interventions for children who are at risk of language disorder has also been recognised globally (Nippold 2012, Norbury 2017).

In the midst of the current debate, it has been suggested that, for interventions to have ecological validity, there needs to be greater consideration of local contexts (Law 2019, Murphy 2019). More research should be carried out in real-life contexts, where the principles of implementation science could facilitate the identification of factors that may facilitate or impede the delivery and/or effectiveness of interventions with young children in the school setting (Nippold 2015).

1.3 The Northern Ireland context

1.3.1 Northern Ireland policy

Northern Ireland (NI) has higher rates of social disadvantage (SD) than other parts of the UK (HSCB 2011), with the most recent figures indicating that 18% of children (approximately 82,000) live in absolute poverty (DfC 2019). Therefore, the issues highlighted so far regarding the impact of SD on children's language skills, academic outcomes, employment opportunities and (ultimately) mental and physical health are particularly relevant in NI (DHSSPS 2014). Policy across the health and education sectors in NI has repeatedly emphasised the need to target services towards the children who fare worst in society in order to reduce inequalities and narrow the attainment gap (OFMDFM 2006). Two key strategies have been identified: early intervention and integrated service delivery through partnerships across the health and education sectors (DHSSPS 2014, HSCB 2011).

The most recent review of services across the five Health and Social Care Trusts (HSCTs) in NI highlighted a lack of evidence-based services, inconsistent provision and persistent health inequalities (Bengoa 2016). In response to this, a subsequent report made a number of recommendations including extending the role of Allied Health Professionals (AHPs) (such as SLTs, Occupational Therapists (OTs) and Physiotherapists (PTs)) in preventative work (DoHNI 2016). It also advocated the use of co-production with service users and stakeholders to increase the accessibility and acceptability of services (tying in with national initiatives). This strategic thinking has had a direct impact on the design of services in NI. It also has implications for the conduct of research involving staff from the HSCTs in NI, where service managers are more likely to support staff engagement in research studies that are consistent with current policy.

1.3.2 The Regional Integrated Support for Education (RISE) Teams

In Northern Ireland (NI), extending the role of AHPs began as early as 2007 when teams of healthcare professionals were established in each of the five HSCTs to support children in mainstream primary schools. The Regional Integrated Support for Education (RISE) Teams were commissioned to:

> *"…reduce underachievement and improve the life chances of children and young people by enhancing their educational development and fostering their health, well-being and social inclusion through the integrated delivery of the support and services necessary to ensure that every child has the best start in life"* (DENI 2006, p. 35).

The RISE teams include SLTs, OTs, PTs and social, emotional and behavioural specialists (SEBs). They support children from 3-8 years (nursery to year four in primary education). In NI, children commence formal education (year one) at age 4. The teams' model of service delivery incorporates 2 key features: 1) A three tier model of support including specialist, targeted and universal interventions described previously (see 1.2.4); and 2) A transdisciplinary model of teamwork (see 1.3.3).

1.3.3 Transdisciplinary teamwork

According to Kuhlmann (2004), the term transdisciplinary was first used in the mid-1970s to describe a model of teamwork that involves the sharing of information and skills across disciplines. The transdisciplinary model of teamwork has been widely adopted in a variety of industries and, over the past two decades, its potential benefits for research and healthcare settings have been discussed and promoted (e.g., Hall *et al.* 2012, Stokols *et al.* 2006).

In healthcare settings, transdisciplinary teamwork shares many of the features of the multidisciplinary model including: ongoing interaction between team members; coordinated intervention planning; and attention to the needs, desires, and goals of the family (King *et al.* 2009). What distinguishes the two approaches is that the transdisciplinary model involves an element of role release (or role blurring), where some elements of a professional's role can be taken on by others (Gascoigne 2008, Hewitt *et al.* 2014, Sims *et al.* 2015) (Figures 1-2 and 1-3). According to King *et al.* (2009, p. 213):

> *"The team becomes truly transdisciplinary in practice when members give up or "release" intervention strategies from their disciplines, under the supervision and support of team members whose disciplines are accountable for those practices"*

Role release is said to increase the efficiency and cost effectiveness of services because more children can be seen by fewer professionals, thereby streamlining the pathway through a service and enhancing the continuity of care (King *et al.* 2009). It also aims to improve the quality of care by supporting clinical decision-making with a more holistic perspective (D'Amour *et al.* 2005, Foley 1990, Mackey and McQueen 1998). In this model, the specialist contribution of each profession is important and no discipline becomes unnecessary; the 'whole' is greater than the 'sum of the parts' (Gascoigne 2008). Through carefully negotiated roles and robust governance arrangements, care and efficiency can be optimised while the quality and safety of input to the service user is maintained (Gascoigne 2013). There has been international recognition by SLT professional bodies that the transdisciplinary model may be one way of supporting children with SLCN, provided robust governance arrangements are in place (ASHA 2004, Gascoigne 2006, SPA 2009).

Figure 1-2 Model of multidisciplinary teamwork (Gascoigne 2006)

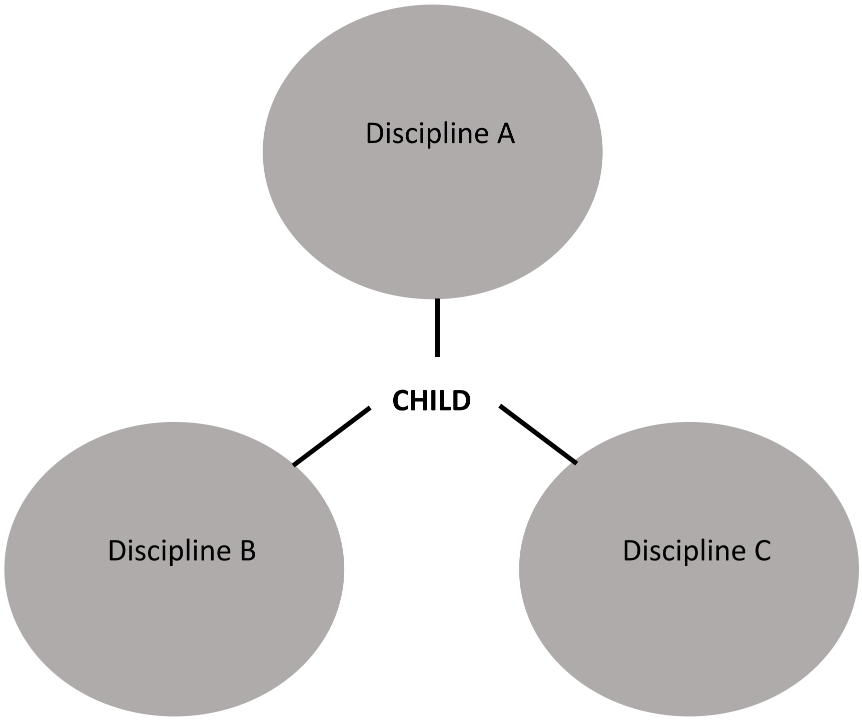
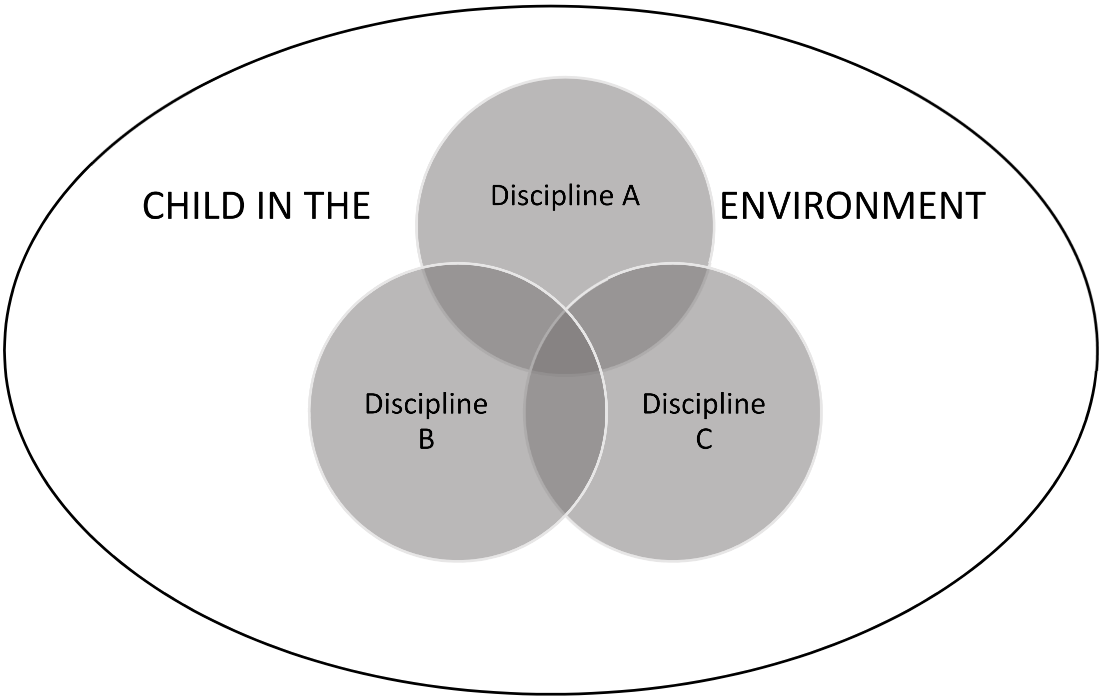


Figure 1-3 Model of transdisciplinary teamwork (Gascoigne 2006)



The RISE teams provide both specialist support (for specific children) and targeted support (for vulnerable children at risk of language and other neurodevelopmental disorders) through the transdisciplinary model. In practice, this means that the professionals jointly design and deliver interventions, which integrate goals from each discipline. e.g., the SLT may carry out an intervention that incorporates SLT, OT and PT goals (Harron and Dickson 2013). Hence, an intervention that targets language skills may be delivered by a PT or OT, under the supervision of the SLT. Targeted interventions include classroom-based programmes delivered to whole classes of children during which the HPs work alongside teachers and classroom assistants. This form of collaborative practice aims to be mutually beneficial: teachers have the opportunity to observe activities and strategies used by HPs that they can incorporate into their teaching; and HPs gain a greater understanding of the skills children need to succeed in the classroom and access the education curriculum (Archibald 2017a, Nippold 2011). This approach may also be adopted to increase the dosage with which an intervention is provided because education staff can practise therapeutic tasks with children on a more frequent basis than HPs (Nippold 2012).

The RISE teams have gathered evidence, through service evaluation projects, that suggests their use of the transdisciplinary model enhances the accessibility and acceptability of the service to its users (teachers and parents) (Harron and Dickson 2013). Despite this, and the intuitive appeal of the model, the fact that it has not been evaluated empirically is a challenge for the teams. Reviews by McPherson *et al.* (2006) and Saxon *et al.* (2014) found limited evidence of evaluation of this model. Any studies that have been conducted have focused on service outputs (e.g., waiting times and rates of attendance) (Bell *et al.* 2010, Malin and Morrow 2007) or on the benefits for team members (Hewitt *et al.* 2014, Sims *et al.* 2015) rather than on outcomes for children. Finally, the RISE teams report that they view the teachers (with whom they collaborate in relation to planning and implementing services in the classroom) as actual members of the transdisciplinary team. However, this is another facet of current practice that has not been evaluated robustly and it is possible that teachers have a different perspective on their role when working alongside the RISE teams.

1.3.4 The prevalence of attention difficulties in the classroom for children from areas of social disadvantage and current practice to address them

Prior to the conception of this doctoral study, consultation with the RISE team managers revealed that teachers in NI have particular concerns about children's attention skills. This was evidenced in three ways. Firstly, during routine focus groups carried out by the RISE teams for the purpose of service evaluation, teachers typically estimated that between 25-50% of children in their class present with inattentive and distractible behaviour that affects their learning. Secondly, the RISE teams provide short training courses for teachers as part of their universal support (for all children) and training on how to manage attention difficulties in the classroom is the most frequently requested course (Harron and Dickson 2013). Thirdly, an audit of referrals made to the RISE teams revealed that in 100% of cases, teachers identified *'attention and listening'* as a concern. On the referral forms, the teachers typically described children as: highly distractible; 'zoning' out during lessons; unable to complete tasks; finding it difficult to follow instructions; and being unable to keep track of a task (losing their place). Indeed, across NI the majority of referrals to the RISE teams are for year one pupils (4-5 year olds) in areas of social disadvantage (SD) who have difficulties with both attention and language skills.

Supporting children with attention difficulties in the classroom is a key aspect of the RISE teams' service provision to schools because there is increasing empirical evidence of the associations between inattentive behaviour in the classroom and reduced academic outcomes, even where the inattentiveness falls below the threshold for a clinical diagnosis of ADHD (Dittman 2016, Sims and Lonigan 2013, Tambyraja *et al.* 2019). To address this, the RISE teams developed a whole class intervention, delivered to all of the children in any involved class, which aims to improve children's attention skills through repeated practice on listening tasks (see Chapter 8 for further details). This intervention was developed informally by the teams and it has not been evaluated robustly. Significantly, it is not underpinned by a clear theory around how or why it should improve the attention skills of 4-5 year olds from areas of SD (see Chapter 5 for evidence of this point and an exploration of its implications for evidence-based practice). This leads to some reflection on the factors that may contribute to these children's attention difficulties in the classroom.

1.4 Factors contributing to attention difficulties in the classroom

The human brain does not have the capacity to process all of the information it receives. Attention is the ability to focus our cognitive resources on the most relevant stimuli and discard other information (Ward 2006). There are many reasons why young children, particularly those from areas of social disadvantage (SD), may have difficulty paying attention in the classroom setting. These are discussed in greater detail in Chapter 2, but two key factors are introduced here.

Firstly, classroom learning places unique demands on the high-level cognitive resources associated with attention control. The classroom is an environment that is laden with distractions e.g., another child making a noise or the brightly-coloured wall display behind the teacher. In order to listen to their teacher or complete a set task, children have to ignore (or resist) these distractions (Gathercole *et al.* 2008, Jacob and Parkinson 2015). This means that, in order to access the education curriculum, children must use *selective attention* i.e., the *"ability to apply goal-directed focus on one aspect of the environment, while ignoring irrelevant aspects"* (Gazzaley and Nobre 2012, p. 129). They also have to be able to *sustain* their attention in order to process the information (such as the teacher's spoken instructions) or see the task through to completion (Leclercq 2002). The ability to use selective and sustained attention is reliant upon a set of high-level cognitive skills known as executive functions (EFs) (Henry 2012, Jacob and Parkinson 2015) (see Chapter 2 for a detailed definition). Since one of the most important aspects of classroom learning is the ability to follow instructions spoken by the teacher, whilst resisting distraction, it is clear that classroom learning places significant demands on children's EFs (Holmes *et al.* 2010).

The second reason why young children, particularly those from areas of SD, may find it difficult to pay attention in the classroom is that their EF skills may be poorly developed (Noble *et al.* 2007). The cognitive skills associated with attention control develop rapidly between the ages of 3-6 years, (Betts *et al.* 2006, Hanania and Smith 2013, Manly *et al.* 2001). However, this can vary significantly and some 4-5 year olds will have immature EF skills. Children from areas of SD are especially at risk in this regard, because repeated studies have shown that their EFs are likely to develop at a slower pace than those of their more-advantaged peers (Kapa and Plante 2015, Noble *et al.* 2007). This means they are poorly equipped to handle the heavy cognitive demands of classroom learning. Furthermore, linguistic and environmental factors exacerbate the difficulties experienced by these children. They typically have low language skills (Law *et al.* 2011, Locke *et al.* 2002, Noble *et al.* 2007) and limited experience of structured learning tasks prior to starting school (Chowdry and McBride 2017), meaning these children may find it hard to comprehend the teacher's spoken instructions and understand how to complete a set task. Since it is harder for children to focus and sustain their attention when tasks are highly demanding (Manly *et al.* 2001), it is perhaps unsurprising that children from areas of SD are particularly at risk of inattentive behaviour in the classroom.

This introduction to attention in the classroom demonstrates that it is highly dependent upon EF skills (Henry 2012, Jacob and Parkinson 2015). One EF in particular, working memory, is strongly associated with inattentiveness in the classroom (Alloway *et al*. 2009, Gathercole *et al.* 2008). Indeed, WM is inextricably linked to both attention and language skills in young children (Tambyraja *et al.* 2019), which is why it is the focus of this doctoral study. The rationale for this is outlined further in the next section of this thesis and in detail throughout Chapter 2.

1.4.1 The importance of working memory

Working Memory (WM) is the ability to hold in mind and mentally manipulate information over short periods of time in the face of distraction (Allen *et al.* 2009, Baddeley and Hitch 1974, Cowan 2008). It is an executive function that is strongly associated with attention (Bunting and Cowan 2005, Cowan *et al.* 2006) and language learning (Baddeley *et al.* 1998). WM is a limited capacity system, meaning we can only hold in mind and process a certain amount of information at a time and this capacity varies from person to person (Alloway and Alloway 2015a, Henry 2012). Children with low WM capacity may 'zone out' or become distractible in the classroom because the WM demands of classroom learning (such as following teacher's spoken instructions) exceed their capacity limit (Alloway *et al.* 2009, Gathercole *et al.* 2008). Low WM is also associated with a range of developmental disorders including DLD (Archibald and Gathercole 2007). It follows that many of the children about whom teachers in NI have concerns and those who are referred to the RISE teams may have underlying WM deficits. This leads to the suggestion that targeting WM as an underlying skill may improve attention and language. The viability of this suggestion is dependent on the effectiveness of WM training, a topic that has been debated fervently in the WM literature.

The debate about the effectiveness of WM training will be reflected at several junctures in this doctoral thesis so is not expounded on in detail at this point (see Chapters 2, 4 and 8). In brief, at the heart of the debate is the inconsistent evidence for transfer effects (the generalisation of positive effects on trained tasks to other untrained tasks) from computerised WM training to real-world skills such as attention and language (Melby-Lervåg and Hulme 2013, 2016). Nonetheless, there are many unanswered questions about the therapeutic value of WM training and a lack of clear empirical evidence does not necessarily mean there is no potential for future interventions (Shipstead *et al.* 2012). Embedding WM training within the typical activities in which benefits are needed may be more ecologically valid and have greater potential to benefit real-world skills than computerised training (e.g., Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014). However, there are significant gaps in the literature around the effectiveness of WM interventions applied in children's everyday contexts and a lack of studies conducted with young children (under seven years of age) (Wass *et al.* 2012). Furthermore, there have been no previous studies that have focused on the feasibility of implementing WM interventions the classroom setting (Jaeggi and Buschkuehl 2014).

1.5 Rationale for the current study

Attention and language difficulties have been highlighted as problematic for 4-5 year olds in mainstream schools in areas of social disadvantage in NI (Harron and Dickson 2013). These children are at risk of academic underachievement, poor employment prospects and (ultimately) poor mental and physical health (ICAN/RCSLT 2018). The current classroom-based intervention used by the RISE teams to address this issue is limited by three factors: 1) the lack of research-based evidence for universal and targeted interventions for children at risk of language disorder and the transdisciplinary model of teamwork; and 2) it has not been evaluated robustly; and 3) it is not underpinned by theory or the potential for change to attention and language that may result from targeting WM skills.

Through the development and testing of a novel intervention, targeting WM to enhance attention and language skills, this doctoral study specifically addresses gaps in the literature regarding the feasibility of implementing WM interventions with young children in real-life contexts (Jaeggi and Buschkuehl 2014, Wass *et al.* 2012). It responds to calls for the investigation of universal and targeted interventions for children at risk of language disorder and the need for novel, innovative interventions that are theoretically underpinned (Ebbels *et al.* 2019, Nippold 2012, Norbury 2017, Schmitt *et al.* 2017). In addition, utilising the existing collaborative practice between the RISE teams and mainstream primary schools in NI, it contributes to an understanding of the ecological validity of classroom-based interventions and the factors that may facilitate or impede their implementation (Law 2019, Murphy 2019, Nippold 2015).

This study ties in with the identified research priorities for allied health professionals (AHPs) in NI (PHA 2011) and the strategic thinking on early intervention and prevention for children from areas of SD who are at risk of poor academic achievement set out in the

Bengoa Report (DHSSSPS 2014). Moreover, it is consistent with the research priorities of the RCLST regarding the need to expand the evidence-base for universal programmes in mainstream schools and early intervention (RCSLT 2015).

1.6 Aims

This doctoral study aims to develop and test a classroom-based intervention targeting working memory to enhance attention and language skills in 4-5 year old children from areas of social disadvantage.

1.6.1 Objectives

To achieve the research aims this study has four objectives:

1) To conduct a systematic review of non-computerised interventions that target WM in children's everyday contexts.
2) To explore the contextual factors that may impact on the development and testing of a novel classroom-based intervention targeting WM, attention and language skills in 4-5 year olds.
3) To co-produce a novel classroom-based intervention targeting WM, attention and language skills in 4-5 year old children and develop an intervention logic model.
4) To examine the feasibility and acceptability of the novel intervention and the factors that impact on the delivery, dosage and potential effectiveness of classroom-based interventions.

1.7 Study design and methods

This doctoral study employed a mixed methods, multi-phase design (Creswell and Plano Clarke 2011). It was framed within the Six Steps in Quality Intervention Development (6SQuID) model (Wight *et al.* 2016) that builds on the Medical Research Council guidance on developing complex interventions (Craig *et al.* 2008, MRC 2000, 2008, 2019) (see Chapter 3). This involved four major phases: 1) a systematic review; 2) a qualitative study 3) intervention co-production; and 4) a cluster randomised feasibility trial. These phases were connected by the integration of mixed methods evidence. The methodology is discussed in greater detail in Chapter 3.

1.8 Structure of thesis

Overview

The thesis is presented in two volumes. The first volume covers the background, aims, methods, findings and conclusions of the doctoral study. The second volume presents the facilitator manual that accompanies the novel intervention developed through this study and samples of the bespoke materials and resources created by the PhD researcher.

Volume 1

Volume 1 is structured according to the Ulster University's PhD Thesis with Papers format. It includes ten chapters, four of which are comprised of published or publishable papers: two that have been published; and two that have been submitted to international, peer-reviewed journals. Each paper (Chapters 4, 5, 8 and 9) has its own introduction, methods, results and discussion sections along with its own reference list. The reference list at the end of the thesis covers the citations used in the remaining chapters (1-3, 6, 7 and 10). The duplication of material within the thesis has been kept to a minimum. However, at times information contained within the papers is repeated in the main body of the thesis to support the clarity of the argument presented. Table 1-1 shows how each of the chapters in Volume 1 corresponds to the 6SQuID model (Wight *et al.* 2016) that was used to frame the study, and how the four papers fit within this structure.

Table 1-1 Thesis Volume 1: structure and relationship of chapters to the 6SQuID model (Wight *et al.* 2016)

Volume 1 Chapter	**Chapter title**	**Corresponding step in the Six Steps in Quality Intervention Development (6SQuID) (Wight *et al.* 2016)**
1	Thesis structure and study rationale	Step 1 Understand the problem
2	Working memory, attention and language	
3	Design and methods	
4	Systematic review **(Paper 1)**	Step 2 Clarify which causal and contextual factors are malleable
5	Qualitative study **(Paper 2)**	
6	Identifying the change mechanism	Step 3 Identify the change mechanism
7	Intervention co-production	Step 4 Identify how to deliver the change mechanism
8	Study protocol for the feasibility trial **(Paper 3)**	Step 5 Test and refine on small scale
9	Findings from the feasibility trial **(Paper 4)**	Step 6 Collect evidence to justify rigorous evaluation
10	Conclusions	

Chapter 1 - Introduction: thesis structure and rationale

This chapter introduced the doctoral thesis. It highlighted the high prevalence of children from areas of social disadvantage (SD) who experience speech, language and communication needs and how current national policy and practice in the UK aim to address these issues. The NI context, including the RISE teams and the transdisciplinary model of teamwork they employ, was introduced and the high incidence of attention and language difficulties in children from areas of SD was recognised. WM was identified as a cognitive skill that is associated with attention and language skills, leading to the aims, objectives and design of the doctoral study and the structure of the thesis.

Chapter 2 - Setting the scene: an overview of working memory, attention and language

Chapter 2 builds on Chapter 1 and lays a foundation for the rest of the doctoral thesis by setting out the theoretical assumptions that underpin this doctoral study regarding working memory and its associations to attention and language. It explores the concepts that are crucial to the potential effectiveness of the to-be-developed intervention regarding: the effectiveness of WM training; and current thinking around the mechanisms of transfer from trained WM tasks to untrained WM tasks and real-world skills. This chapter highlights specific gaps in the existing evidence base that augment the broad rationale for the study presented in Chapter 1, demonstrating how the thesis aims to make a significant contribution to knowledge.

Chapter 3 - Design and methods

The specific methods used for each of the main phases of the doctoral study are contained within the corresponding published/publishable papers (Chapters 4, 5, 8 and 9). Therefore, Chapter 3 intends to describe the aspects of the study methods not explained in other parts of the thesis, or to supplement the details provided elsewhere. It includes an overview of the realist paradigm, complexity theory and ecological perspective that underpin the entire doctoral study. The Six Steps to Quality Intervention Development Model (6SQuID)

(Wight *et al.* 2016) is also described. In particular, this chapter explains how logic modelling, co-production and process evaluation methods strengthened the rigour of the study. The integration of mixed-methods evidence and data triangulation is also elucidated, as are the ethical issues considered during the conduct of the research.

Chapter 4 - Systematic review

Chapter 4 presents the findings of the first systematic review of interventions targeting working memory in 4–11 year olds within their everyday contexts. The findings were reported following the PRISMA-P (2015) guidelines (Moher *et al.* 2015) and published in *Developmental Review* (Rowe *et al.* 2019a). The chapter starts with a brief introduction to the review, showing how it fits within the doctoral study. The citation details and the PhD researcher's contribution to the paper are provided and the full pdf version of **Paper 1** then constitutes the main body of the chapter. It ends with a brief summary of the implications of the review findings for the to-be-developed intervention.

Chapter 5 - Qualitative study

Chapter 5 reports the findings of the qualitative study that ran concurrently to the systematic review with the aim of exploring the contextual factors that may affect the development and testing of the novel intervention. A brief introduction situates the qualitative study within the wider doctoral study. This is followed by **Paper 2** that has been submitted to the *Journal of Educational Psychology*. The paper includes its own introduction, aims, methods, findings, conclusions, references and appendices. The chapter concludes with a brief summary of the implications for the to-be-developed intervention.

Chapter 6 - Identify the change mechanism

Throughout this doctoral thesis, the need for interventions to be underpinned by a sound theory of change is emphasised. Chapter 6 demonstrates how the mixed methods evidence (from the systematic review and the qualitative study, Chapters 4 and 5) was integrated into a theory of change that underpins the novel classroom-based intervention. The proposed theory of change is identified and presented in a theory logic model. The chapter then describes how the intervention components (executive-loaded tasks) were extracted from the systematic review evidence on this basis. It concludes with an initial intervention logic model that presents how the intervention should work if implemented according to the theory.

Chapter 7 - Intervention co-production and refinement

This chapter presents the aims, methods and findings from a co-production study that was conducted with health professionals, teachers and parents of 4-5 year old children from areas of social disadvantage to delineate the delivery of the novel intervention. It then provides a detailed overview of the intervention itself, entitled Recall to Enhance Children's Attention, Language and Learning (RECALL). This includes the structure of the classroom-based sessions and descriptions of the intervention components. It outlines how the directly trained tasks progress in difficulty over the course of the intervention and their dosage (amount and intensity of training) is specified. A final aspect of this step in the intervention development was the refinement of the intervention logic model (presented in Chapter 6) and the revised model is presented. The benefits and limitations of the co-production process and logic modelling are discussed. Finally, this chapter shows how the RECALL intervention was refined through expert and practitioner review.

Chapter 8 - Feasibility study protocol

Chapter 8 presents the study protocol for a cluster randomised feasibility study that investigated whether it would be possible to conduct a full-scale trial of the novel RECALL intervention and to explore the acceptability of the intervention to the teacher and health professionals who deliver it. The study protocol was published in *Pilot and Feasibility Studies* (Rowe *et al.* 2019b). This chapter includes the full pdf. version of the published paper (**Paper 3**) that presents comprehensive details of the study's aims, design and methods.

Chapter 9 - Feasibility study results

Chapter 9 presents the findings of the cluster randomised feasibility study. This is also presented as a paper that has been submitted to *Pilot and Feasibility Studies* **(Paper 4).** The paper includes its own introduction, aims, methods, findings and conclusions. The chapter concludes with some further reflections on the study findings and a revised version of the intervention logic model.

Chapter 10 - Conclusions

This chapter concludes the doctoral thesis. It summarises the main contributions, implications and recommendations arising from the design and methods used in this doctoral study and from each of the four main phases of the research. It also provides an overview of how the study findings have been disseminated to date and the plans for future research and dissemination.

Volume 2

Volume 2 presents the facilitator manual for the RECALL intervention that was developed and tested through this doctoral study, along with examples and photographs of the bespoke materials created for its delivery. Volume 2 should be referred to alongside the current volume, as indicated in the text. In particular, it is a useful accompaniment to Chapters 6 and 7. Details of the structure of Volume 2 can be found on the contents page contained within it.

Chapter 2 - Setting the scene: an overview of working memory, attention and language

2.1 Introduction

Chapter 1 laid out the problem being addressed by this doctoral study, namely that in areas of social disadvantage, high proportions of children (4-5 year olds) are referred to health services due to attention and language difficulties in the classroom that may be associated with working memory deficits. A broad rationale for developing a novel, classroom-based intervention targeting working memory (WM) to enhance attention and language skills was provided. The legitimacy of this approach hinges on several theoretical assumptions. The current chapter is not intended to be a comprehensive review of the WM literature; rather it provides an overview of theory and current thinking in the field of WM research. It commences with an overview of the theoretical WM model that underpins this study and progresses to explore: the symbiotic relationship between WM, attention and language; the evidence regarding the effectiveness of WM training; and issues of transfer to real-world skills. The gaps in the current evidence base are highlighted, underscoring the need for this doctoral study and the potential for it to make a significant contribution to knowledge.

2.2 Understanding working memory

2.2.1 Defining working memory

Working memory (WM) is defined consistently throughout this thesis as the ability to hold in mind and mentally manipulate information over short periods of time in the face of distraction (Allen *et al.* 2009, Baddeley and Hitch 1974, Cowan 2008). WM is often thought of as a mental workspace (or notepad) that supports the storage and processing of information in almost all everyday activities e.g., mental arithmetic or doing a crossword (Alloway 2018, Henry 2012). It is generally agreed that WM is one constituent of several higher-level cognitive processes known as executive functions (EFs) that enable individuals to regulate their thoughts and actions during goal-directed behaviour (Friedman and Miyake 2017).

There is no widely accepted model of EFs, but there appears to be consensus that WM, inhibition and cognitive flexibility are separable but related core EF skills (Diamond 2013, Henry, 2012, Jacob and Parkinson 2015, Miyake *et al.* 2000). Inhibition is the ability to block/ignore stimuli that are not relevant to an ongoing task (Baddeley 1996, Friedman and Miyake 2004, Henry 2012). It protects the contents of WM (the mental workspace) from interference arising from external distractors or internal stimuli such as memory intrusions from previously relevant material or experiences (Friedman and Miyake 2004). Cognitive flexibility is the ability to adapt behaviour whilst carrying out a task in order to achieve its goals (Diamond 2013). In other words, when you are carrying out an everyday task, you may realise the strategy that you are using is not working so you adopt a different approach. In doing so, the contents of your WM is updated in accordance with the new strategy (Henry 2012).

The overview of WM provided so far demonstrates that it is a useful and flexible cognitive system (Gathercole 2008). However, information held in WM is easily lost through distraction or overload (Gathercole 2008). Furthermore, the capacity of WM is limited, thereby it constrains the types of things we can handle concurrently (Alloway and Alloway 2015a, Henry 2012). WM capacity varies considerably from person to person and individuals with low capacity struggle with the heavy WM demands of many tasks (e.g., Pickering *et al.* 1998). As discussed in Chapter 1, this has particular consequences for children's learning, where low WM impacts on children's ability to pay attention and in the classroom and complete structured tasks (Gathercole 2008) (see also Chapter 4).

Considering the impact of low WM, it is not surprising that one of the main goals of WM research over the past 40 years has been to understand its functioning and the individual differences between people's WM capacity. Despite a wealth of research in this regard, there are still gaps in what we know about how WM functions. Various theories have been put forward to account for the structure and function of WM (see Chapter 4 for further details). This doctoral study is underpinned by the Working Memory Model (Baddeley and Hitch 1974, Baddeley 2000, 2007). This model has been used widely in theoretical and applied WM research and has provided clear and testable predictions regarding memory development in both typical and atypical populations (Henry 2012). In so doing, it has gained widespread empirical support. For example, evidence shows that the structure of WM in typically developing children between the ages of 4-6 years (encompassing the age range of interest in this study) corresponds to the components of the model (described below) (Alloway *et al.* 2004, Gathercole *et al.* 2004b). In addition, it has been the most influential model of WM in relation to language learning and language disorders that are particularly relevant to this doctoral study (e.g., Baddeley *et al.* 1998).

2.2.2 The Working Memory Model

The original multicomponent model of WM (Baddeley and Hitch 1974) consisted of a central executive and two temporary passive stores (the phonological loop and the visuospatial sketchpad) that are responsible for the temporary storage of verbal and non-verbal information, respectively. These components are described below.

The central executive (CE) controls attention and co-ordinates the processing of information while directing the resources of the phonological loop and the visuospatial sketchpad for storage. That is to say, in tasks that require both the storage and processing of information, or the completion of two things at once, the role of the CE is to coordinate and monitor the performance of all of the components. Indeed, in the revised versions of the WM model, Baddeley (2000, 2007) proposed that the key function of the CE is the appropriate allocation of attentional resources within the WM system. It is responsible for: *focusing* attention on one task; *dividing* attention between the various aspects of task; and *switching* attention between tasks. Thus, it is closely related to other executive functions outlined earlier in this chapter, namely inhibition and cognitive flexibility (Henry 2012) (discussed further in section 2.3).

The phonological loop (PL) provides a temporary store for holding speech-based information and is divided into two sub-components: the phonological store that passively holds information for a short period, and an articulatory rehearsal mechanism that prevents the loss of information by refreshing it through sub-vocal rehearsal (Baddeley 2000).

The visuospatial sketchpad (VSS) is responsible for maintaining visual and spatial information and, like the phonological loop; it stores information for short periods of time. Logie (1995) proposed that the visuospatial sketchpad could be segmented further into two components analogous to the phonological store and articulatory rehearsal components of the phonological loop (Baddeley 2012). The visual cache acts as a passive visual store and plays a role in retaining visual patterns. The second subcomponent, known as the inner scribe, is an active spatial system that is presumed to store information related to spatial/movement sequences and is closely linked to the planning and control of movement to targets in space (Baddeley and Logie 1999, Logie 1995, Logie and Pearson 1997). In later revisions of the multi-component model, Baddeley (2000, 2007) suggests the visuospatial sketchpad also deals with a third class of activity referred to as kinaesthetic input i.e., the storage of sequences of movements or actions. Baddeley (2007) proposed that kinaesthetic memory is needed to learn new motor skills (Baddeley 2007, Henry 2012). Recent data suggest there may be an additional store within working memory dedicated to the temporary maintenance and processing of motoric information, although more research is needed to validate this (Jaroslawska *et al.* 2018).

A fourth component, ***the episodic buffer,*** was introduced by Baddeley (2000) to account for how information temporarily held in WM interacts with the contents of long-term memory (LTM). It is said to hold multi-modal information (verbal and visuospatial) and provide an interface between the slave systems (the phonological loop and the visuospatial sketchpad) and LTM. Baddeley (2007) appears to place great importance on the role of the episodic buffer, suggesting it even gives us our sense of consciousness (Baddeley 2007, p. 148) but how it does this and how to assess its functioning is uncertain.

2.2.3 Measuring working memory

The WM model has enabled psychologists to differentiate memory tasks on the basis of their storage and processing requirements (Henry 2012). Tasks can be differentiated into:

1. **Simple span (storage-only) tasks:** these require the simple recall or recognition of verbal or visuospatial information in the form in which it was presented e.g., recalling a list of words or a series of spatial positions in the same order as they were presented (Holmes *et al.* 2015). These tasks measure *short-term memory (STM)* and, according to the WM model, they assess the functioning of the phonological loop (for verbal tasks) or the visuospatial sketchpad (for visuospatial material) (Henry 2012).
2. **Complex span (storage + processing) tasks:** these involve the storage of verbal or visuospatial information while completing a processing element of the task e.g., recalling a list of words or series of spatial locations in the reverse order (Henry 2012).

Complex span tasks require the engagement of attentional resources, since attention is divided between the storage and processing aspects of the task (Barrouillet *et al*. 2004, Engle 2002, Kane *et al.* 2007). These tasks assess the functioning of the central executive so they can be described as *executive-loaded working memory (ELWM)* tasks (Henry 2012). Complex, ELWM tasks can also include the interpolation of a processing item between the presentation of the to-be-remembered information and its subsequent recall e.g., listening to a short sentence, judging whether it is true or false, then recalling the last word of the sentence. In tasks with interpolated items, the to-be-remembered item must be protected from the interference (distraction) of the interpolated item and from the decay that is caused by the period in between presentation and recall, thus engaging executive resources (Gathercole *et al.* 2019).

The distinction between STM and ELWM tasks is crucial to understanding the associations between the WM system and real-world skills, including attention (Shipstead *et al.* 2014) and language (Archibald 2018, Henry and Botting 2017) which are central to this doctoral study. Hence, it is important that WM tasks are defined and differentiated accurately. Throughout this thesis, consistent terminology is used to delineate WM tasks based on: their storage and processing requirements; and the input modality of the stimuli presented. ELWM is a term not widely used in the WM literature. Therefore, it may be new to some readers of this thesis but it is favoured here to describe complex span tasks because it makes explicit the involvement of the central executive and the fact that these tasks require attentional resources (Henry 2012). Figure 2-1 provides operational definitions for four aspects of WM and Figure 2-2 depicts how these sit within the WM model and gives examples of tasks that measure each aspect.

Figure 2-1 Operational definitions of four aspects of WM

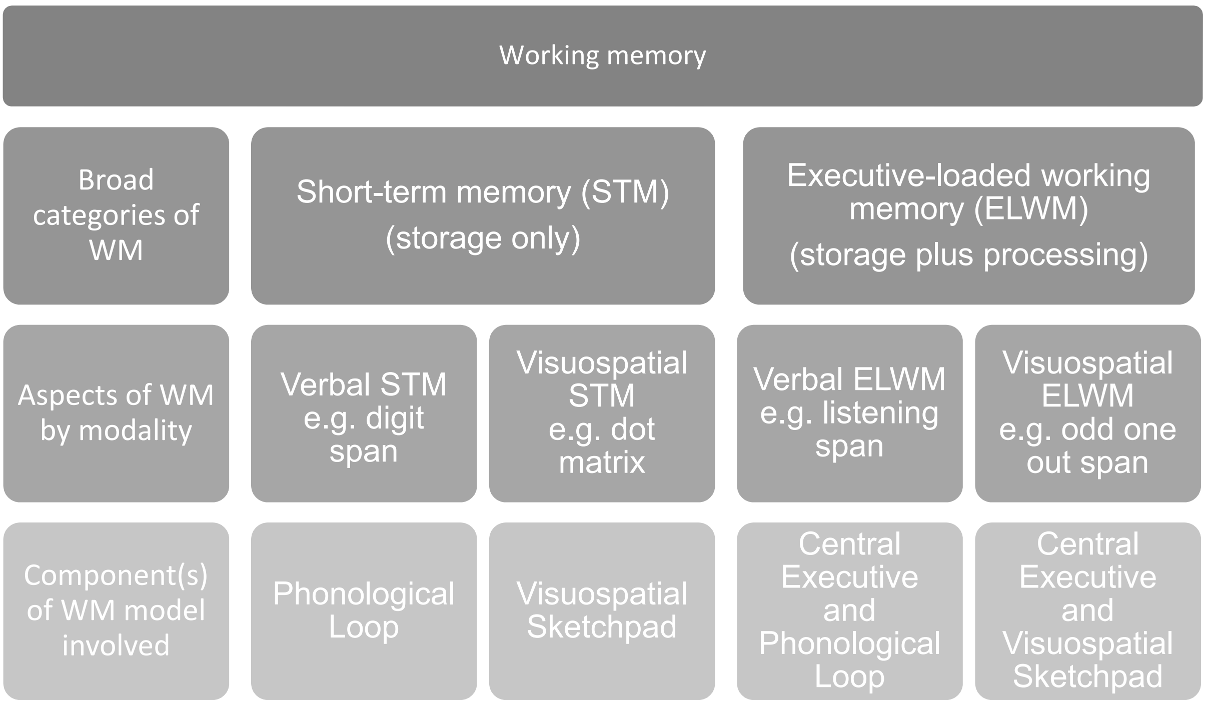
Verbal short-term memory: the ability to repeat a short list of verbally presented items immediately in the correct order (Henry and Botting 2017).

Visuospatial short-term memory: the ability to hold in mind and report back immediately spatial or visual information/details (e.g., usually assessed by asking the child to recall patterns or spatial positions) (Henry and Botting 2017).

Verbal executive-loaded working memory: the concurrent storage and processing of verbal information.

Visuospatial executive-loaded working memory: the concurrent storage and processing of visual and spatial information.

Figure 2-2 Task examples for each aspect of WM and the corresponding component of the WM Model (Baddeley and Hitch 1974, Baddeley 2000, 2007)



2.3 Working memory and attention

There is still a lot to be uncovered about the relationship between WM and attention but there is no doubt that attention control in real-life is dependent upon the capacity and allocation of resources in the WM system that, according to Baddeley (2000, 2007) are coordinated by the central executive (CE). As outlined in Chapter 1, the WM demands of any everyday task are dependent upon: how complex it is; how familiar we are with it; and what else is going on at the same time. Familiar, simple tasks become automatic and require few attentional resources (Baddeley 2007). In other words, we can carry out familiar tasks without thinking too much about them. It has been theorised that this may be because these tasks rely on existing, established cognitive routines (Gathercole *et al.* 2019). Novel, complex tasks require more attentional resources due to their higher cognitive or processing load i.e., it takes more controlled attention to maintain the to-be-remembered information in mind, whilst carrying out the processing part of a task (Barrouillet *et al*. 2004, Engle 2002, Kane *et al.* 2007). This may be why an individual's performance on ELWM tasks is strongly predictive of their attention control (Hutchison 2007, Shipstead *et al*. 2004, Unsworth and Spillers 2010, Unsworth *et al.* 2009). Evidence also shows that the processing load of a WM task (and therefore its attentional demands) is dependent upon how much information has to be retrieved from long-term memory and the quality of the information stored there (Barrouillet and Camos 2001). Following the cognitive routine theory, complex, ELWM tasks require the development of new cognitive routines that control the sequence of processes needed to perform the task (Gathercole *et al.* 2019).

Of course, in real-life, we sometimes attribute too few attentional (executive) resources to a task. For example, on a Saturday morning your goal may be to go to the supermarket but when you start driving you follow your weekday routine and automatically head towards your workplace (Archibald 2018). You then have to allocate more attentional resources to the task, to correct your plan and direct you back to your original goal. Errors like this often occur when we are distracted by other stimuli that compete for our limited mental workspace. These may be external stimuli (e.g., the sound of a car horn) or indeed our own thoughts (e.g., an existing memory). To achieve our intended goal, we must focus on the relevant information and ignore the distractions to protect the contents of WM that can be lost easily (Shipstead *et al.* 2014). This is evidenced by studies showing that people with high WM capacity appear to be better at inhibiting external distractions or prepotent responses than those with low WM (Conway *et al*. 2001).

The point that there is still much to learn about the association between attention and WM must be reiterated here (Shipstead *et al.* 2014). However, it is clear that attentional demands are greatest when tasks are unfamiliar and when there are environmental distractions (Archibald 2018, Shipstead *et al.* 2014). Therefore, learning activities in the classroom setting place heavy demands on the WM system, particularly for children with low WM capacity (Archibald 2017b, Gathercole 2008). The next section describes this in more detail, especially in relation to the population of interest in this doctoral study (4-5 year olds from areas of social disadvantage).

2.3.1 Working memory and attention in the classroom

As outlined in Chapter 1, the key aspects of attention that are essential prerequisites for learning are selective attention and sustained attention[1] (Dittman 2016, Sims and Lonigan

[1] Selective attention is the *"ability to apply goal-directed focus on one aspect of the environment, while ignoring irrelevant aspects"* (Gazzaley and Nobre 2012). Sustained attention is the ability to attend continuously to input so that information in that input can be processed (Leclercq 2002).

2013, Tambyraja *et al.* 2019). Attention skills typically develop rapidly during early childhood. Selective attention goes through key developmental transitions between 3-6 years (Hanania and Smith 2013) and there is rapid growth in sustained attention from 5-6 years (Betts *et al.* 2006, Manly *et al.* 2001). However, the development of these skills in young children is highly variable (Underbjerg *et al.* 2013) and children from areas of SD are likely to develop more slowly in the development of attention and other executive function skills (Noble *et al.* 2007). Therefore, for the population of interest in this doctoral study (4-5 year olds from areas of SD), the WM demands of the classroom will be greater than for their more advantaged peers.

Since the attentional demands of learning tasks depend on their novelty and complexity (Baddeley 2007), it is easy to see why young children may present as inattentive in the classroom. They are often completing unfamiliar tasks, which place high demands on the WM system in order to focus and sustain their attention (Archibald 2018). This is particularly the case for children from areas of SD who, due to their home environment and a lack of previous experience with structured learning tasks, may find many classroom tasks entirely novel (Chowdry and McBride 2007). The classroom setting is laden with distractions that compete for their mental workspace, increasing further the WM demands of all learning tasks. Furthermore, whilst the WM system develops rapidly in childhood, it does not reach maturity until around 14 years of age (Gathercole *et al.* 2004). This means that young children's WM system is under pressure and the information stored there, such as a verbal instruction on what they have to do, is lost through overload or distraction (Gathercole *et al.* 2008).

Children with low WM typically present as highly inattentive and distractible in the classroom and have poor long-term academic outcomes (Alloway *et al.* 2009, Gathercole *et al.* 2004a, Gathercole and Alloway 2008) (see Chapters 4 and 5 for further details on the learning difficulties associated with low WM). They have difficulties with: remembering and carrying out instructions (Engle *et al.* 1991); problem-solving (Swanson *et al.* 2008); and planning, organising and keeping track of tasks (Alloway *et al.* 2009, Gathercole *et al.* 2008). It is notable that these symptoms are strikingly similar to those frequently cited by teachers in Northern Ireland (NI) when referring children to the Regional Integrated Support for Education (RISE) Teams (presented in Chapter 1, section 1.3.4). Whether this inattentive behaviour in the classroom signals WM difficulties to the teachers and health professionals (HPs) who seek to support these children is revisited later in this thesis (section 2.4.3 and Chapter 5), but the evidence outlined here clearly speaks to the importance of identifying and supporting children with WM difficulties:

> *"The early recognition of working memory difficulties and the provision of effective educational support and targeted intervention are therefore paramount to improving the long-term outcomes for a vast number of children"* (Holmes *et al.* 2010, p.2).

2.4 Working memory and language

The relationship between WM, language acquisition and language disorder has been an area of research interest for many years. This has generated consistent evidence that verbal short-term memory (VSTM) and executive loaded WM (ELWM) tasks reflect distinct systems, which are related differently to language learning and processing (Archibald and Gathercole 2006). The way in which these skills are related is still unclear and there has been a lot of debate around the direction of the relationship between WM and language skills i.e., whether WM supports language acquisition and processing or whether linguistic knowledge supports the function and capacity of WM. Indeed, the literature around this is complex and there is some empirical evidence to support both positions. It is beyond the scope of this thesis to provide a detailed account of the complex literature in this regard. However, the subsequent sections of this thesis provide an overview of some of the seminal literature and emergent thinking in this field and elucidate the theoretical assumptions that underpin this thesis (see also Chapters 4 and 5).

2.4.1 Working memory supports language learning and processing

Since the 1990s, research has demonstrated strong links between children's WM and their language learning and processing ability. Specifically, studies have repeatedly shown that children's verbal short-term memory (VSTM) (measured by nonword repetition) is associated with their vocabulary development (Gathercole *et al.* 1990, Gathercole *et al.* 1992, Gathercole *et al.* 1997, Engel de Abreu *et al.* 2011). A seminal study conducted by Baddeley *et al.* (1998) demonstrated that the phonological loop plays a crucial role in word learning and there is now a widely held view that the retention of new words in VSTM supports the establishment of lexical representations in long-term memory (LTM) (Archibald 2018). Furthermore, once sufficient vocabulary knowledge has been accumulated, hearing new words triggers existing lexical knowledge, which in turn supports subsequent word learning (Gathercole 2006).

In addition to supporting word learning, VSTM may also support the comprehension of syntactically complex spoken sentences by enabling their mental replay (Papagno *et al.* 2007, Ellis Weismer *et al.* 2017, Frizelle *et al.* 2007, Noonan *et al.* 2014). This may be because poor verbal storage makes it hard to retain the grammatical details in spoken language (Montgomery *et al*. 2010). In recent years, it has become apparent that VELWM also plays a role in sentence comprehension, especially for sentences with high linguistic (morphosyntactic) demands (Engel de Abreu *et al.* 2011, Ellis Weismer *et al.* 2017, Frizelle *et al.* 2007). That is to say, as the morphosyntacic complexity of sentences increases, their processing places greater demands on executive aspects of the WM system. This suggests a continuum along which ELWM plays an increasing role in language comprehension as the amount and complexity of to-be-processed verbal information increases (Archibald 2018). It follows that, for children from areas of SD who may have had limited knowledge of the type of language used by teachers, processing complex multi-step classroom instructions will be dependent on attention-demanding working memory (ELWM). This means their WM is frequently overloaded and the information stored there is lost easily (Gathercole 2008).

2.4.2 Language supports working memory

In recent years, there has been increasing evidence to suggest that efficient and accurate language processing supports the functioning of the WM system (Archibald 2017b, 2018). For example, Engel de Abreu *et al.* (2014) suggested that elaborate linguistic knowledge supports the functional capacity of WM by enabling: the grouping of memory items (chunking); and the rapid retrieval of information from LTM. Put simply, children with wider and deeper vocabulary knowledge will be able to retrieve words from their LTM more efficiently and this will support their recall of verbal material. Accordingly, children with weaker vocabulary will constantly face higher WM demands in everyday tasks and environments such as the classroom (Archibald 2018).

2.4.3 Working memory and DLD

Children with Developmental Language Disorder (DLD) (persistent language difficulties that cause functional impairment and are not associated with a known biomedical aetiology

(Bishop *et al.* 2016)) are a highly heterogeneous group (Bishop 2003). However, there is strong evidence that many children with DLD also have WM deficits. Most of this evidence stems from studies of children with specific language impairment (SLI) (now encompassed within the term DLD) that have consistently demonstrated specific difficulties with VSTM tasks (e.g., Archibald and Joanisse 2009, Archibald and Gathercole 2006, Bishop *et al.* 1996, Botting and Conti-Ramsden 2001, Chiat and Roy 2007, Gathercole and Baddeley 1990, Vugs *et al.* 2014). Indeed, VSTM is recognised as a reliable marker (predictor) of DLD (Bishop *et al.* 1996, Archibald and Joanisse 2009). As a consequence of their deficits in verbal storage, these children may find it hard to retain the grammatical elements of spoken language and therefore have difficulty comprehending what is said to them (Montgomery *et al.* 2010).

There has been less research into the relationships between other aspects of WM and DLD but this is an area of increasing research interest. A review conducted by Henry and Botting (2017) found more than 50 papers (published since 2000) that examined executive aspects of WM in children with DLD. Evidence from these studies points to a connection between verbal ELWM and DLD (e.g., Ellis Weismer *et al.* 1999, Marton and Schwartz 2003, Archibald and Gathercole 2006, Henry *et al.* 2012). Children with DLD seem to rely on verbal ELWM when repeating utterances with complex syntactic structures whereas typical children find these tasks less cognitively demanding and can rely on passive verbal storage (VSTM) (Frizelle and Fletcher 2015). Vugs *et al.* (2015) looked at correlations between all four aspects of WM and receptive and expressive language skills in 4-5-year-old children with DLD and typically developing children (*n*= 116). They found that both VSTM and VELWM were related to receptive vocabulary, expressive vocabulary, verbal comprehension and syntactic development. Furthermore, there is also some emerging meta-analytic evidence to suggest that children with SLI may have deficits in visuospatial WM in addition to those in the verbal domain, albeit to a lesser degree (Vugs *et al.* 2013). This is possibly due to the role of verbal mediation in the processing of visuospatial information (Archibald and Gathercole 2006, Gillam *et al.* 1998) because children with SLI show disadvantages on non-verbal tasks that contain elements which would typically be verbalised (Botting *et al.* 2013).

The involvement of executive aspects of WM in SLI is also implied by the fact that the majority of children with SLI also have difficulties with other aspect of executive functioning, including: inhibition (Henry *et al*. 2012, Im-Bolter *et al.* 2006, Marton *et al*. 2012, Spaulding 2010); sustained attention (Finneran *et al*. 2009, Montgomery 2009, Spaulding *et al.* 2008); and cognitive flexibility (Marton 2008). Henry *et al.* (2012) assessed 10 aspects of executive functioning in children with SLI and found that two-thirds had difficulties with at least three EFs. Children with SLI have particular difficulties in selective and sustained attention when tasks have high verbal or non-verbal WM demands (Noterdaeme *et al.* 2001). Furthermore, their deficits in sustained attention, albeit below the threshold of clinically significant attention problems, could contribute over time to their persistent language learning difficulties (Finneran *et al.* 2009).

Overall, it is beyond the scope of this thesis to present a full, detailed review of the extant literature on the relationship between WM, language learning, language processing and DLD. However, it must be noted that there are some limitations to the strength of the evidence discussed. Children with SLI are not a heterogeneous group and there have been many issues over the years in relation to how these children are diagnosed (Bishop *et al.* 2016). This means the evidence from individual studies may not be generalisable. Also, many of the studies conducted in this area have used small sample sizes. That said, the evidence available to date and current thinking in this area generally supports the concept of a complex reciprocity between these skills that should be duly considered in both practice and research contexts (Archibald 2017b, 2018, Tambyraja *et al.* 2019).

2.4.4 The symbiotic relationship between WM, attention and language and implications for practice and research

The evidence described so far in this chapter implicates a symbiotic relationship between WM, attention and language skills. Children with low language skills and those with DLD are likely to face higher WM demands in the classroom than their typically developing peers. When WM demands are high (as they are during times of new learning), these children's reduced WM skills, coupled with their low language ability, mean that all classroom tasks are highly attention-demanding. This means their WM skills are uniquely stretched and, consequently, they repeatedly fail to complete learning tasks and reach their academic potential (Alloway and Alloway 2015a, Alloway *et al.* 2009, Gathercole and Pickering 2000). This has significant implications for the population of interest in this doctoral study (4-5 year old children from areas of social disadvantage (SD), who are likely to start school with limited vocabulary (Law *et al.* 2011, Locke *et al.* 2002). Indeed, these children are likely to experience a 'double whammy' in terms of language and cognitive difficulties (Botting 2006, p. 38).

In order to support this population, education staff and health professionals (HPs) working with these children need to recognise that these classroom behaviours may indicate WM difficulties (Holmes *et al.* 2010). It has been suggested that teachers may misattribute these behaviours to low motivation or laziness (Gathercole *et al.* 2006). This is supported by the findings of Alloway *et al.* (2012) who found teachers in Scotland had limited awareness of WM (see Chapter 5 for further details). However, this is the only study to have investigated this explicitly and there have been no studies of health professionals' (HPs) understanding or practice in relation to children with WM difficulties. This is a gap in the evidence that clearly needs to be addressed, since HPs in services such as the RISE Teams work on a daily basis with children referred on the basis of attention and language difficulties that may be related to WM deficits.

In terms of research, the fact that it is difficult to separate difficulties in WM, language and attention underscores the value of research (such as this doctoral study) that co-investigates these skills (Adams *et al.* 2018, Tambyraja *et al.* 2019). Of course, the critical question is whether targeting WM as an underlying skill could improve WM, and effect change to attention and language. The next two sections of this chapter provide an overview of the current state of the evidence (and the gaps therein) regarding WM training and language interventions.

2.5 Working memory training and transfer: current evidence and gaps in knowledge

The historical trajectory of research into the effectiveness of adaptive, computerised WM training, and the debate surrounding it is outlined comprehensively in the introduction of the systematic review paper (Rowe *et al.* 2019a, Chapter 4). To avoid duplication in this thesis, these issues are not discussed in detail at this point. Rather, what follows is a summary of the identified gaps in the WM literature found at the outset of this doctoral study and an overview of the current areas of debate.

2.5.1 The effectiveness and feasibility of WM interventions applied in children's everyday contexts

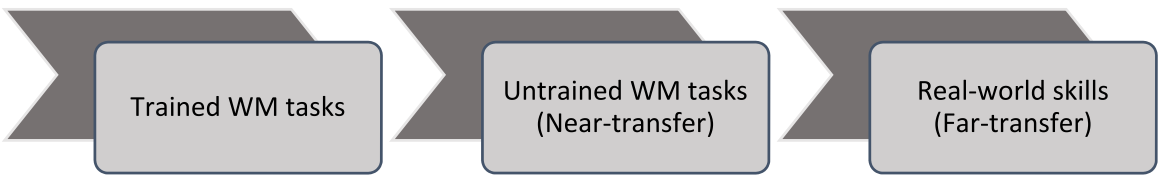
The major source of contention around the therapeutic value or educational relevance of WM training lies in the limited evidence for transfer effects from computerised WM training to untrained WM skills (near-transfer) and real-world skills (far-transfer) (e.g., Melby-Lervåg and Hulme 2013, Melby-Lervåg *et al.* 2016). This has led to speculation that embedding WM training within the types of educational activities that depend on it may be a less artificial, ecologically valid way of improving WM to enhance real-world skills such as attention, language and academic attainments (e.g., Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014). Also, it has been suggested that more varied training regimes may increase people's motivation and engagement with training (Wass *et al.* 2012). Indeed, a diverse range of tasks and activities has been suggested as benefitting WM and real-world skills, including: mindfulness (Ricarte *et al.* 2015), sporting activities (Halperin *et al.* 2015), sensory activities (Alloway and Alloway 2015b, Worthen 2010), and educational curricula that specifically target EFs (Diamond *et al.* 2007, Diamond 2012). However, there has been no previous systematic review of the evidence in this regard so very little is known about the validity of these claims.

There are significant gaps in the evidence regarding the factors that may impact on the implementation of WM training in real-world settings. A small number of studies have conducted computerised WM training in schools (e.g., Holmes *et al.* 2009, St Clair Thompson *et al.* 2010, Roberts *et al.* 2016, Rode *et al.* 2014). However, these have focused on investigating the effects of training on children's WM, rather than looking at the contextual factors that may impact on the implementation of interventions in the school setting. There has been some speculation that providing training in school may enhance children's motivation (Jaeggi *et al.* 2012). On the other hand, the unpredictability of real-life settings could make it hard to control the quality and fidelity of training and the amount of distraction in the environment (De Simoni and von Bastian 2018, Jaeggi and Buschkuehl 2014). These potential advantages and disadvantages have been highlighted but there has been no explicit investigation of the factors that may impede or facilitate the feasibility of WM training in the school setting.

2.5.2 Underlying mechanisms of transfer

Since the debate around the value of WM training has centred on the lack of transfer effects, it is not surprising that researchers are now focusing on investigating the underlying cognitive mechanisms that may support transfer. This focus has reiterated the importance of clearly specified causal pathways in WM training studies i.e., in order to demonstrate near-transfer effects, the trained tasks must have been measured. Similarly, in order to claim far-transfer effects, near-transfer must have been observed (Melby-Lervåg and Hulme 2013, Redick *et al.* 2015). Figure 2-3 depicts this.

Figure 2-3 Causal pathway required in WM research to demonstrate transfer effects



Recent reviews and meta-analyses have scrutinised previous studies of computerised WM training to explore whether the trained and untrained tasks measured have overlapping or distinct features (e.g., De Simoni and von Bastian 2018, Gathercole *et al.* 2019, Guye and von Bastian 2017, Schwaighofer *et al.* 2015, Soveri *et al.* 2017, von Bastian and Oberauer 2014). The key findings from these studies suggest that practice effects from WM training tend to be highly task and modality specific. For example, improvement on one complex span task may transfer to another complex span task (Gathercole *et al.* 2019). However, there are several caveats to this. Firstly, most of the studies included in the meta-analyses have small sample sizes reducing their potential to demonstrate even small transfer effects (Gathercole *et al.* 2019). Secondly, the included studies are often heterogeneous and the evidence has often been inconsistent (von Bastian and Oberauer 2014). Crucially, it may be that the potential for transfer effects depends on the nature of the trained task and the evidence in this regard is unclear.

Overall, there are still considerable gaps in what we know about the mechanisms of transfer in WM training. Table 2-1 provides a summary of the theories presented in the literature. This is based on the work of Gathercole *et al.* (2019) who proposed the theory (referred to in Chapter 1) that transfer results from the development of new cognitive routines, which specify and control the sequence of processes needed to perform a task. This emergent thinking is underpinned by empirical evidence sourced from a meta-analysis of both computerised and non-computerised WM interventions conducted with both children and adults (n= 23) but is still a largely untested theory.

Table 2-1 Theories of transfer (based on Gathercole *et al.* 2019)

Theory	Description	Comment/challenge
Neuroplasticity (Klingberg 2010)	Repeated practice on WM tasks causes changes in the neural system underpinning WM. This implies that the whole cognitive WM system is enhanced in an undifferentiated way.	It does not account for the inconsistent near- and far-transfer effects from WM training since improved neural networks should affect all skills/tasks.
Process-specific transfer (Dahlin *et al.* 2008)	WM training supports specific processes. This implies that transfer should only occur when trained and untrained tasks use the same processes.	To date, this theory does not explain how similar the process demands between shared tasks have to be to support transfer.
Cognitive training as skill acquisition (Anderson 1982, Newell 1991)	Transfer is viewed as a result of the acquisition of complex cognitive skills that can subsequently be applied to similar untrained tasks and become increasingly automatic with practice.	This may imply that transfer does not occur if the trained task can be performed automatically and does not therefore allow the acquisition of complex cognitive skills.
Cognitive routine framework (Gathercole *et al.* 2019, p.21)	This theory builds on the skill acquisition theory (above) and assumes that training on unfamiliar WM tasks promotes the development of new cognitive routines (i.e., structured specifications of the processes that are needed to perform a task) that can then be applied to other tasks with shared features. This suggests that new cognitive routines can be adapted to fit tasks with overlapping properties.	This is supported by the authors' meta-analysis of studies (*n*= 23) that transfer only occurs to structurally similar WM tasks e.g. Holmes *et al.* (2019) found that gains on updating tasks did not transfer to complex span tasks

This overview suggests that there needs to be an overlap between trained tasks (that require a new cognitive routine) and untrained tasks in order for transfer to occur. On this basis, embedding WM training within typical educational activities in the classroom setting might support the transfer of training effects to real-world skills (e.g., Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014). Administering training in the classroom setting, which is laden with distractions, might uniquely tap into ELWM and its associations with inhibitory control (Henry 2012). This may mirror the way these skills are used in everyday classroom learning and, consequently, support the creation of new cognitive routines that could transfer to real-world skills (see section 2.2.1). This theory has not been tested and there is still a lot to learn around WM training and transfer effects where, to date, methodological issues have contributed to a lack of clarity. There is a pressing need for well-designed studies that investigate the cognitive mechanisms underlying WM training and test theories around new cognitive routines.

2.5.3 Children under 7 years and population sub-groups

In addition to significant gaps in what is known about transfer effects, there are also unanswered questions about the individual differences that may mediate or moderate training and transfer effects (Jaeggi *et al.* 2012, Morra and Borella 2015). In particular, there have been copious amounts of research into computerised WM training with adults but far fewer studies have been conducted with children, especially those under seven years. This is striking in some of the frequently cited systematic reviews and meta-analyses of WM training (Melby-Lervåg and Hulme 2013, Melby-Lervåg *et al.* 2016, Schwaighofer *et al.* 2015). Across these reviews, only four of the included studies were conducted with children under seven years of age (Ang *et al.* 2015, Nutley *et al.* 2011, St Clair Thompson *et al.* 2010, Thorell *et al.* 2009).

The evidence in relation to WM interventions with certain population sub-groups is also sparse, since the majority of studies have been conducted with healthy adult participants (Morra and Borella 2015). What is perhaps surprising is that few studies have been conducted with children with identified WM difficulties. For example, of the studies (n= 47) reviewed by Schwaighofer *et al.* (2015), only two focused on this population (Dunning *et al.* 2013, Holmes *et al.* 2009). Whilst these studies showed improvements on children's WM following training, the strength of the evidence was constrained by methodological issues: the lack of active control groups; small sample sizes; and limited consideration of transfer effects.

Overall, the evidence for the effectiveness of WM training with young children is extremely limited, particularly for those with low WM. Furthermore, for the specific population of interest in this doctoral study (children from areas of social disadvantage who are at risk of language disorder and low academic achievement) no previous studies of WM training have been found.

2.5.4 Features of WM training

The cumulative evidence from computerised WM training has led to a general acceptance that, to have any potential to produce transfer effects, training must be continually challenging (adaptive) (e.g., Holmes *et al.* 2009, Klingberg *et al.* 2005, Melby-Lervåg and Hulme 2013). However, with regards to other features of WM training regimes, there are significant gaps in the evidence base. In particular, there has been limited consideration of whether dosage (the amount and intensity of training) moderates or mediates the effects of WM training. There is some evidence to suggest that the greater the number of training sessions and the higher their frequency, the more likely it is that the intervention will be effective and produce transfer effects (Jaeggi *et al.* 2008, Alloway *et al.* 2013). However, wide variations have been found in the total amount of intervention provided and the length of training sessions in training studies. For example, von Bastian and Oberauer's (2014) review of 45 studies found that the number of training session ranged from 3 to 100 sessions, which varied in length from 10 minutes to 45 minutes duration. Therefore, whether the effectiveness of WM training is dose-dependent and, if so, what are the optimum levels of training required cannot be stated with any certainty.

2.5.5 Summary and implications

There has been wide dissemination of high profile systematic reviews and meta-analyses demonstrating the inconsistent evidence for far-transfer effects from computerised WM training to real-world skills (e.g. Melby-Lervåg and Hulme 2013, Melby-Lervåg *et al.* 2016). This has resulted in considerable skepticism about the value of WM training. Nonetheless, this chapter has shown there are many gaps in what is known about the value of non-computerised interventions applied in young children's everyday contexts that may be more ecologically valid than the computerised approach (e.g., Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014). In light of current theorising around the underlying mechanisms of transfer, the pertinent question is whether WM training applied in everyday contexts might promote transfer effects. Since this approach more closely resembles (overlaps with) how WM is used in everyday life, it may support the development of new cognitive routines that can be applied to other real-world tasks. Schwaighofer *et al.* (2015) and Diamond (2013) propose that delivering WM training within educational activities may indeed promote cross-over from one cognitive activity to another, due to the interplay between cognitive functions in a complex environment. There is a clear need for hypothesis-driven investigations in this regard.

2.6 Conclusions and gaps in the evidence base

This chapter has demonstrated that the literature regarding the associations between WM, attention and language is complex. However, it has highlighted the symbiotic nature of the relationship between these skills, leading to the suggestion that targeting WM as an underlying skill may improve WM and promote transfer to attention and lanuage skills. This is intuitively appealing given the current policy objective in the UK that promotes the use of collaborative, classroom-based approaches to support children from areas of social disadvantage (SD) who are at risk of language disorder and academic underachievement (DENI 2006, DfES 2003, DFE 2017). However, there are significant gaps in what is known about the effectiveness of WM interventions applied in children's everyday contexts or the factors that may impact on their implementation. In addition, very little is known about how the population of interest in this doctoral study (4-5 year olds from areas of SD who are at risk of WM, language and attention difficulties) respond to WM training or how the teachers and HPs who support them perceive their difficulties. The aims of this doctoral study (as defined in Chapter 1) explicitly address these gaps in the evidence base.

Chapter 3 - Design and methods

3.1 Introduction

This chapter provides an overview of the theoretical framework, study design and methodology used throughout this doctoral study. It begins with a description of the realist paradigm (Bhaskar 1997), complexity theory (Byrne 1998) and ecological perspective (Glanz and Rimer 2005, McLeroy *et al.* 1988) that underpin this study and the rationale for why they were adopted. It then describes the study design that is based on the Six Steps to Quality Intervention Development Model (6SQuID) (Wight *et al.* 2016). The chapter progresses to describe each step of the model and the methods used throughout, presented in chronological order. This chapter reflects on the use of co-production and logic modelling and how these methods enhanced the rigorous approach applied across all steps of the intervention development and testing. It also covers the integration of mixed methods evidence, the ethical issues considered during the study and the methodological limitations that may compromise the strength of the evidence found.

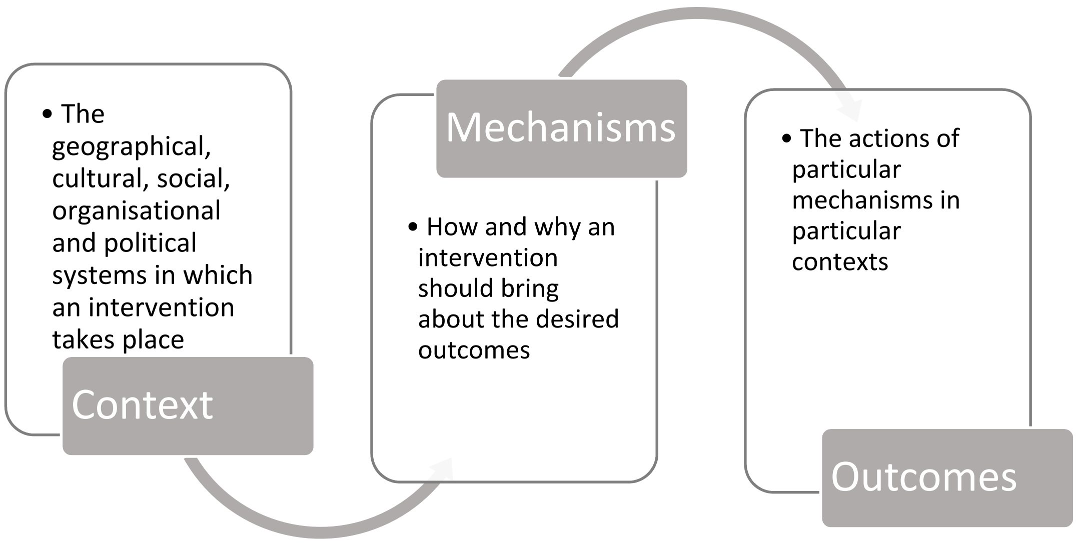
3.2 Theoretical frameworks

3.2.1 The realist paradigm

This doctoral study is underpinned by a realist paradigm, supported by complexity theory and an ecological perspective. According to Kuhn (1962) paradigms are sets of beliefs that provide theoretical frameworks for the purpose and conduct of research. Over the past 60 years, positivism has been the predominant paradigm adopted in nursing and healthcare research. For positivists, the world is subject to general laws that can be observed, explained and predicted (McKenna 1997). Consequently, the aim of research is to collect facts using objective methods to identify laws that are empirically observable (Parahoo 2014). More recently, the merits of alternative paradigms have been recognised (Corry *et al.* 2018). In particular, the realist paradigm has become more prominent in public health and healthcare research.

Scientific realism emerged from the work of philosophers, such as Durkheim (1966), who challenged the empiricist ontology of positivism. Realists argue that causal laws are not constant, rather causal mechanisms operate according to *context* (Bhaskar 1997). From this perspective, healthcare interventions are viewed as events that take place within open systems, meaning that multiple causal mechanisms may exert an influence on them (Bhaskar 2008). It supports a nuanced understanding of intervention effectiveness, which goes beyond asking 'what works', to ask 'for whom it works and under what circumstances' (Pawson and Tilley 1997, p.72). From the realist perspective, intervention research should identify and explain or propose the causal *mechanisms* that influence an intervention's *outcomes*. Pawson and Tilley (1997) introduced a framework for realist inquiry consisting of *context, mechanism and outcomes* (CMO) configurations. Figure 3-1 depicts how the CMO framework can be applied throughout the development and testing of interventions.

Figure 3-1 Representation of Context-Mechanism-Outcomes (CMO) Framework (Pawson and Tilley 1997)



The realist paradigm underpinned every aspect of this doctoral study including its aims, design and methods. This is highlighted throughout the remainder of this chapter, which explains the methodological choices made during the research. Overall, the adoption of the realist philosophy resulted in a continual focus on understanding the impact of the intervention's *context* on its (ultimate) implementation, and to viewing this context from a systems perspective (Bhaskar 1997, 2008). This led to the conceptualisation of the context as the interacting systems of the Regional Integrated Support for Education (RISE) teams and mainstream primary schools in areas of social disadvantage in Northern Ireland (NI).

Specifically, the following aspects of the research design exemplify the realist underpinning to this study: the intentional investigation of the intervention context through the inclusion of a qualitative study to explore health professionals' and teachers' perceptions of WM (see Chapter 5); the use of co-production work to develop the intervention in a way that would be deliverable by the RISE teams and teachers in schools in areas of social disadvantage in Northern Ireland (NI) (see Chapter 7); and the integration of a process evaluation in the feasibility trial that explored the contextual factors impacting on the fidelity of the intervention implementation in the classroom setting (Moore and Evans 2017) (Chapters 8 and 9). Furthermore, the adoption of a realist paradigm is evidenced through the explicit application of the CMO framework (Pawson and Tilley 1997) that typifies this philosophy. This resulted in a continual focus on having a clearly articulated theory of change around how and why improving WM should enhance children's attention and language skills (see Chapter 6 and Chapter 6, Figures 6-1 and 9-1).

3.2.2 Complexity theory and the ecological perspective

In the development and testing of public health interventions, realist thinking has been complemented by complexity theory because both "*understand reality as comprising* *multiple, nested, open systems in which change is generative, context dependent and time irreversible*" (Westhorp 2012, p.406). Complexity theory proposes that an intervention's outcomes are determined by multiple, interacting factors at the system level (Byrne 1998). Complexity is regarded as a property, not just of an intervention, but also of the context (or system) within which it is implemented (Shiell *et al.* 2008, Hawe 2015). Schools, hospitals and other healthcare organisations represent complex social systems that are constantly adapting (Shiell *et al.* 2008). These systems interact with each other but are also nested within larger supra-systems: schools within the educational supra-system; and clinical services within the health supra-system (Moore *et al.* 2019). Therefore, they constantly respond to internal and external pressures and are extremely dynamic.

Systems thinking is now being applied to other types of health and education interventions. Through the systems lens, any intervention can be viewed as a disruption to a complex system (Hawe *et al.* 2009). Intervening at one level within a system generates patterns of outcomes at other levels, which are often difficult to predict (Glouberman and Zimmerman 2002). In this way, an intervention is as much about what is displaced or disrupted within a system as it is about what is introduced (Moore and Evans 2017). Consequently, understanding the complex social system(s) within which an intervention is to be placed is vital during intervention development (Hawe *et al.* 2009, Moore *et al.* 2019). Thinking about interventions as events within complex systems inherently involves an ecological perspective where the role of context is truly acknowledged (Hawe *et al.* 2009). This means recognising that complex systems comprise *multiple levels* of influence that both affect and are affected by an individual, event or intervention (Glanz and Rimer 2005, McLeroy *et al.* 1988). The ecological perspective is described in greater detail later (see 3.5.2.5).

3.2.3 Rationale for the theoretical framework

There are several reasons for the adoption of a realist paradigm, supported by complexity theory and an ecological perspective, as the underpinning to this doctoral thesis. Most importantly, this approach is consistent with the overall aim and objectives of the research regarding the development and testing of a novel classroom-based intervention within the context of the dynamic, interacting systems of the RISE teams and mainstream primary schools in areas of social disadvantage in NI. The appeal of the realist paradigm lay in its focus on each aspect of Pawson and Tilley's (1997) basic trio of intervention implementation – context, mechanism and outcomes (CMO framework).

The clear focus on the intervention *context* adheres to guidance from the National Institute for Health Research (NIHR) (Howarth *et al.* 2016) and the Medical Research Council (MRC) on the development of complex interventions (Craig *et al.* 2008, MRC 2008, 2019). It also responds to calls for greater examination of the contextual factors that impact on the implementation of interventions for children at risk of a language disorder (Law *et al.* 2017b, Law 2019, Murphy 2019). Viewing this context through a systems lens, and consequently from an ecological perspective, led to the use of the socio-ecological model (see 3.5.2.5) and logic modelling (see 3.6.1) that were applied at each stage of the intervention development and during its evaluation.

Placing an emphasis on understanding the *mechanism* by which the novel intervention was expected to work and the impact of other mediators and moderators on its effects was vital to this study (Noyes *et al.* 2013, Petticrew *et al.* 2013). It ensured that the intervention was theoretically underpinned using both individual and systems theories, and evidence-based in terms of both its content and dosage, thereby addressing gaps in the WM and DLD literature identified in Chapters 1, 2 and 4 of this thesis.

Having a thorough understanding of the intervention *context* and a sound theory about the *mechanism* by which it was intended to work meant that it was possible to clearly identify the factors that may influence its *outcomes*. Consequently, this enabled the identification of the factors that may impact on the fidelity of the intervention delivery (and ultimately its implementation in a full trial) (Moore and Evans 2017). Overall, the theoretical framework adopted in this study supported a practical methodological framework based on sound reasoning that was consistently applied throughout this doctoral study.

3.3. Study Design

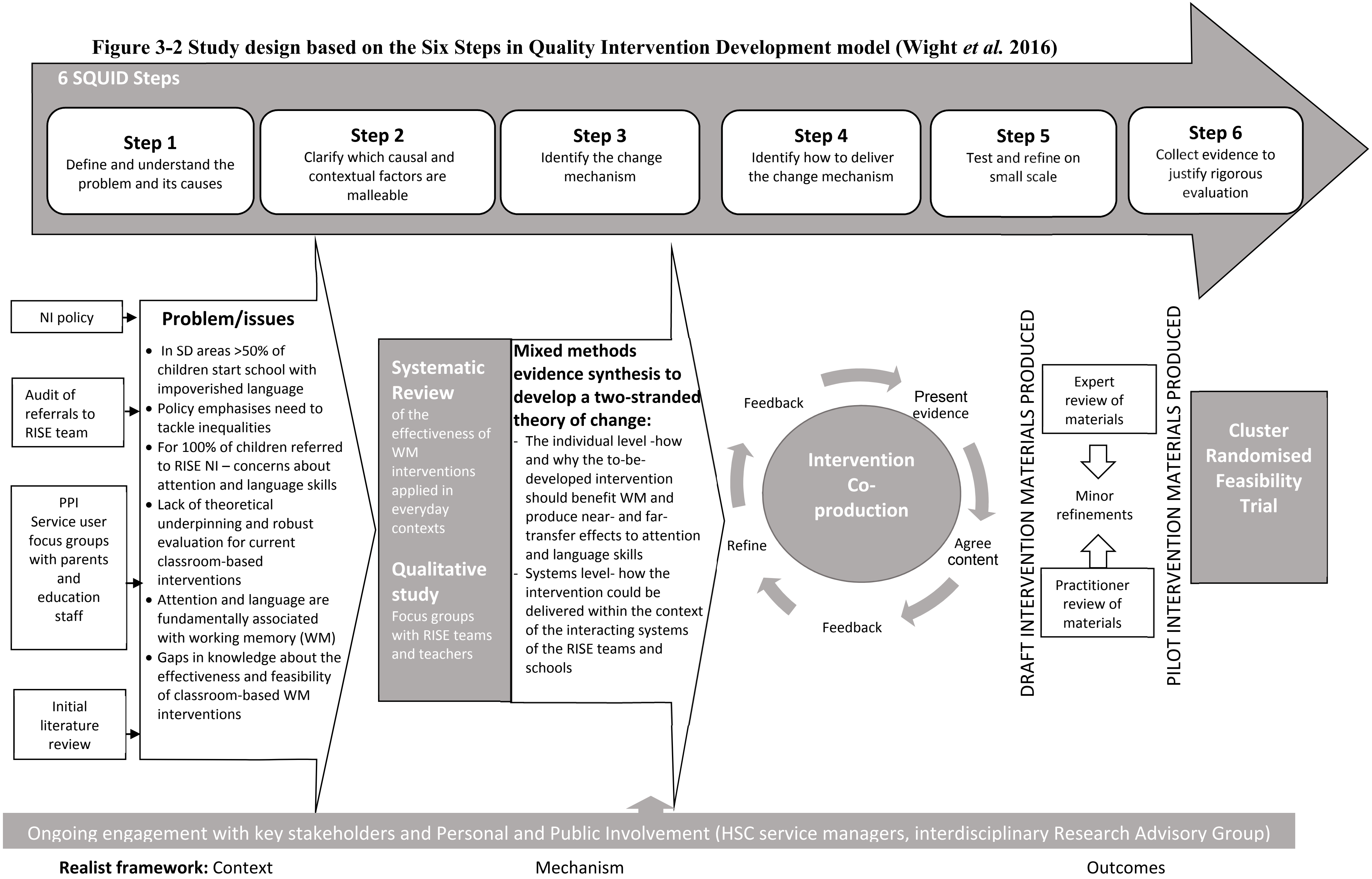
3.3.1 Overview of study design

This was a mixed methods study, involving both qualitative and quantitative components in a multi-phase design framed by the Six Steps in Quality Intervention Development (6SQuID) model (Wight *et al.* 2016). As implied by its name, this model guides researchers or practitioners through a logical, stepped process in order to maximise an intervention's potential effectiveness (O'Cathain *et al.* 2019a, Wight *et al.* 2016). Sections 3.4 to 3.9 in this chapter detail the six steps of the model and explain the specific methods used in this doctoral study. However, to provide an overview, the six steps in the process are listed here: 1) Define and understand the problem and its causes; 2) Clarify which causal and contextual factors are malleable; 3) Identify the change mechanism; 4) Identify how to deliver the change mechanism; 5) Test and refine on a small scale; and 6) Collect evidence to justify rigorous evaluation/implementation.

Within the overall framework of the 6SQuID model (Wight *et al.* 2016), there were four main research components in this doctoral study: 1) A systematic review of WM interventions applied in children's everyday contexts; 2) A qualitative study that explored health professionals' (HPs); and teachers' perceptions of WM; 3) Co-production work with HPs, teachers and parents of 4-5 year olds; and 4) A cluster randomised feasibility trial of the novel intervention. Figure 3-2 visually depicts how these components sit comfortably within the 6SQuID model (Wight *et al.* 2016). It shows how the research design is underpinned by the CMO framework (Pawson and Tilley 1997) that typifies the realist research paradigm adopted in this doctoral study.

The engagement of key stakeholders is an inherent aspect of the 6SQuID model (Wight *et al.* 2016). In the current study, this was supported by the establishment of a research advisory group that met biannually throughout the research process (see section 3.4). This demonstrates a commitment to Personal and Public Involvement (PPI) in research (Health and Social Care Reform Act Northern Ireland 2009, PHA 2014) and the emphasis placed on understanding the real-life context within which the to-be-developed intervention would be implemented (Bhaskar 1997). Throughout the research, expert opinion was also provided by two advisors: Professor Lucy Henry (L.H.) (City, University of London); and Dr Joni Holmes (J.H.) (MRC Cognition and Brain Sciences Unit, University of Cambridge). The detailed rationale for the use of a mixed methods design and the selection of the 6SQuID model (Wight *et al.* 2016) are outlined in the next sections.

Figure 3-2 Study design based on the Six Steps in Quality Intervention Development model (Wight *et al.* 2016)



3.3.2 Rationale for using a mixed methods, multi-phase design

Mixed methods research (MMR) has been defined as *"an intellectual and practical synthesis based on qualitative and quantitative research"* (Johnson *et al.* 2012, p.129). MMR is distinguished from multi-methods research by the intentional integration of both quantitative and qualitative data with the purpose of gaining a better understanding than any one single method could provide i.e., the whole is greater than the sum of the parts (Anguera *et al.* 2018). In intervention research and implementation science, the merits of MMR are widely recognised (Hawe 2015, Petticrew *et al.* 2013). They provide an understanding of different perspectives that support the development of better programmes (Creswell and Creswell 2018). Multi-phase designs are applied frequently in realist studies because the integration of data from separate phases can be used iteratively to build an intervention theory so that there is clear understanding of the change mechanism (Wong 2015).

From the conception of this doctoral study, it was apparent that a MMR design would be required to address the research questions. An initial scope of the literature indicated that little was known about the effectiveness of WM interventions applied with young children in everyday contexts and that a systematic review would be a prerequisite to identify the active components for a novel intervention. It was also clear that qualitative methods would be necessary to explore the contextual factors that may act as facilitators or barriers to intervention implementation (Leeman and Sandelowski 2012, Song *et al.* 2010). As there have been no previous studies of the implementation of WM interventions in the classroom setting, the need for feasibility testing prior to a full-scale trial was also evident (Jaeggi and Buschkuehl 2014).

In MMR designs, quantitative and qualitative data can be integrated in a number of ways including: merging the data, explaining the data, building the data from one element to another, or embedding the data within a larger framework (Creswell and Creswell 2018). In this doctoral study, the integration of mixed methods evidence was intrinsic to the intervention development model employed (6SQuID, Wight *et al.* 2016). The rationale for the use of the 6SQuID model is explained below (Section 3.3.3). The integration of mixed methods evidence and the data triangulation are described later in this chapter (Section 3.10).

3.3.3 Rationale for using the 6SQuID model (Wight *et al.* 2016)

The original MRC guidance for the development of complex interventions (Campbell *et al.* 2000) had a strong influence on the methodological approach chosen for the current work. However, over the past two decades, the field of intervention development has evolved rapidly, with an increasing number of approaches reported in the literature, ranging from standardised approaches to broad overviews (O'Cathain *et al.* 2019a). This growth has been fuelled by the move towards systems thinking (Brainard and Hunter 2016, Hawe *et al.* 2009, Howarth *et al.* 2016, Moore and Evans 2017, Shiell *et al.* 2008). Whilst the revised MRC guidance (Craig *et al.* 2008a, 2008b, MRC 2008, 2019) places more emphasis on the exploration of the intervention context (than the original guidance), it has been criticised for not incorporating a systems lens (Fletcher *et al.* 2016, Moore *et al.* 2019). In recognition of this, the MRC funded the IdentifyiNg and assessing different approaches to DEveloping compleX interventions (INDEX) study that aimed to produce guidance for researchers on how to develop complex interventions (O'Cathain *et al.* 2019b).

As part of the INDEX study, O'Cathain *et al.* (2019a) conducted a systematic review of the literature on intervention development. Having reviewed 87 papers that took a variety of approaches to intervention development, they identified eight categories of emerging intervention development approaches (see Table 3.1). The authors highlighted some common features across these eight categories: synthesising existing evidence; theory; primary research; co-production; logic modelling; and testing.

Table 3-1 Intervention development approaches (O'Cathain *et al.* 2019a)

Intervention Development Approach	Description
1. Partnership	Intervention development involves the equal participation of the research team and people who will receive the intervention
2. Target population-centred	Interventions are based on the views of the people who will use them
3. Evidence and theory-based	This includes influential approaches such as the MRC framework (MRC 2000, 2008, 2019) and Intervention Mapping (Bartholomew *et al.* 2016)
4. Implementation-based	Interventions are developed with attention to the factors that may ensure their use in the real world
5. Efficiency-based	Intervention components are tested using experimental designs to select those that will optimise efficiency
6. Stepped or phased	Interventions are developed with an emphasis on following a systematic set of processes. For example, 6SQuID (Wight *et al.* 2016)
7. Intervention-specific	A particular approach is constructed for the development of a specific intervention. Examples are emerging in the nursing literature e.g., van Meijel *et al.* (2004) who constructed a four-stage model including stages: problem definition, accumulation of building blocks for intervention design, intervention design and intervention validation
8. Combination	These are hybrid approaches in which existing models are formally combined with other elements. For example: Hawkins *et al.* (2017) used a three stage framework for intervention co-production and prototyping described as being complementary to other approaches including 6SQuID; and Bleijinberg *et al.* (2018) used the MRC guidance and added 4 additional elements

There are strengths and limitations to each of the approaches identified by O'Cathain *et al.* (2019a). The 6SQuID multi-phase approach was selected for this doctoral study for several reasons. Firstly, it is consistent with the realist paradigm, complexity theory and the ecological perspective underpinning the study. Secondly, through the ongoing involvement of stakeholders at all stages of the process, it supported a thorough understanding of the intervention context (the interacting systems of the RISE teams and schools). Thirdly, by focusing on the identification and malleability of causal and contextual factors (steps 2 and 3 of the 6SQuID model), it ensured the novel intervention was based on empirical evidence and had a solid theoretical rationale. Lastly, the authors of the model promoted the use of co-production to maximise the intervention's acceptability and feasibility. This is consistent with the principles of Personal and Public Involvement (PPI) (also underpinned by realism) that are a requirement of publicly funded research in health and social care and indeed practice settings (Health and Social Care Reform Act Northern Ireland 2009, PHA 2014). Furthermore, the 6SQuID model provided a logical and practical framework for this study, thereby minimising the potential of research waste (O'Cathain *et al.* 2019a).

3.4 6SQuID Step 1. Define and understand the problem and its causes

Defining a problem that may require a novel intervention requires an understanding of: the history and extent of the observed phenomenon; what interventions currently exist to address these and why they are not adequate; and what other factors shape and perpetuate the situation (Funnell and Rogers 2011). This requires two key activities: a review of the wider literature; and the involvement of stakeholders (Wight *et al.* 2016). During the development of the research proposal for this doctoral study, a thorough examination of the background literature was conducted. This included a review of health and education policy in the UK (at a national level) and in NI (at a regional level), and the literature pertaining to WM and DLD internationally. These findings were outlined in Chapters 1 and 2 of this thesis. An audit of referrals to the RISE teams was also undertaken by the PhD researcher, and the perspective of service users and stakeholders were obtained via focus groups conducted by the RISE teams, as part of their routine service evaluation (Harron and Dickson 2013).

As part of an ongoing commitment to PPI and to support the continued understanding of the contextual factors that could impact on the conduct of the research and intervention implementation, a Research Advisory Group was established at the commencement of the study. This group comprised: RISE team managers (*n*= 2); a senior member of staff from the Education Authority NI; a school principal; a year one teacher; and two parents of children with DLD. Face-to-face meetings were held with this group biannually throughout the doctoral study.

3.5 6SQuID Step 2. Clarify which causal or contextual factors are malleable and have the greatest scope for change

This step in the 6SQuID model informs the development of a theory (or theories) of change about the mechanism by which an intervention is expected to work. Since this doctoral study is underpinned by complexity theory, there was a need to investigate how the intervention would impact on WM (at the individual level) and how it could be delivered within the interacting systems of the RISE teams and schools (at a system level) (Shiell *et al.* 2008, Hawe 2015). Step 2 therefore involved two separate but concurrent studies: a systematic review of interventions targeting working memory in 4-11 year olds within their everyday contexts (Chapter 4, Rowe *et al.* 2019a); and a qualitative study using focus groups with HPs and teachers (Chapter 5, Paper 3 submitted for publication) (see Figure 3-2). The methods used in each of these studies are outlined below.

3.5.1 Systematic review

The systematic review of interventions targeting working memory in 4-11 year olds within their everyday contexts included eighteen papers (Rowe *et al.* 2019a). Full details of the review methods can be found in Chapter 4. This section provides a description of the type of review conducted and the rationale underpinning it. Since one of the key aims was to identify the active ingredients in effective interventions that impact on WM (the change mechanism) a diverse range of interventions were included in the review. It also judiciously included studies with both randomised and non-randomised designs (Gough *et al.* 2012, Pawson 2006). The heterogeneity of the review is also consistent with the realist perspective underpinning this doctoral study and reflects the way in which systematic review methodology has evolved in recent years (Gough *et al.* 2012, Petticrew 2015, Wong *et al.* 2013).

Over the past 20 years there has been a huge increase in the number of systematic reviews conducted, making a vital contribution to evidence-based healthcare (Clarke and Chalmers 2018). Systematic reviews have been defined as: *"a way of bringing together what is known from the research literature using explicit and accountable methods"* (Gough *et al.* 2012, p.1). Traditionally, systematic reviews were associated with the summative evaluation of an intervention's effectiveness by combining the results of several empirical studies with a randomised control design (Noble and Smith 2018). However, in recent years, the methodology has moved away from a narrow focus on effect sizes, with both the Cochrane and Campbell Collaborations recognising that reviews may include non-randomised and quasi-experimental designs, as well as RCTs (Higgins and Green 2008). Many types of reviews have developed, varying in their: aims and approach; structure and components; breadth and depth (Gough *et al.* 2012). Configurative reviews and realist syntheses are now becoming popular (Wong *et al.* 2013). These apply the same principles of transparency and auditability as traditional systematic reviews, but ask broader (though not unfocused) questions about what is known (Petticrew 2015).

Realist reviews focus on 'why' an intervention may work (or not) and under what circumstances i.e., they focus on the intervention mechanism(s) and its context (Fletcher *et al.* 2016, Pawson *et al.* 2005, Wong *et al.* 2014). This chimes with the aims and objectives of the systematic review conducted for this current study, which sought to uncover the theoretical underpinning (the mechanism) of the interventions in order to identify the active ingredients for a novel, classroom-based intervention. It employed the rigorous and transparent methods of a traditional systematic review including: a systematic search strategy; data extraction; appraising the evidence using a recognised tool; and pre-defined primary and secondary outcomes (Higgins and Green 2008). However, the results were viewed through a realist lens, looking at the intervention effectiveness for decision-making rather than hypothesis-testing purposes (Petticrew 2015). The study conducted was not defined as a full realist synthesis because CMO configurations were not formally tested (Fletcher *et al.* 2016, Wong *et al.* 2014). This was due to the heterogeneity of the included studies. Different intervention approaches were applied in different contexts, meaning the impact of context on the intervention outcomes could not be tested consistently.

3.5.2 Qualitative study

A qualitative study was conducted concurrently with the systematic review (Chapter 5, Paper 3 submitted for publication). The aim was to explore the factors that may impact on the development, testing and ultimate implementation of the novel (to be developed) classroom-based intervention targeting WM to enhance attention and language skills in 4-5 year olds from areas of social disadvantage. This included the exploration of: HPs' and teachers' knowledge, perceptions and practice in relation to WM; and how context (the interacting systems of HP services and schools) influences their decision-making and impact on service delivery for school-aged children in their everyday classroom. The specific details of the methods used are provided in Chapter 5. The broad rationale for conducting a qualitative study and for the choice of data collection and analysis methods are outlined below.

3.5.2.1 Rationale for the qualitative study

Pawson and Tilley (1997) posited that (within the CMO framework) the triggers of change in most interventions (the mechanism) are ultimately located in the reasoning of the individuals involved. Whilst qualitative research is often considered to sit firmly within an interpretivist paradigm (Mason 2002), it also sits comfortably alongside the realist paradigm adopted in this study. From an ecological perspective, exploring individuals' understanding and behaviour can clarify aspects at various levels of a system that may facilitate or impede intervention implementation (Westhorp 2012). Furthermore, this supports the evaluation of how and why and intervention may (or may not) work in real-life settings.

3.5.2.2 Focus groups

Focus groups were used to explore HPs' and teachers' knowledge, perceptions and current practice in relation to WM and the rationale that underpins it because they are considered to be useful when researchers aim to understand not just what people think, but their reasons for thinking that way (Kitzinger 1995). The focus group methodology is based on the premise that group dynamics stimulate discussion between participants (Bowling 2014, Belzile and Oberg 2012). They can also be particularly effective for obtaining participants' perspectives on a certain stimulus (Newell and Burnard 2011). In the current study, the focus group setting provided a stimulating environment for group discussion around the

WM model as part of the exploration into participants' knowledge of WM (Baddeley and Hitch 1974).

The qualitative literature reflects mixed opinions on whether focus groups should be heterogeneous or homogenous in terms of the participants' professional backgrounds. Since different healthcare professions have different cultures (Hall 2005), some researchers propose that they should not be mixed during focus groups (Carey 2016, McClafferty 2004). However, others suggest that anticipated difficulties caused by professional boundaries in healthcare research should not pre-empt focus group design and that there is limited logic in separating professionals who work together every day (Clavering and McLaughlin 2007). Hence, due to the close working relationships between the professionals in the RISE teams, the HPs were seen in focus groups that included participants from all four professional backgrounds (SLT, OT, PT and SEBs). The HPs and teachers were seen in separate focus groups since the study aimed to explore how they influence each other. Further rationale for this decision can be read in Chapter 5.

During focus groups, there is a risk that participants' responses may be inhibited by a perception of 'power' being held by the researcher (Rodriguez *et al.* 2011). In this study, the PhD researcher had insider status (sharing a role or experience with participants) which may have perpetuated or mitigated against this (Corbin Dwyer and Buckle 2009). To minimise the risk of this affecting the data collection, careful consideration was given to the design of the focus group schedule. The questions were primarily open-ended and categorised according to Krueger and Casey's (2015) questioning route (Chapter 5).

3.5.2.3 Thematic analysis

The focus group data were analysed using Thematic Analysis (Braun and Clarke 2006). This method was employed in this study for three reasons. Firstly, it is theoretically flexible and consistent with the realist paradigm adopted in this doctoral study. It can be used to understand people's perceptions of reality and the ways in which social contexts influence them (Braun and Clarke 2006). Secondly, it has the capacity to produce findings that are robust, usable and accessible (Braun and Clarke 2013, 2014, Sandelwoski and Leeman 2012). This means that the findings from the focus groups could be used to examine both the participants' knowledge of WM and how context influences HPs' and teachers' decision-making and impacts on service delivery. Thirdly, it can be applied in an inductive manner to identify both explicit (semantic) and conceptual (latent) themes, thereby supporting the identification of tacit beliefs underpinning people's thinking or practice (Braun *et al.* 2019).

The rationale for using thematic analysis is bolstered by the fact that its robustness as a methodological tool has been increasingly recognised in recent years. Previously five major approaches to qualitative inquiry were recognised: narrative research; phenomenology; grounded theory; ethnography; and case study research (Creswell 2007). However, in recent years, thematic analysis (often referred to interchangeably as content analysis) has become widely recognised as an approach in its own right (Braun and Clarke 2006). This may be due to greater understanding that all qualitative approaches share the same goal (to understand a particular phenomenon from the perspective of those experiencing it) and therefore all involve the identification of themes in some way or another (Sandelowski and Leeman 2012, Vaismoradi *et al.* 2013). At both points in the doctoral study where this approach was implemented (step 2 focus groups and the semi-structured interviews conducted during the feasibility study – see chapters 5, 8 and 9) the six steps in Braun and Clarke's method were implemented. This process is described in further detail in Chapter 5 (Paper 2).

3.5.2.4 Trustworthiness

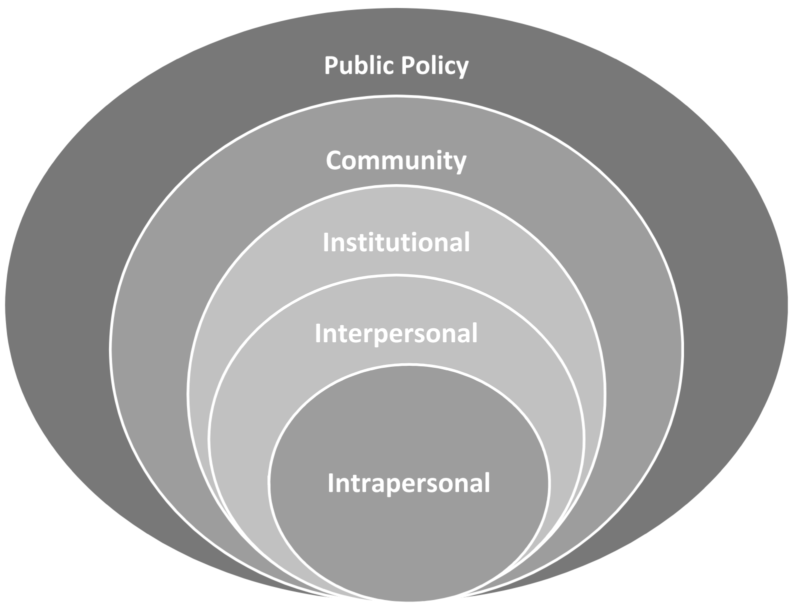
In qualitative research, rigour has been conceived as trustworthiness (Sandeloski 1993). Lincoln and Guba (1985) proposed that trustworthiness is constructed with four pillars: credibility, transferability, dependability, and confirmability. A number of steps were taken to address these facets of trustworthiness in the conduct of the qualitative components of this doctoral study. To ensure credibility i.e., confidence in the accuracy of the findings, careful consideration was given to the PhD researcher's 'insider' status (shared experience with participants) (Corbin Dwyer and Buckle 2009). Bracketing was applied strictly in the collection and analysis of the data in order to reduce the risk of bias (see Chapter 5). To enhance the dependability of the findings, the data were analysed independently by a member of the supervisory team (J.T.) as a form of investigator triangulation (see Section 3.10). Furthermore, the codes and themes identified were checked frequently against the complete raw dataset (Braun and Clarke 2006, 2013). To ensure transferability, the research findings were described in sufficient detail to enable readers to judge whether the findings could be transferred to other contexts (Creswell 2007). This detail and transparency in the reporting of outcomes, following the Consolidated Criteria for Reporting Qualitative Research (COREQ) guidelines (Tong *et al.* 2007), also aimed to enhance the confirmability of the findings.

3.5.2.5 The socio-ecological model (McLeroy *et al.* 1988)

The focus group data were mapped onto the socio-ecological model (McLeroy *et al.* 1988) to explore how context (the interacting systems of HP services and schools) influences HP's and teachers' decision-making and impacts on service delivery for school-aged children in their everyday classroom. This model was chosen due to its consistency with complexity theory and the ecological perspective adopted in this doctoral study, recognising that the schools and RISE Teams are complex interacting systems that constantly adapt in response to internal and external pressures.

McLeroy *et al.*'s model (1988) facilitated the identification of contextual factors at five levels: 1) intrapersonal factors – characteristics of the individual such as knowledge and attitudes e.g., HPs' and teachers' knowledge of WM; 2) interpersonal processes - formal and informal social networks and social support systems e.g., the relationship between individual HPs and teachers; 3) institutional factors - organisational characteristics e.g., school timetables; 4) community factors - relationships among organisations or institutions e.g., the relationship between the RISE team and schools; and 5) public policy - local, state and national laws and policies e.g., the education curriculum (Figure 3-3). Clearly delineating contextual factors at each of these levels enabled the generation of a systems theory regarding which factors may be malleable and support the implementation of a novel classroom-based intervention. A further benefit of using this model was that it could be applied consistently throughout the doctoral study.

Figure 3-3 The socio-ecological model (McLeroy *et al.* 1988)



3.6 6SQuID Step 3. Identify how to bring about change: the change mechanism

The third step of the 6SQuID model requires the development of a theory of change, which can often address more than one causal element (Wight *et al.* 2006). This is based on the assumption, consistent with a realist research paradigm, that *all* interventions are based on a theory of change even if it is not articulated explicitly (Moore and Evans 2017). Indeed, Pawson and Tilley (1997) proposed that interventions are 'theories incarnate' (Pawson and Tilley 1997). Intervention theories are often poorly elucidated which is why they have been referred to as a 'black box' (Hoddinott 2015). According to Walker and Avant (2011) an intervention theory is:

> *"An internally consistent group of relational statements that presents a systematic view about a phenomenon and that is useful for description, explanation, prediction, and prescription or control."* (Walker and Avant 2011, p. 60-61)

In other words, it should explain how and why the intervention should lead to change. Without a clearly articulated intervention theory, the success of an intervention may be serendipitous. Committing limited health and social care resources and/or research funding to interventions that are not grounded in sound theoretical reasoning about why and how they will result is concerning. It raises ethical issues around the allocation (and potential waste) of limited resources to interventions that may be ineffective at best and harmful at worst (Ebbels *et al.* 2019, Hawe 2015). Furthermore, it is difficult to evaluate the effectiveness of an intervention if it is based on weak causal assumptions (Craig *et al.* 2008, Glanz and Rimer 2005, Petticrew *et al.* 2013).

Based on the complexity theory and ecological perspective underpinning this doctoral study, there was a need to develop an intervention theory composed of two strands:

1) an individual theory/theories of change to explain why the intervention is expected to benefit children's WM, attention and language; and 2) a systems theory to explain how the intervention could be implemented successfully within the context of the dynamic, interacting system of the RISE teams and schools (Shearn *et al.* 2017, Shiell *et al.* 2008).

The development of this two-stranded theory was based on merging the mixed methods evidence from the systematic review to inform the individual theory of change and the qualitative study to inform the systems theory of change. Layering existing scientific theory/theories supports the reasoning embedded in an intervention theory (Westhorp 2013). The individual theory of change developed in the current study was underpinned by the Working Memory Model (Baddeley and Hitch 1974) and its subsequent revisions (Baddeley 2000, 2007). This multi-component model of working memory is outlined in Chapter 2 and Chapter 4 (the systematic review). It was also informed by the emerging literature and current theorising around the mechanisms of transfer in WM training, as discussed in Chapter 2 (Gathercole *et al.* 2019) The systems thinking was underpinned by the ecological perspective supported by the socio-ecological model, alongside the use of logic modelling (McLeroy *et al.* 1988, WK Kellogg Foundation 2014).

3.6.1 Logic modelling

Over the past 20 years, logic modelling has become a recognised tool to: clarify a problem; understand the mechanism by which an intervention might address it; and identify the essential processes required to implement an intervention (Campbell *et al.* 2007). Logic models are now frequently a requirement of research grant applications (Peyton and Scicchitano 2017), which is why they have been employed in this doctoral thesis. The WK Kellogg Foundation Guide to Logic Modelling (2014) defines logic models as visual representations of a how a program works and describes three categories of logic models:

1) *Theory logic models*. These link the theoretical assumptions about how and why a programme should work (the theory of change) to the activities required to carry it out;
2) *Outcomes logic models*. These show the causal linkages between activities and their intended outcomes; and
3) *Activities logic models*. These are similar to outcomes logic models but go into greater detail about the steps that need to be taken to implement an intervention.

Theory logic modelling is used most frequently during programme design and planning. Hence, this was the most appropriate method for the current doctoral study and it was used in three ways. Firstly, it was used to represent how the study aims and design address the identified research gaps (Figure 3-2). Secondly, it supported the identification of the individual and systems theories of change that underpin the novel intervention (Figures 6-2, 6-4 and 6-5). Lastly, it was used to identify the activities and resources needed to test (and ultimately implement) the intervention (see Tables 6-4, 7-3 and 9-1). In essence, logic models represent what should happen if an intervention functions according to its theory. Figures 3-4 and 3-5 present the templates used to develop the theory logic models used in the current doctoral study. The way to read logic models is from left to right using *if-then* statements e.g., *if* we do x, *then* y activities can occur, *if* y activities occur *then* z outputs will be achieved, and so on.

Figure 3-4 Template for a basic theory of change logic model

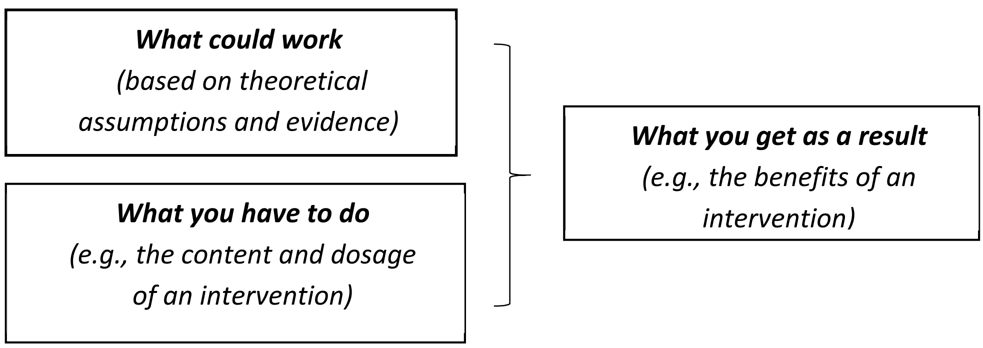
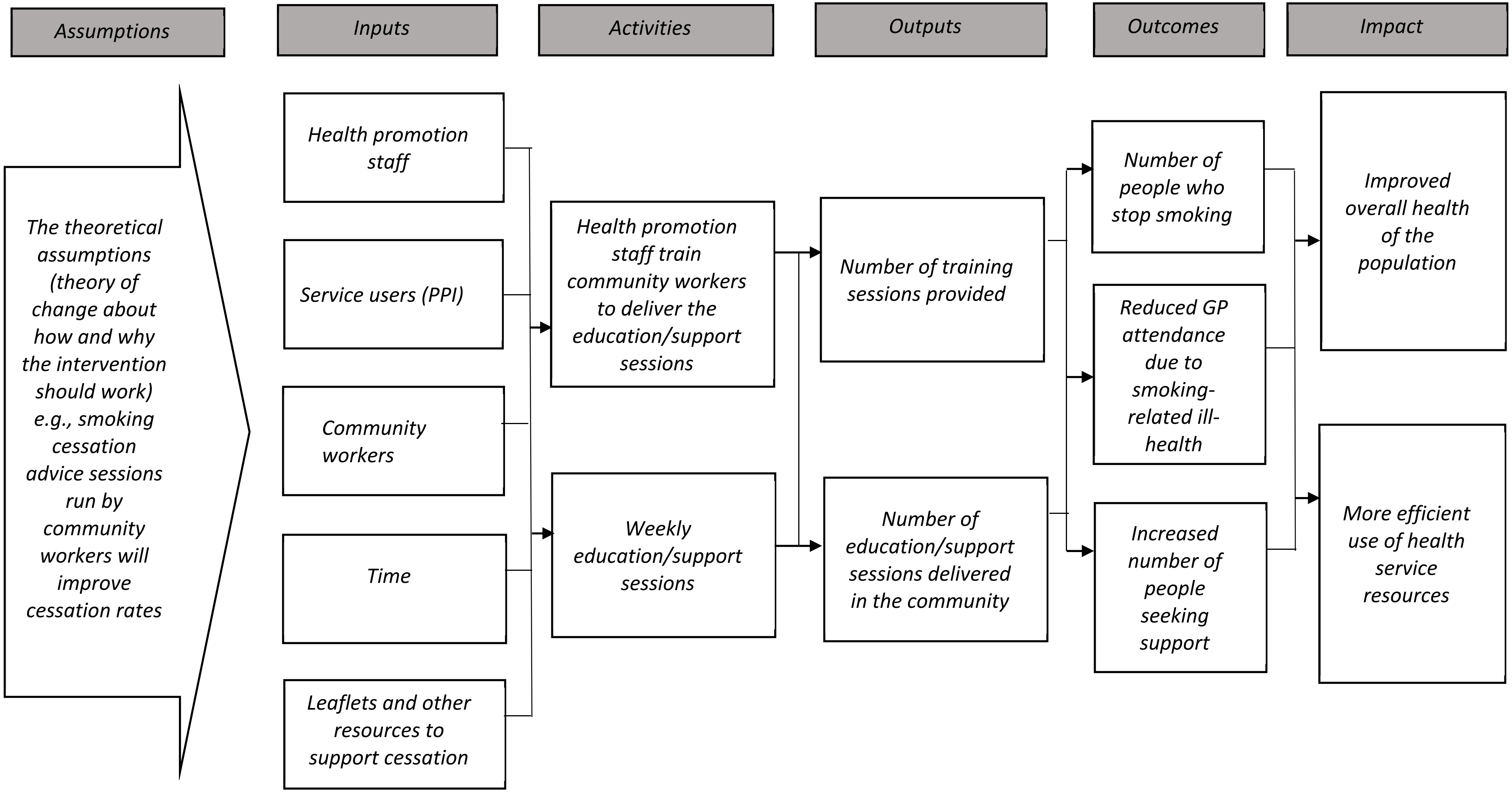


Figure 3-5 Template for the theory logic model linking the theory of change to the intervention activities and outcomes (based on WK Kellogg Foundation 2014)

Worked example (fictional) for a community-based smoking cessation intervention



The purpose of logic modelling in the current study was to identify the (potentially) competing demands within the interacting systems of the RISE teams and schools in order to minimise the risk of them compromising the intervention implementation (Hawe 2015). To have functional use, logic models should be used iteratively. They should be used as a starting point and updated as the understanding of a system or intervention deepens (Funnell and Rogers 2011, Peyton and Scicchitano 2017). In this doctoral study, the initial intervention logic model (developed from the systematic review and qualitative study evidence, see Table 6-4) was refined during the co-production phase (Table 7-3) and revised again based on the findings of the feasibility study (see Table 9-1). This logic model would subsequently undergo further development and refinement prior to a full-scale trial.

3.7 6SQuID Step 4. Identify how to deliver the change mechanism

The fourth step in the 6SQuID (Wight *et al.* 2016) model involved co-production (also referred to in the literature as co-creation and co-design) of the novel intervention through a partnership approach between the research team, HPs from the RISE teams (n= 7), teachers (n= 2) and parents (n= 2) of 4-5 year olds from schools in areas of SD. The aim was to elucidate how (or if) the evidence-based activities harvested through the systematic review could be delivered in the classroom setting by HPs and teachers, by harnessing their unique knowledge of the context within which it would be implemented.

3.7.1 Co-production

According to Clarke *et al.* (2017), co-production was introduced in the USA in the 1970s to include service users in service delivery. It has been defined as *"the collaborative generation of knowledge by academics working alongside stakeholders from other sectors"*

(Greenhalgh *et al.* 2016, p. 393). The decision to use co-production in this study was based on several factors. Firstly, co-production has been widely hailed as a positive facet of intervention development within the most prominent models, including the MRC guidance (Craig *et al.* 2008, MRC 2008, 2019) and the 6SQuID model (Wight *et al.* 2016). It is also consistent with the realist paradigm and ecological perspective that underpin this doctoral study, acknowledging that the intended outcome of the process is to create an intervention that can be implemented in real-world settings (Stokols 2006). This is based on the assumption that frontline practitioners have unique knowledge of their specific context and the factors that may facilitate or impede intervention implementation. Therefore, harnessing their knowledge can enhance the feasibility and acceptability of interventions (Funnell and Rogers 2011, Glasziou *et al.* 2010, Moore *et al.* 2019, van Meijel *et al.* 2004, Wight *et al.* 2016). It has also been suggested that co-production can engender a sense of buy-in (ownership) from practitioners (Hawkins *et al.* 2017). According to Wight *et al.* (2016, p. 520):

> *"Interventions are best developed through collaborations between interdisciplinary teams of practitioners, researchers, the affected population and policymakers. Such coproduction maximises the likelihood of intervention effectiveness by improving: the fit with the target group's perceived needs and thus acceptability; practicality; evaluability, including the theorising of causal pathways; and uptake by practitioners and policymakers."*

There is increasing research interest regarding the benefits and potential disadvantages of co-production and there are challenges in evaluating its worth (Clarke *et al.* 2017, Voorberg *et al.* 2015). Greenhalgh *et al.* (2016) conducted a narrative review of studies that employed co-production and found that certain principles were common to successful instances of co-production: having a clearly identified systems perspective; framing the research as a creative enterprise utilising participants' experience; and having clearly stipulated processes, governance and facilitation arrangements. These principles were duly considered in the co-production phase of the current study. How this was carried out and what it revealed about the value of co-production are discussed in Chapter 7.

3.8 6SQuID Step 5. Test and refine on small scale

Following the co-production work, a prototype of the intervention was created. This included bespoke materials to enable the delivery of the selected intervention components and a comprehensive, written facilitator manual to support their delivery in the classroom (see Volume 2 of this thesis). To conduct a formative evaluation, the expertise of eminent researchers in the field of WM were sought through research networks developed by the PhD researcher over the course of the study. Two leading experts in WM (L.H. and J.H) provided feedback on the manual, materials and resources through face-to-face meetings, Skype meetings and e-mail communications. Practitioner opinion was obtained further through face-to-face meetings with the two teacher representatives from the Research Advisory Group engaged in this study. The outcomes of this feedback, and the value of this step in the 6SQuID process, are discussed in Chapter 7 (see Section 7.9).

3.9 6SQuID Step 6. Collect sufficient evidence to justify rigorous evaluation/implementation

The final step of this doctoral study was a three-arm cluster randomised feasibility study that compared the novel classroom-based intervention to an existing intervention used by the RISE teams and education as usual. As soon as the aims of this doctoral study were identified, the need for a feasibility trial of the to-be-developed intervention was clear. There are major gaps in the literature around the delivery of WM interventions in the classroom setting (Jaeggi and Buschkuehl 2014) and indeed limited research regarding the implementation of classroom-based interventions for children at risk of language disorder (Archibald 2017a, Cirrin *et al.* 2010, Ebbels *et al.* 2019).

The conduct of a feasibility trial was supported also by the increasing importance placed on feasibility studies prior to full trials of the efficacy of novel interventions (Moore *et al.* 2019). Yet, despite their popularity, guidance on how to design and carry out feasibility trials is limited. Hallingherg *et al.* (2018) carried out a systematic review of 25 unique sources of guidance on the conduct and design of feasibility trials and found that the existing recommendations are inconsistent with regards to the aims, design and conduct of studies (Hallingberg *et al.* 2018). Indeed, current MRC guidance for the development of complex interventions and the 6SQuID model provide only general advice regarding the conduct of feasibility trials (MRC 2008, MRC 2019, Wight *et al.* 2016). Therefore, in this doctoral study, the design of the cluster randomised feasibility trial was based primarily on the aims of the study, general guidance on trial design and the realist paradigm that underpin this study.

Hence, the feasibility study was designed to address uncertainties about: the intervention itself; its implementation in the classroom setting; and how these two aspects interact and may affect the intervention's potential effectiveness (Shearn *et al.* 2017). The study protocol was developed according to the SPIRIT 2013 Statement recommendations for protocol items for clinical trials (Chan *et al.* 2013) and reported according to the Consolidated Standards of Reporting Trials (CONSORT) 2010 extension to cluster randomised pilot and feasibility trials (Eldridge *et al.* 2016a). The study protocol was published and the paper constitutes Chapter 8 of this thesis (Rowe *et al.* 2019b). Full details of the trial methods can be found in the paper; the following provides a broad rationale for the design of the trial and how this fits with the realist paradigm underpinning the entire doctoral study.

From the realist perspective, feasibility trials can enhance an understanding not just of the feasibility of implementing the intervention, but of the intervention itself and of the implementation context (system) (Campbell *et al.* 2007). Examining the *outcomes* of a feasibility trial in tandem with an exploration of the c*ontext* means the hypothesis about the potential *mechanism* can be refined (Fletcher *et al.* 2016). In this way, feasibility trials can go beyond asking about the feasibility of an intervention in general, to explore for whom and under what circumstances it may be acceptable and potentially effective (Hawe *et al.* 2009). Viewing the trial from this perspective highlighted the importance of carrying out a process evaluation (including both qualitative and quantitative methods) outlined below.

3.9.1 Process evaluation

A process evaluation is *"a study which aims to understand the functioning of an intervention, by examining implementation, mechanisms of impact, and contextual factors"* (Moore *et al.* 2015, p.8). In essence, a process evaluation should open the *'black box'* of the intervention to observe its mechanism(s) (Grant *et al.* 2013). A key aim of any process evaluation is to capture the fidelity of: the intervention delivery (whether the intervention was delivered as intended); and the dosage (the quantity of intervention implemented) (Moore *et al.* 2015). Given the uncertainties about the fidelity of intervention delivery in this study, a process evaluation was clearly indicated. Moreover, process evaluations are now viewed as an essential component of feasibility trials in order to ensure the robustness of subsequent RCTs (Hawe 2015).

In this doctoral study, the process evaluation was conducted in parallel to the feasibility trial of the intervention (Moore *et al.* 2015). Process evaluations typically include a combination of methods: quantitative methods to measure key process variables (recruitment, retention); and qualitative methods to capture emerging changes in the intervention implementation, any unanticipated consequences and to illuminate participants' views and experiences (acceptability) (Grant *et al.* 2013, Hawe *et al.* 2004, Moore *et al.* 2015, O'Cathain *et al.* 2015). This is reflected in the mixed methods used in this study, detailed in the study protocol (Chapter 7).

Due to the cluster randomised design of the study, the process evaluation undertaken was based primarily on Grant *et al.'s* (2013) framework for the design and reporting of process evaluations of cluster randomised trials. This highlighted the need to interrogate the trial processes at both the cluster and individual participant levels including: recruitment of clusters; intervention delivery to clusters; response of clusters; recruitment of individuals; delivery to individuals; response of individuals; maintenance; unintended consequences; theory; and context. The inclusion of these elements in the process evaluation conducted in the current study can be seen in the aims set out in the study protocol (Chapter 8, Rowe *et al.* 2019b).

Grant *et al.* (2013) acknowledge that their framework does not reflect an exhaustive list of the elements that may require investigation in a process evaluation. Notably, two areas that are key to this doctoral study are not included in their framework: dosage and system elements. Therefore, elements of Steckler and Linnan's (2002) model were also considered: context (local factors that influence implementation); fidelity (the extent to which the intervention is delivered as conceived); dose delivered (the amount of intervention offered to participants); and dose received (the extent of participants' engagement in the intervention). The fidelity of the intervention delivery was viewed through an ecological lens to examine how the intervention was adapted in context (Hawe *et al.* 2004).

3.10 Integration of mixed methods evidence and data triangulation

As noted previously, MMR is defined by the intentional integration of both quantitative and qualitative data (Anguera *et al.* 2018). Following the steps of the 6SQuID model (Wight *et al.* 2016) inherently involved the integration of mixed methods evidence in this doctoral study. This included: *merging* the mixed methods evidence within a single step of the process; *building* the data from one step to the next; *explaining* the findings; and *embedding* the data within a larger framework (Creswell and Creswell 2018). For example, the findings from the systematic review (Chapter 4) and the qualitative study (Chapter 5) that were both completed at step two of the 6 SQuID model were merged and used to build the intervention theory consisting of individual and systems levels at step 3 (see Figure 3-2). The intervention theory was subsequently *embedded* in the intervention itself and informed the subsequent steps of the study including the co-production (step 4) and feasibility testing (step 6). During the process evaluation aspect of the feasibility study (Step 6, Chapters 8 and 9), the quantitative findings regarding the intervention delivery were used to *explain* the qualitative data obtained from interviews with the HP's and teachers and vice versa.

The integration of the mixed methods evidence described above constitutes a form of methodological data triangulation in the doctoral study i.e., the cross-referencing of data from one method in a study with another (Morse 1991). It can include looking for complementarity or dissonance between the data collected by different methods or steps in a study (O'Cathain *et al.* 2007, 2010). This can be seen in the use of the qualitative and quantitative data to look at the acceptability of the novel intervention in the feasibility study.

Of course, the overall goal of triangulation is to reduce the risk that the personal biases of the investigator(s) will influence the research findings (Denzin 1989). As mentioned previously, the PhD researcher previously worked in one of the RISE teams involved in this study and therefore held insider status (Corbin Dwyer and Buckle 2009). Therefore, investigator triangulation was also important component of the study to enhance its rigour and trustworthiness (Denzin 1989). At every step of the study, review of the data interpretation by the supervisory team, including L.H and J.H. (external advisors) was carried out and agreement reached before proceeding. Furthermore, the Research Advisory Group were consulted to check the findings on the contextual factors that may impact on the intervention implementation. Finally, theory triangulation was used to examine the utility of the proposed intervention mechanism (Denzin 1989), meaning that the individual and systems theories were checked for their consistency with substantive theories e.g., the WM model (Baddeley and Hitch 1974, Baddeley 2000, 2007). The iterative approach to logic modelling taken in this study also shows that the data were continually triangulated across the course of the doctoral study.

3.11 Ethical considerations and approval

Overall, this was a low risk study for all of the participants involved. However, full consideration was given to any potential issues at every step of the study. In terms of the risk and burden to participants, the conduct of the feasibility trial raised the most issues. These were addressed carefully, particularly in relation to safeguarding the welfare of the children who participated in the feasibility study. Full details are provided in the study protocol (Chapter 8, Rowe *et al.* 2019b), but the key considerations and actions taken are outlined here.

Two applications for ethical approval were made during the conduct of this doctoral research. The first application was made to the Institute of Nursing and Health Research Ethics Filter Committee for the conduct of the focus groups undertaken for the qualitative study (step 2 of the 6SQuID model, Chapter 5) and the co-production workshops (step 4 of 6SQuID, Chapters 7). The second application was for the feasibility trial (Chapters 8 and 9). Ethical approval for this part of the research was granted by the Ulster University Research Ethics Committee (REC/18/0036). The feasibility trial was also registered with the International Standard Randomised Controlled Trial Registry (ISRCTN13633886). In respect of both applications, approval was granted prior to the commencement of the studies (Appendices A and B). For each study, approval was also obtained from the relevant HSCT research offices to conduct research with Trust personnel.

This study involved adult participants (HPs from the RISE teams, teachers and parents of 4-5 year olds from areas of social disadvantage) in the focus groups, co-production work and feasibility trial. It also involved 4-5 year old children from areas of social disadvantage in the feasibility trial. The key ethical considerations in relation to participant involvement related to: the welfare of all participants (particularly the children recruited for the feasibility trial); the potential burden arising from involvement in the study; consent issues; and data management. To safeguard the welfare of the children, the schools' child protection policies were followed strictly and the PhD researcher ensured that all members of the research team who had direct contact with the children held valid Access NI Enhanced Disclosure Certificates[2] (in compliance with NI legislation). Further

---

[2] AccessNI Criminal Record checks are compulsory for all employees or volunteers in working with vulnerable adults or children in NI (https://www.nidirect.gov.uk/articles/types-accessni-checks)

details on the steps taken to support the children's welfare are provided in the protocol for the feasibility study (Chapter 8).

In relation to consent issues, all of the adult participants were given detailed Participant Information Sheets (PIS) and written, informed consent was obtained prior to the collection of any data. For the children's involvement in the feasibility trial, parental consent (rather than child assent) was obtained. This was due to the age of the children (4-5 years) because, with this age group, it can be difficult to judge accurately whether they understand involvement enough to provide their assent (Fargas Malet *et al.* 2010, Meaux and Bell 2001). The parents were asked to inform their children that the trial was taking place and a child-friendly leaflet for this purpose was provided (see Appendix G).

At every stage of the recruitment process, care was taken to avoid participants feeling compelled to take part e.g., the PIS forms stated clearly that participation was optional (Appendices C - G). Regarding data management, responses were anonymised immediately during the input of data or at transcription. All data were stored securely according to Ulster University's data management policy and the General Data Protection Regulation (EU) 2016/679.

3.12 Limitations

The methodological limitations of the various steps of this doctoral study are outlined at the relevant points in this thesis. Regarding the overall approach taken, the 6SQuID model (Wight *et al.* 2016) provided a practical and logical structure to support the intervention development. However, it must be noted that it lacks detail (O'Cathain *et al.* 2019a, 2019b). For example, the authors provide limited guidance on how to carry out feasibility testing for novel interventions. This particular issue was compounded by the fact that, as noted by

Hallingberg *et al.* (2018), the guidance on the design of feasibility studies is inconsistent. To overcome this and to ensure the robust design of the trial, the PhD researcher had to consult and cross-reference a significant amount of literature on feasibility trials. For example, because the CONSORT (2010) extension to cluster randomised pilot and feasibility trials (Eldridge *et al.* 2016a) is not specific to study protocols, the SPIRIT 2013 Statement recommendations for protocol items (Chan *et al.* 2013) were also consulted. This led to some challenges in designing the study.

3.13 Conclusion

This doctoral study used a mixed methods, multi-phase design based on the 6SQuID model (Wight *et al.* 2016). Whilst this model lacks detail, it provided a practical and logical framework within which rich mixed methods evidence could be collected and analysed to answer the research questions. A strength of the study design is the continual focus on the contextual factors that may impact on the intervention development and testing. This ecological perspective, married with complexity theory provided a foundation upon which the intervention, its context and the interaction between the two could be investigated (Shiell *et al.* 2008, Moore *et al.* 2019). The adoption of a realist paradigm at all steps of the study ensured a coherent focus, reflecting the importance of research being underpinned by a clear theoretical framework. The iterative use of logic modelling further enhanced the rigour and trustworthiness of the findings.

Chapter 4 - Systematic review

4.1 Introduction

Chapter 4 relates to step 2 of the Six Steps in Quality Intervention Development (6SQuID) model (Wight *et al.* 2016) that aims to clarify which causal and contextual factors are malleable. Working memory (WM) is associated with attention (Bunting and Cowan 2005, Cowan *et al.* 2006) and language learning (Baddeley *et al.* 1998). Therefore, it is proposed as the causal mechanism within the to-be-developed intervention that seeks to enhance these skills. As outlined in Chapter 2, non-computerised WM interventions may be an ecologically valid way of improving WM and producing transfer effects to real-world skills such as attention and language but little is known about the effectiveness of such interventions (e.g., Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014). This chapter presents a systematic review paper that addresses this question. It is comprised of the full pdf. file version of the published paper and includes its own abstract, introduction, methods, findings and discussion sections along with its own reference list. The online supplementary materials referred to in the paper can be found in Appendix I at the end of the thesis. The chapter concludes with a brief summary of the implications of the review findings for the development and testing of to-be-developed intervention.

4.2 Interventions targeting working memory in 4–11 year olds within their everyday contexts: a systematic review (Paper 1)

Citation details

Rowe, A., Titterington, J., Holmes, J., Henry, L. and Taggart, L. (2019) Interventions targeting working memory in 4–11 year olds within their everyday contexts: A systematic review. *Developmental Review*, 52, 1-23.

PhD researcher's contribution

The paper was co-authored by the supervisory team (L.T and J.T) and external advisors for this doctoral study (J.H. and L.H). The PhD researcher was the first and corresponding author of this paper and was responsible for: the design and conduct of the review; writing the first draft of the paper; revising the manuscript on the basis of the co-authors' feedback; submitting the paper to the journal; and responding to reviewers' comments. Two of the co-authors (J.T. and L.T.) were involved in the final decision around the exclusion/inclusion of papers in the review.

Developmental Review 52 (2019) 1–23

Contents lists available at ScienceDirect

Developmental Review

journal homepage: www.elsevier.com/locate/dr

Interventions targeting working memory in 4–11 year olds within their everyday contexts: A systematic review

Anita Rowe[a,*], Jill Titterington[a], Joni Holmes[b], Lucy Henry[c], Laurence Taggart[a]

[a] Institute of Nursing and Health Research, Ulster University, Shore Road, Newtownabbey, Co Antrim BT37 0QB, Northern Ireland, United Kingdom
[b] MRC Cognition & Brain Sciences Unit, University of Cambridge, 15 Chaucer Road, Cambridge CB2 7EF, England, United Kingdom
[c] Division of Language and Communication Science, City, University of London, 10 Northampton Square, London EC1V 0HB, England, United Kingdom

ARTICLE INFO

Keywords:
Working memory
Children
Near-transfer
Far-transfer
Durability

ABSTRACT

It has been suggested that diverse interventions applied within children's everyday contexts have the potential to improve working memory (WM) and produce transfer to real-world skills but little is known about the effectiveness of these approaches. This review aims to examine systematically the effectiveness of non-computerised interventions with 4–11 year olds to identify: (i) their effects on WM; (ii) whether benefits extend to near- and far-transfer measures; (iii) if gains are sustained over time; (iv) the active ingredients; and (v) the optimum dosage. Searches were conducted across 12 electronic databases using consistent keywords. Papers were screened by title and abstract ($n = 6212$) and judged against pre-defined eligibility criteria ($n = 63$). Eighteen papers were included in the review. They used a range of non-computerised WM intervention approaches that included: (i) adapting the environment to reduce WM loads; (ii) direct WM training with and without strategy instruction; and (iii) training skills which may indirectly impact on WM (physical activity, phonological awareness, fantastical play and inhibition). Both direct training on WM tasks and practicing certain skills that may impact indirectly on WM (physical activity, fantastical play and inhibition) produced improvements on WM tasks, with some benefits for near-transfer activities. The common ingredient across effective interventions was the executive-loaded nature of the trained task i.e., training on a task that taps into attentional and processing resources under executive control and not just the storage of information. Few studies reported dosage effects, measured far-transfer effects ($n = 4$), or tested the durability of gains over time ($n = 4$). The lack of a clear theoretical framework in many of the included studies resulted in ambiguous predictions about training and transfer effects, and inadequate use of outcome measures. Methodological issues also constrain the strength of the evidence, including: small samples sizes; an absence of blinding of participant and outcome assessors; and lack of active control groups. Further well-designed and controlled studies with clear theoretical underpinnings are required to expand and enhance the evidence base. The heterogeneity of the interventions and of the study designs (randomised and non-randomised) in the included papers limited the synthesis of evidence across studies. However, this diversity enabled the identification of key ingredients, notably the training of executive-loaded WM tasks, which can help inform novel approaches to WM intervention in everyday contexts.

* Corresponding author.
E-mail addresses: harron-a@ulster.ac.uk (A. Rowe), j.titterington@ulster.ac.uk (J. Titterington), joni.holmes@mrc-cbu.cam.ac.uk (J. Holmes), lucy.henry.1@city.ac.uk (L. Henry), l.taggart@ulster.ac.uk (L. Taggart).

https://doi.org/10.1016/j.dr.2019.02.001
Received 31 July 2018; Received in revised form 13 February 2019

Introduction

Speculation that diverse interventions applied within young children's everyday contexts have the potential to improve their working memory (WM)[1] skills and produce transfer to real-world skills such as attention, language and academic attainment has increased in recent years. However, such approaches have received limited attention to date and questions about their effectiveness remain unanswered. This review aims to systematically explore the effectiveness of such interventions and discuss whether they may provide an ecologically valid alternative to the widely adopted computerised WM training approach.

What is working memory?

WM is the ability to hold in mind and mentally manipulate information over short periods in the face of distraction (Allen, Hitch, & Baddeley, 2009; Baddeley & Hitch, 1974; Cowan, 2008). The capacity of WM is limited (Broadbent, 1975; Cowan, 2001; Miller, 1956) meaning a finite amount of information can be held and processed in mind at any given time. WM limits the number and types of tasks we can carry out concurrently, because they are competing for the same limited cognitive resource (Henry, 2012). It develops more in the first 10 years of life than at any other point across the rest of the lifespan (Alloway & Alloway, 2015a) and reaches adult capacity levels around the age of 14 years (Gathercole, Pickering, Ambridge, & Wearing, 2004).

The impact of working memory difficulties in the classroom

WM supports many everyday activities from reading to learning how to use a new device. It underpins many thinking processes (Henry, 2012), and is strongly linked with attention (Bunting & Cowan, 2005; Cowan, Fristoe, Elliott, Brunner, & Saults, 2006), language learning (Baddeley, Gathercole, & Papagno, 1998; Weiland, Barata, & Yoshikawa, 2014); mental arithmetic (Cragg, Richardson, Hubber, Keeble, & Gilmore, 2017); reading development (Kudo, Lussier, & Swanson, 2015; Swanson, Xinhua, & Jerman, 2009); and sensory and motor skills (Alloway & Archibald, 2008; Leonard, Bernardi, Hill, & Henry, 2015). Consequently, poor WM is associated with a wide range of learning difficulties, including specific language impairment[2] (Archibald & Gathercole, 2007), dyslexia and reading difficulties (Jeffries & Everatt, 2003, 2004; Swanson, 2003) and dyscalculia and mathematical learning problems (Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Szucs, Devine, Soltesz, Nobes, & Gabriel, 2013). Children with weak WM skills have difficulties coping with almost all classroom activities including: remembering and carrying out instructions (Engle, Carullo, & Collins, 1991; Jaroslawska, Gathercole, Allen, & Holmes, 2016; Jaroslawska, Gathercole, Logie, & Holmes, 2016); problem-solving (Swanson, Jerman, & Zheng, 2008); and planning, organising and keeping track of tasks (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Gathercole, Alloway, Willis, & Adams, 2006). Teachers frequently describe such children as inattentive and distractible (Alloway et al., 2009). Children with poor WM struggle to cope with the heavy WM loads of the classroom, leading them to fail to complete individual learning activities. Over time, these failures result in poor educational progress, as problems accumulate and affect knowledge across classroom activities. This may explain why WM is one of the best single predictors of a child's academic achievement (Alloway & Alloway, 2015a; Alloway et al., 2009; Gathercole & Pickering, 2000; Gathercole et al., 2016).

Models of working memory

There are several theoretical models and accounts of the structure and function of WM. Componential theories assume the WM system consists of separate stores for the maintenance of different types of information and for executive control (Baddeley & Hitch, 1974). Baddeley and Hitch (1974) multicomponent model of WM (and its subsequent revisions, e.g., Baddeley, 2000) has received considerable empirical support and been highly influential over the past 40 years. It has been particularly valuable in advancing our understanding of how children learn and acquire language (e.g. Archibald, 2017; Baddeley et al., 1998; Gathercole & Baddeley, 1993; Holmes & Adams, 2006; Swanson, 1994, 2017), which is why it has been used to underpin much of the discussion in this systematic review. Other theories, such as that proposed by Cowan (2005, 2008), are based on an assumption that WM is an activated portion of long-term memory (LTM) rather than a distinct entity, and therefore its capacity is related to attentional resources i.e., the current contents of WM are activated representations of LTM.

Although these models have obvious differences, they agree that WM involves two key features: high-level attentional control plus temporary storage. According to most theories, memory tasks can be differentiated by: (a) simple span tasks that involve the temporary, passive storage of material; and (b) complex span tasks that require the concurrent storage and processing of information and rely on attentional resources under executive control. The fractionation of simple and complex tasks is supported by evidence that complex memory span measures are more strongly associated with other higher-order cognitive (executive) functions and language skills than simple memory span tasks (Engle, 2002; Gathercole et al., 2004; Henry & Botting, 2017). The relationship between complex span performance and other cognitive and learning abilities suggests that improving executive aspects of WM might lead to generalised gains across a wide range of skills.

[1] **Abbreviations:** WM: working memory; ELWM: executive-loaded working memory; STM: short-term memory; VSTM verbal short-term memory; VSSTM: visuospatial short-term memory; VELWM verbal executive-loaded working memory; VSELWM visuospatial executive-loaded working memory.

[2] Following international consensus, specific language impairment is now referred to as developmental language disorder (Bishop, Snowling, Thompson, Greenhalgh, & The CATALISE Consortium, 2016).

Research into the effectiveness of WM training

Research into the effectiveness of WM training has stemmed from two (sometimes conflicting) perspectives (Wass, Scerif, & Johnston, 2012). From a theoretical perspective, the goal has been to understand underlying cognitive processes by exploring the extent to which training can improve WM and identifying variables that moderate or mediate the effects of training and transfer to other cognitive functions (Gathercole, Dunning, Holmes, & Norris, 2019; Jaeggi & Buschkuehl, 2014; Schwaighofer, Fischer, & Bühner, 2015). From an applied perspective, the therapeutic value of WM training lies in its potential to ameliorate problems associated with poor WM. The focus of applied research has been on investigating the impact of WM training on outcomes relating to real-world skills such as attention, language and academic attainment. The benefits of practice on the trained activities should produce improvements both on untrained WM tasks (near-transfer) and on measures of other abilities known to depend on WM, such as educational outcomes and attention (far-transfer).

Morra and Borella (2015) suggest that WM research has evolved in three waves. The first was fuelled by cumulative evidence that WM may not be the fixed entity it was once thought to be (e.g., Ericsson & Chase, 1982; Klingberg, Forssberg, & Westerberg, 2002) but could be altered via training. Most of this evidence was generated through a large number of quasi-experimental studies of the effects of computerised WM training, the majority of which used the Cogmed Working Memory Training program (Cogmed, 2005). Perhaps inevitably, this was followed by a second wave in which questions were raised about the methodological quality of the studies (e.g. lack of randomised controlled trials, failure to blind participants to condition and the absence of adequate control groups – see Shipstead, Hicks, and Engle (2012) for a comprehensive review). Theoretical questions were also asked about why or how repeated practice on tasks would improve WM capacity (Janneke et al., 2016; Melby-Lervåg & Hulme, 2013; Melby-Lervåg, Redick, & Hulme, 2016; Morrison & Chein, 2012; Sala & Gobet, 2017; Shipstead et al., 2012). The most rigorous studies, meta-analyses and systematic reviews provide evidence that computerised training leads to gains on the trained tasks and on untrained activities when the untrained tasks have many features in common with the trained tasks (e.g. Barnett & Ceci, 2002; Gathercole et al., 2019; Noack, Lövdén, Schmiedek, & Linderberger, 2009; Soveri, Antfolk, Karlsson, Salo, & Laine, 2017; Sprenger et al., 2013; Von Bastian & Oberauer, 2014). Some meta-analyses provide evidence for near-transfer effects, but far-transfer effects are often small and not sustained over time (Schwaighofer et al., 2015). Taken as a whole, transfer to WM tasks with few overlapping features with the trained activities is inconsistent (see Gathercole et al., 2019 for a review).

There has been considerable debate in the field of WM research about: (i) the reasons for inconsistent near-transfer effects following computerised WM training; (ii) the lack of and unsustainability of any far-transfer effects; (iii) the factors that may mediate and moderate training and transfer effects; and (iv) the potential theoretical mechanisms underpinning these findings (e.g., Gathercole et al., 2019). Questions have been asked about the impact of experimental factors (e.g., use of active control conditions, location and levels of supervision, instructions and feedback, and methods of statistical analysis). The nature of the learning involved has also been questioned (e.g., whether paradigms support the development of new cognitive routines), and the influence of individual differences in learner characteristics are increasingly investigated (e.g., age, motivation and pre-existing abilities) (Jaeggi, Buschkuel, Jonides, & Shah, 2012; Morra & Borella, 2015). However, there is increasing evidence that near-transfer to structurally dissimilar WM tasks is elusive and that the role of individual differences in mediating these is negligible. Recent studies, taking a Bayesian approach to statistical analysis to explicitly investigate these questions in young and older adults, found an absence of near and far-transfer effects following computerised WM training, which could not be explained by individual differences between participants (De Simoni & von Bastian, 2018; Guye & von Bastian, 2017).

The third wave of WM research questions the utility of intervention approaches that cannot account for how the underlying capacity of WM is altered by training (from a theoretical perspective) and do not improve outcomes on real-world skills (from an applied perspective). In particular, the lack of consistent evidence for far-transfer effects from computerised WM training (Dunning, Holmes, & Gathercole, 2013; Holmes et al., 2015; Shipstead et al., 2012; Simons et al., 2016) has underscored the need for alternative intervention approaches. On the basis that gains transfer to activities with overlapping features to the trained tasks, there have been calls for training to be embedded within the typical activities in children's everyday contexts in which benefits are needed (e.g. educational activities that depend on WM) (Dunning & Holmes, 2014; Dunning et al., 2013).

Taking WM training from the experimental setting into everyday contexts has several disadvantages. When interventions are applied in real-life settings (particularly groups), it is harder to control the training regime including the quality, dose and fidelity of its delivery (Jaeggi & Buschkuehl, 2014). Extracting individual child performance is also challenging. However, the variation in training tasks and materials afforded through this approach may be more motivating than computerised training for young children (Wass et al., 2012) and reduce the frustration they feel as tasks increase in difficulty (Jaeggi et al., 2012). It has been speculated that a diverse range of activities may impact on WM (Diamond, 2012; Otero, Barker, & Naglieri, 2014) but little is known about their effectiveness.

Rationale and scope of this review

The current review is, to our knowledge, the first to focus specifically on the effectiveness of non-computerised WM interventions applied within children's everyday contexts. It is a novel investigation of intervention effects on trained WM skills, on untrained but similar WM skills (near-transfer effects) and on other untrained, real world skills (far-transfer effects). The review seeks to contribute to the third wave of WM research by mapping the types of interventions that have been implemented with young children in everyday contexts and examining the theoretical framework/s used to underpin them (Morra & Borella, 2015). This recognises the need to consider *why* and *how* interventions are intended to improve WM function. Thus, the questions posed in this review are consistent with a realist research perspective (Fletcher et al., 2016; Wong, Greenhalgh, Westhorp, & Pawson, 2014). This goes beyond asking

Table 1
Task examples for each aspect of WM.

Working memory (WM)			
Short-term memory (STM) Tasks: simple span (storage only)		Executive-loaded working memory (ELWM) Tasks: complex span (storage plus processing)	
Verbal (VSTM)	Visuospatial (VSSTM)	Verbal (VELWM)	Visuospatial (VSELWM)
Digit span Word span Non-word span	Dot matrix Corsi block tapping	Backward digit span Listening span	Backward Corsi block tapping Odd one out span

'what works', to ask 'for whom it works and under what circumstances' (Pawson & Tilly, 1997, p. 72) and recognises that all interventions, whether explicitly stated or not, are based on causal assumptions (Moore & Evans, 2017). The review includes an examination of intervention intensity (dosage) and which intervention tasks (if any) appear to be the active ingredients i.e., those attributes of the treatment that play a role in its effects (Hart et al., 2014).

In the case of WM interventions, identifying active ingredients highlights the need to spell out what memory measures really assess and the skills targeted in training (Morra & Borella, 2015). It is evident that this has not always occurred, or at least that it has not been clearly articulated. Indeed, the terminology used to describe WM tasks is inconsistent in the literature and the differentiation between simple span and complex span tasks is often unclear. Short-term memory typically describes simple span tasks (storage-only). Working memory is an umbrella term describing all memory tasks (simple span and complex span tasks), but can also be used to describe only complex tasks (storage plus processing).

To avoid confusion, clear operational definitions are essential. Here, the term executive-loaded working memory (ELWM) (Henry, 2012) is used to refer to tasks with an attentional or processing load (e.g. complex span tasks). Short-term memory (STM) describes storage only tasks (simple span tasks) and working memory (WM) is used as an umbrella term to refer to all memory tasks. Tasks are also defined by modality i.e., verbal or visuospatial. Thus four aspects of WM are delineated (verbal and visuospatial STM and ELWM) to categorise trained tasks and outcome measures. Table 1 provides examples of tasks representing each aspect of WM.

Aim

The aim is to examine systematically the effectiveness of non-computerised interventions targeting WM in 4–11 year olds applied within their everyday contexts.

Research questions

1. What types of WM interventions are implemented and what is their theoretical underpinning?
2. What are the effects of the interventions on WM, and which aspects of WM (if any) are impacted?
3. Do WM gains made (if any) extend to:
   (a) Similar untrained WM tasks (near-transfer effects)?
   (b) Dissimilar abilities linked with WM i.e., real world skills including language, literacy, numeracy and paying attention in class (far-transfer effects)?
4. Are WM gains durable over time?
5. What are the active ingredients and the optimum dosage of effective interventions?

Methods

Systematic review protocol

The protocol for this review was reported in line with the PRISMA-P (2015) (Moher et al., 2015) checklist. It was registered with and published by the International Prospective Register of Systematic Reviews (PROSPERO) which is available at https://www.crd.york.ac.uk/PROSPERO/ (Registration number CRD42017056360).

Eligibility criteria

The PICO model (population, intervention, comparison, and outcomes) (Booth & Fry-Smith, 2004) was used in the development of the eligibility criteria for the inclusion of studies.

Population: Studies must have been conducted with children aged 4–11 years. This represents the age span of children attending mainstream primary schools in the United Kingdom (UK). This population is of interest to the review team due to suggestions that WM interventions applied in everyday contexts may be more ecologically valid and motivating for younger children than computerised training (Jaeggi et al., 2012; Wass et al., 2012). Where participants in a study spanned the age band (4–11 years) but also included participants on either side of this range e.g., 7–14 year olds, the age of the majority of participants was considered. Papers were included if more than 50% of the participants were aged 4–11 years. In the UK, the mainstream school population can include typically developing children and those with diagnosed or undiagnosed developmental difficulties or intellectual disability. Studies were therefore not included or excluded on this basis.

Intervention: Studies may have implemented any intervention that targets WM and is applied within children's everyday contexts. Computerised WM training studies were excluded from the current review as these have been rigorously reviewed and debated previously. Interventions may have been delivered by a teacher, healthcare professional or researcher and may have been carried out in a school, clinical or research setting, but must have provided a total duration of more than one session and less than one year of intervention.

Comparison: Studies must have a randomised controlled, quasi-experimental or single case experimental design. While adhering to the core principles of systematic review methodology in the transparent reporting of study selection, analysis and synthesis, this review applies realist principles and judiciously includes non-randomised studies (Gough, Thomas, & Oliver, 2012; Pawson, 2006). This is consistent with: previous systematic reviews/meta-analyses of the topic e.g., Melby-Lervåg and Hulme (2013), Melby-Lervåg et al. (2016) and Danielsson, Zottarell, Palmqvist, and Lanfranchi (2015) and the early stage of development of much of the research in this field whereby even weaker studies may provide information of value (Petticrew, 2015). The risk of bias that this may introduce is considered and reported transparently.

Outcomes: Studies must have at least one pre- and post-intervention measure of WM. Studies that investigated training on other tasks that may indirectly impact on WM must also include at least one measure of an aspect of the trained task (s). The primary outcome of interest is the effect on WM. In order to discern whether the effects on WM can be attributed to the intervention, the trained task must have been objectively measured (Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016). Studies that explicitly taught cognitive strategies to enhance direct WM training were included regardless of whether they had measured children's use of the strategies because the use of strategies is seen as an integral part of the WM intervention. Near- and far-transfer effects and the durability of effects over time are secondary outcomes, so studies were included regardless of whether these had been measured. Interventions may have the potential to demonstrate such effects even if these have not been measured yet. The current review will contribute to ongoing debates about transfer effects and the time-frame within which they may be demonstrable (Redick, Shipstead, Wiemers, Melby-Lervåg, & Hulme, 2015).

Data sources

The search strategy (outlined below) was applied to twelve electronic databases: MEDLINE (Ovid) Pubmed; EMBASE; CINAHL Plus; AMED; PsycINFO; Scopus; Educational Resource Information Center (ERIC); Web of Science; British Education Index; Cochrane Central Register of Controlled Trials (CENTRAL); Linguistics and Language Behavior Abstracts (LLBA). The authors also inspected the reference lists of relevant papers. Where papers could not be directly accessed via these databases authors were contacted directly. Searches imposed a date limit with studies pre-1974 (when Baddeley and Hitch first proposed the multi-component model) being excluded. Due to resource constraints, searches were restricted to studies in the English language.

Search strategy

The search strategy was devised through scoping the literature for keywords indexed on published papers, reflection on search terms used in previous reviews e.g., Melby-Lervåg and Hulme (2013), and consultation with the subject-specific librarian at Ulster University. Following trials of two draft search strategies (January 2017), final searches were conducted (February 2017) with Boolean phrases using the terms ("working memory" OR "short-term memory" OR "executive function*") AND child* AND (training OR intervention*OR treatment OR therap* OR program*). Searches were updated on a regular basis throughout the review and just prior to its completion (July 2017). The results were exported to Refworks (2.0) and duplicates were removed. An excel spreadsheet was then created to manage the bibliography of all potential papers.

Study selection

As anticipated, electronic database searches produced a large number of results (n = 6262). This was considered unavoidable as narrowing the search terms would have excluded relevant studies. The first author screened the results by title and removed studies which clearly did not meet the criteria (n = 5903). For example, titles which explicitly stated that the intervention implemented was computerised or that it was conducted with adults were immediately excluded. Where there was any doubt about the eligibility of a study, it was included for further screening. The abstracts of the remaining studies (n = 359) were screened again by the first author and this process was checked by the second author. Abstracts frequently provided insufficient detail to support inclusion/exclusion from the review and, where there was any uncertainty, the full paper was considered. Following this, all potential papers were reviewed against a checklist of the eligibility criteria (n = 69) and 50% of these were reviewed independently by two other members of the review team. The first reviewer compiled a table to aggregate the information on each reviewer's decision, which was discussed at a face-to-face meeting of the review team in May 2017 where there was full agreement.

Data extraction

The data extraction process was guided by the PICO framework (Booth & Fry-Smith, 2004). Population, comparison and outcomes data were extracted from each study and collated on an excel spreadsheet. Data relating to the theoretical underpinning, content and delivery (including dosage) of each intervention were extracted using the Template for Intervention Description and Replication (TIDieR) Checklist (Hoffmann et al., 2014). When available, data on four variables of intervention dosage were extracted following definitions proposed by Warren, Fey, and Yoder (2007): (i) dose - the number of properly administrated trials per training session; (ii) dose frequency – the number of times the dose is provided per day or per week (which may also include session duration); (iii) the total intervention duration – the time period over which the intervention is presented e.g., 3 weeks or 6 months (see Warren et al., 2007) and iv) cumulative intervention intensity i.e., dose × dose frequency × total intervention duration (e.g., 10 trials × 4-times per week × 12 weeks = 480).

Data analysis

After careful consideration, it was decided that a meta-analysis was not appropriate for this review. This decision was partially based on the purpose of the review and the research questions posed. The current review aims to map a diverse range of studies to investigate the best approach to WM intervention for young children. The Cochrane Handbook for Systematic Reviews advises that meta-analyses are not indicated for reviews with this focus (Deeks, Higgins, & Altman, 2008). Further, a meta-analysis could be misleading, given the clinical heterogeneity of the included interventions (Hoffman, 2015). The interventions are diverse in their approach, content, dosage and outcomes measured so the interpretation of effects in a meta-analysis would be challenging. The low number of studies in each intervention category would also result in very low power for any sub-group meta-analyses so it would be difficult to make generalisations from the results (Borenstein, Hedges, Higgins, & Rothstein, 2009)

The data analysis process involved three steps. First, the included studies were categorised according to the type of WM intervention implemented (see results section). Next, the results from each study were examined in respect of: the primary outcomes - effects on aspects of WM (research objective 2); and the secondary outcomes- near- and far-transfer effects and the durability of intervention effects over time (research objectives 3 and 4). During this process, all of the trained WM tasks and outcomes were defined according to which of the four aspects of WM they involved because this was not always clearly identified in the papers. In the majority of cases, studies did not clearly differentiate between trained and untrained but similar tasks (near-transfer effects) when reporting outcomes. To be deemed effective, a logical pattern of treatment effects must have been demonstrated. Where an intervention trained other skills to indirectly impact WM, there must have been improvements on the trained task as well as WM (Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016; Redick et al., 2015). Likewise, interventions were considered to have produced far-transfer effects, if near-transfer effects were observed (Redick et al., 2015). The third step involved extracting the results from those studies which demonstrated positive treatment effects and synthesizing the evidence for the overall effectiveness of the interventions on the primary and the secondary outcomes. This enabled consideration of the active ingredients and optimum dosage implemented in the most effective interventions (research objective 5).

Assessing risk of bias and confidence in cumulative evidence

The external and internal validity of the studies was investigated using the Cochrane Collaboration tool for assessing the risk of bias (Higgins & Altman, 2008) which can be applied to both randomised and non-randomised studies (Reeves, Deeks, Higgins, & Wells, 2008). When considering the strength of the evidence, the criteria suggested by Redick et al. (2015) for the evaluation of WM training effectiveness were also considered, prompting particular attention to the nature of the control condition. Reporting quality was measured using the CONSORT guidance on the reporting of randomised trials (Schulz, Altman, Moher, & for the CONSORT Group, 2010) and the TREND statement (Des Jalais, Lyles, Crepaz, & the TREND Group, 2004) for non-randomised study designs. The Grading of Recommendations Assessment, Development and Evaluation working group methodology (GRADE) (GRADE working group, 2004), increasingly recommended for systematic reviews (Shamseer et al., 2015), was used to assess the cumulative strength of the evidence for the synthesized findings on the primary and secondary outcomes.

Results

Study selection and characteristics

The number of studies screened at each stage of the selection process and the reasons for exclusion are shown in Fig. 1. Most of the excluded studies ($n = 25$) were omitted on the basis of the outcomes measured. Eighteen studies have been included in the review and an overview of their characteristics is provided in Table 2. The studies were carried out in eight countries, with most being conducted in the United States ($n = 5$), Italy ($n = 5$) and the UK ($n = 3$). Publication dates ranged from 1994 to 2016 and seventeen were published after the publication of the CONSORT (Schulz et al., 2010) and TREND (Des Jalais et al., 2004) statements. The majority of studies ($n = 12$) were conducted with typically developing children, only one study focused on children with WM difficulties and none specifically targeted children from low socio-economic backgrounds. To be included in the review, studies must have been conducted with children aged 4–11 years. In the final study selection, participants ranged from 4 to 10 years (mean age = 7.8 years). Fewer than 50% of the studies ($n = 7$) were randomised controlled trials, only two studies used an active control group and none reported having undertaken a power calculation in determining sample size. In terms of outcome measurement, fewer than 50% of the studies ($n = 7$) measured more than one aspect of WM, and the use of standardised WM measures was limited. Verbal skills were more frequently measured than visuospatial WM. Few studies measured transfer effects, but more assessed far- ($n = 7$) than near-transfer effects ($n = 4$), with only one study explicitly investigating near-transfer effects using standardised WM

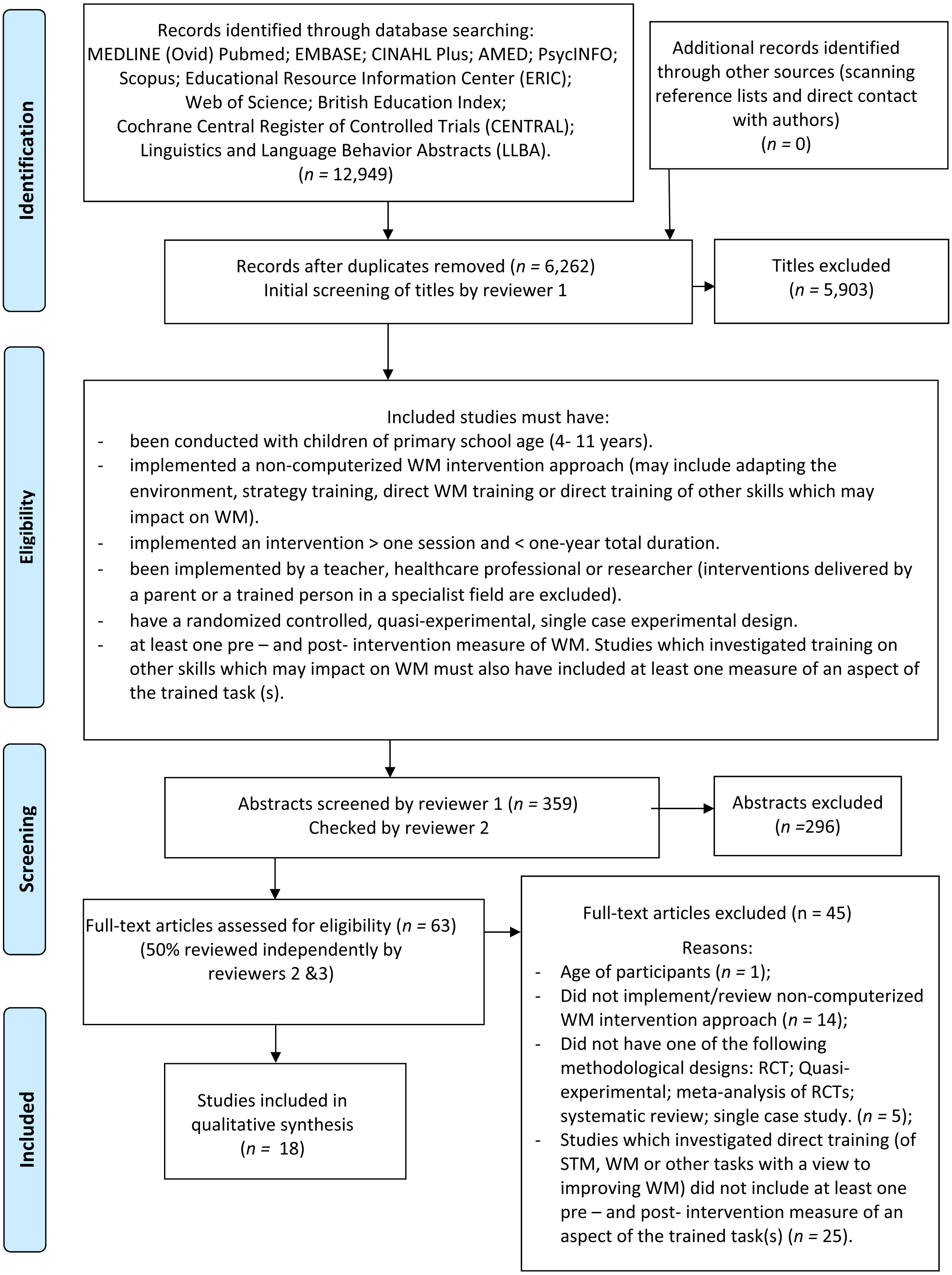


Fig. 1. Flow Diagram for search strategy with criteria and reasons for exclusion following the PRISMA statement (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009).

assessments (Henry, Messer, & Nash, 2014). Appendix A provides the dosage data extracted from each paper, showing significant gaps in the reporting of treatment intensity.

The first research objective was to identify the types of WM interventions implemented with 4–11 year olds in their everyday

Table 2
Summary of characteristics of all studies included in the review (n = 18).

PICO variable	Study characteristics
Population	Age range: 4; 4–10 years. Mean ($\bar{x}$ = 7.8 y)
	Status:
	Typically developing children (n = 12)
	Language impaired children (n = 1)
	Children with reading difficulties (n = 1)
	Children with identified WM difficulties (n = 1)
	Children considered at risk of learning difficulties (n = 1)
	Children with Down's syndrome (n = 1)
	Overweight children (n = 1)
	Studies specifically targeting children from low socio-economic status (SES) (n = 0)
Intervention	Intervention approach:
	Adapting the environment (n = 1);
	Direct WM training without strategy instruction (n = 3)
	Direct WM training with strategy instruction (n = 5);
	Training skills that indirectly impact on WM (n = 9).
	– physical activity (n = 5);
	– phonological awareness skills (n = 2);
	– fantastical play (n = 1);
	– inhibition (n = 1).
	Where the intervention was delivered:
	via Skype (n = 1)
	school (n = 12)
	preschool setting (n = 1)
	gym (n = 1)
	No detail given (n = 3)
	Unit of delivery (grouping of participants):
	Individual (n = 8)
	Small group (n = 6)
	Whole class (n = 2)
	Combination of individual and small group (n = 2).
	Dosage:
	Total duration of intervention ranged from 10 days to 11 months
	Average total intervention duration in weeks ($\bar{x}$ = 13)
Comparison	Study design:
	Randomised controlled trials (n = 8)
	Quasi-experimental designs (n = 9)
	Case series (n = 1)
	Control group conditions:
	Active control groups (n = 2)
	No intervention control groups (n = 14)
	Own matched controls (n = 2)
	Sampling:
	Power analysis reported (n = 0)
	Sample size range across all included studies (n = 4 to n = 256).
	Average sample size ($\bar{x}$ = 74)
Outcomes	Measurement of WM:
	Verbal STM (n = 11)
	Visuospatial STM (n = 7)
	Verbal ELWM (n = 14)
	Visuospatial ELWM (n = 4)
	Studies which measured more than one aspect of WM (n = 7)
	Studies which implemented a standardised measure of WM (n = 5)
	Measurement of transfer effects:
	Near-transfer (n = 4)
	Far-transfer (n = 7)
	Durability over time (n = 4)

contexts and their theoretical underpinnings (the causal assumptions embedded within them). There is no agreed system for the classification of WM interventions that are applied in children's everyday contexts (see Diamond & Lee, 2011; Otero et al., 2014 for examples). In this review, the included studies have been classified into four intervention types:

(1) Adapting the classroom environment: Only one study reviewed here investigated the effectiveness of this approach which does not require direct intervention with children. Instead, teachers are educated about how to detect children with WM difficulties and trained in how to adapt learning activities to reduce WM loads for these children. By reducing WM demands in the classroom, children with poor WM may successfully complete more learning tasks and consequently acquire knowledge across lessons.
(2) Direct WM training without strategy instruction: Three interventions involved repeated practice on verbal or visuospatial tasks

requiring STM (storage only tasks) or ELWM (storage plus an additional attentional or processing load).

(3) Direct WM training with strategy instruction: Five studies investigated the effectiveness of explicitly teaching children to use cognitive strategies while practising WM tasks. The use of strategies to support the efficiency of WM emerges during childhood e.g., verbal rehearsal (repeating the to-be-remembered information out loud or in your head) develops at about 7 years (Gathercole, 1998). Other strategies, such as organization and grouping (Bjorkland & Douglas, 1997) and chunking information (Ottem, Lian, & Karlsen, 2007) develop later than this. It has been suggested that younger children may benefit more from this strategy-supported direct training than older children who may have established these skills already (St. Clair-Thompson & Holmes, 2008; St. Clair-Thompson, Stevens, Hunt, & Bolder, 2010).

(4) Training skills that indirectly impact on WM: A wide range of activities including martial arts, physical exercise, yoga, mindfulness, music, sports and traditional childhood games can impact on executive function skills including WM (Diamond, 2012; Otero et al., 2014). Other approaches including sensory-based interventions (Worthen, 2010), proprioceptively demanding exercise (Alloway & Alloway, 2015b) and motor skills training (Halperin et al., 2015) have also been suggested as benefitting WM. Nine studies were included that implemented a range of interventions: physical activity (n = 5); phonological awareness (n = 2); fantastical play (n = 1) and inhibition[3] (n = 1). Studies investigating sensory-based and mindfulness interventions did not meet the eligibility criteria for this review.

Table 3 provides the theoretical underpinnings stated in the included papers and the methodological characteristics of each study. This shows that many of the studies lacked a clear theoretical account of why the intervention should impact WM. In particular, the studies looking at indirect training of WM through physical activity, fantastical play (Thibodeau, Gilpin, Brown, & Meyer, 2016), or inhibition (Volckaert & Noël, 2015) did not refer to theoretical models of WM in their study rationale.

Results of individual studies

The main findings of each study and the evidence for each of the four identified intervention approaches are summarised below (see supplementary material Table A for a comprehensive overview).

1. Adapting the environment

One paper (Elliott, Gathercole, Alloway, Holmes, & Kirkwood, 2010) investigated the effects of adapting the classroom environment on children's WM skills, measuring effects on all four aspects of WM and far-transfer to vocabulary, reading and maths. Benefits were only reported on the VSSTM measure for one of the cohorts (see Table 3 for details of the study design). The second phase of the study included observation of whether teachers were using the WM strategies. The study authors reported that there was a positive association between teachers' use of strategies and children's post-intervention reading and spelling scores but that this association was also seen on pre-intervention measures of reading comprehension, suggesting that the most effective teachers were already using appropriate strategies prior to the intervention. This review has found no evidence that adapting the classroom environment in the absence of direct training improves children's WM.

2. Direct WM training without strategy instruction

All three studies (Banales, Kohnen, & McArthur, 2015; Henry et al., 2014; Passolunghi & Costa, 2016) that implemented a direct WM training approach without strategy instruction reported improvements on trained WM measures. Between study comparisons revealed that all of the intervention ingredients were ELWM tasks and the training produced greater effects on ELWM outcomes than on STM skills. Evidence for near- and far-transfer effects was variable. Banales et al. (2015) did not find any transfer from verbal ELWM training to reading skills. Henry et al. (2014) did find near-transfer effects from trained ELWM tasks to some (but not all) untrained STM skills and to an untrained ELWM task (counting recall), but far transfer effects to single word reading and maths were absent (although there was some evidence for a far transfer effect on reading comprehension). Passolunghi and Costa (2016) reported far transfer effects on numeracy skills following training on all four aspects of WM but they did not measure near-transfer effects. The results here show that non-computerised direct WM training produces positive effects on the trained tasks when these are executive-loaded but the evidence for near- and far-transfer effects is mixed.

3. Direct WM training with strategy instruction

Five studies, all with children between 7 and 9 years of age, implemented direct WM training with strategy instruction. Table 4 gives an overview of the WM aspect(s) trained and the strategies taught in these interventions, showing that two studies trained STM tasks and three targeted ELWM tasks.

The two studies that targeted STM skills produced limited evidence for positive effects on the trained skills. Caviola, Mammarella, Cornoldi, and Lucangeli (2009) found that both the experimental and the control groups improved on the trained VSSTM measure but

[3] Due to the overlapping nature of executive functions, it could be argued that training inhibitory control should be considered as direct WM training. This study (Warren et al., 2015) was categorised as indirectly targeting WM as the intervention did not involve repeated practice on memory tasks.

Table 3
Characteristics of individual studies included in review (n = 18).

Intervention type	Study author and year	Population			Intervention type	Theoretical underpinning provided by study authors	Design	Control condition
		Status	Age in years (y)/months (m) E (C)	Total sample size				
Adapting the environment	Elliott et al. (2010)	TD	5–6 year olds 9–10 year olds	256	Adapting the environment Teachers divided into 2 groups and provided with training on: (1) WM intervention: the use of strategies to modify and reduce WM loads in the classroom; or (2) Behavioural teaching. the use of behavioural approaches in the teaching of directly targeted academic skills.	Baddeley and Hitch Working Memory Model. Based on hypothesis that reducing WM overload may result in improved learning.	Quasi-experimental with nested design. Two age groups participated in each of two successive cohorts.	No intervention
Direct WM training without strategy instruction	Banales et al. (2015)	R + WM	9.92y.	4	Direct WM without strategy instruction	Baddeley and Hitch Working Memory Model	Case series	Each child completed 8 weeks of verbal working memory training and 8 weeks of reading training, acting as their own matched control.
	Henry et al. (2014)	TD	7 year olds 84.2 m. (84.0 m.)	36	Direct WM without strategy instruction	Baddeley and Hitch Working Memory Model Training explicitly targets ELWM skills.	RCT	Active control: similar task with no memory element.
	Passolunghi and Costa (2016)	TD	5 year olds Group 1 65.8 m. Group 2 64.67 m. (64.4 m)	48	Direct WM without strategy instruction 2 trained groups: (1) WM training (2) numeracy training	Baddeley and Hitch Working Memory Model	RCT	No intervention
Direct WM training with strategy instruction	Caviola et al. (2009)	TD	“Fourth grade” 8–9 year olds	46	Direct WM training with strategy instruction	Reference to meta-cognitive literature and Baddeley and Hitch Working Memory Model but trained tasks not clearly differentiated as STM or ELWM.	Quasi-experimental	General cognitive strategies
	Comblain (1994)	DS	8 year olds	8	Direct WM training with strategy instruction	No theory provided	Quasi-experimental	No intervention
	Cornoldi et al. (2015)	TD	8–10 year olds	135	Direct WM training with strategy instruction	Baddeley and Hitch Working Memory Model Hypothesis that combining WM training with meta-cognitive strategies might promote more robust and persistent effects on problem solving.	Quasi-experimental with a cross-over design (2 groups taking part in 8 weeks of training consecutively).	When not in a training period, children took part in their usual mathematics lessons.
	Peng and Fuchs (2015)	LD	Strategy – 7.19y No-strategy	58	Direct WM with strategy instruction 2 intervention conditions: (1) WM with strategy	The authors distinguish between WM tasks pertaining to either the verbal or visuospatial domain and refer to the debate between	RCT	No intervention

(*continued on next page*)

Table 3 (*continued*)

Intervention type	Study author and year	Population			Intervention type	Theoretical underpinning provided by study authors	Design	Control condition
		Status	Age in years (y)/months (m) E (C)	Total sample size				
			7.09y. Control 7.13y.		(2) WM without strategy	domain-general and domain-specific WM theories, hypothesising that domain-specific training will produce effects on related academic skills. They refer to 'Strategy Mediation Theory' - view that WM is a finite fixed capacity and performance is determined by the efficiency with which this capacity is used.		
	Witt (2011)	TD	9 year olds 116.13 m.	38	Direct WM training with strategy instruction	Baddeley and Hitch Working Memory Model. Training explicitly targets ELWM skills.	Quasi-experimental	No intervention
Training skills which may indirectly impact on WM - physical activity	Alesi et al. (2016)	TD	8.78y. (9.25y.)	44	Physical activity Football exercise program	No reference to WM theory. Based on concept that new tasks stimulate co-activation of prefrontal cortex and may impact on cognition.	Quasi-experimental	No intervention ("sedentary children")
	Davis et al. (2007)	O	9.2y.	94	Physical activity 2 intervention conditions (1) low dose (20 min) (2) high dose (40 min)	No reference to WM theory.Based on concept that children's cognitive functioning may be particularly sensitive to the influence of physical activity.	RCT	No-exercise control condition
	Kamijo et al. (2011)	TD	8.9y. (9.1y.)	43	Physical activity	No reference to WM theory. Based on evidence of a positive relation between cardiorespiratory fitness and neurocognitive functioning in children Hypothesised that greater improvements would be made on tasks with greater WM demands due to improvements in cognitive control.	RCT	Waitlist control
	Koutsandréou et al. (2016)	TD	CE group 9.3y. ME group 9.4y. (9.3y.)	71	Physical activity 2 trained groups: (1) Cardiovascular exercise program (CE group) Motor-demanding exercise program (ME group).	No reference to WM theory. Based on evidence of a motor-cognition link: that motor exercise leads to adaptation of brain areas, which might benefit cognition more than mere cardiovascular exercise.	RCT	Control group: assisted homework sessions
	Van der Niet et al. (2016)	TD	8.8y (8.9y)	112	Physical activity	No reference to WM theory. Based on evidence of the relationship between regular aerobic exercise and executive	Quasi-experimental	Normal daily school routine (included 2 PE lessons per week)

(*continued on next page*)

Table 3 (*continued*)

Intervention type	Study author and year	Population			Intervention type	Theoretical underpinning provided by study authors	Design	Control condition
		Status	Age in years (y)/months (m) E (C)	Total sample size				
						functions and suggestions that: exercise induces neurochemical and morphological changes in the brain areas associated with executive functioning; and that physical activities in which specific goals have to be achieved are cognitively demanding.		
Training skills which may indirectly impact on WM - phonological awareness	Melby-Lervåg and Hulme (2010)	TD	7y1m.	160	Phonological awareness 3 intervention conditions (1) phoneme awareness training (2) Rhyme training (3) vocabulary training.	Baddeley and Hitch Working Memory model.The authors aimed to Investigate the interrelationship between verbal memory and language processing, hypothesizing that phoneme training would enhance serial recall more than rhyme training based on the assumption that serial recall serial recall depends on the quality of the phonological representations of the words to be recalled (phonological representation hypothesis).	Quasi-experimental	No-intervention
	Van Kleeck et al. (2006) Van Kleeck et al. (1998)	SLI	4–5 years Group 1 48.87 m. Group 2 60 m (71.5 m).	24	Phonological awareness	Baddeley and Hitch Working Memory model. Based on hypothesis that phonological awareness training improves the functioning of the phonological loop.	Quasi-experimental	1998 paper: No-intervention control
Training skills which may indirectly impact on WM - fantastical play	Thibodeau et al. (2016)	TD	3–5 years Group 1 50.62 m. Group 2 54.06 m. (52.37 m.)	110	Fantastical play 2 intervention conditions: (1) fantastical play (2) non-imaginative play	No reference to WM theory. Vygotsky's theory that complex pretend-play provides natural experience in which cognitive skills are developed and that in fantastical play children may use WM to remember the rules and scripts in the pretence.	RCT	No intervention (business as usual)
Training skills which may indirectly impact on WM - inhibition	Volckaert and Noël (2015)	TD	4–5 years 60.13 m. (60.52 m.)	112	Inhibition	No reference to WM theory. Based on associations between executive functions and children's externalising behaviours in pre-schoolers.	RCT	"Passive" control group -handicraft lessons

Key: C = control group (s); E = experimental group; TD = typically developing; DS = Down's syndrome; SLI = specific language impairment; O = overweight; LD = at risk of learning difficulties; RD = reading difficulties' R + WM = reading and WM difficulties. RCT: Randomised Controlled Trial.

there was no significant post-intervention difference between the groups. Comblain (1994) reported improvements on trained VSTM tasks but there was no clear comparison with a control group. Training on ELWM tasks produced more consistent data. The studies by Witt (2011) and Cornoldi, Carretti, Drusi, and Tencati (2015) demonstrated significant gains for the experimental groups compared to their control conditions, although in both cases they were passive controls. Peng and Fuchs (2015) paper was the only study to compare the effects of WM training with and without strategy use. These two intervention groups were compared to a no-intervention control group. Neither of their experimental groups made significantly greater gains than the control group on the trained ELWM tasks and there was no difference between the strategy and the no-strategy groups.

Three studies in this category (Caviola et al., 2009; Witt, 2011; Peng & Fuchs, 2015) measured near-transfer effects. Caviola et al. (2009) reported improvements on one VSELWM near-transfer task (backward Corsi block tapping task) but did not demonstrate effects on the trained VSSTM task (see above). Similarly, Peng and Fuchs (2015) measured three untrained WM tasks and saw improvements on one of these (listening recall, VELWM, where the strategy group outperformed the control group) but not on the trained task. One study, Witt (2011), found improvements on both the trained task and a near-transfer effect to an ELWM measure (visual patterns task). With regards to far-transfer, three studies measured a range of academic outcomes and all reported substantial effect sizes: Caviola et al. (2009) on arithmetical problem solving, and Cornoldi et al. (2015) and Witt (2011) on maths (addition accuracy). However, Caviola et al. (2009) had not shown effects on the trained task and Cornoldi et al. (2015) had not measured near-transfer effects.

Evidence regarding whether children actually used the taught cognitive strategies was limited with only two studies measuring strategy use. Cornoldi et al. (2015) directly measured this using a meta-cognitive questionnaire to investigate the effects of training on children' strategy use and reported that this significantly increased. Peng and Fuchs (2015) used detailed training logs and also reported increases in strategy use following training.

Overall, the results of the five studies reviewed in this category suggest that effects on trained WM tasks were observed when ELWM tasks were trained. There is inadequate evidence regarding near-and far-transfer effects and the impact of strategy-instruction due to a lack of comprehensive outcome measurement.

4. (a) Training skills which may indirectly impact on WM: physical activity

For the nine studies in which skills that may indirectly impact WM were trained, the effects on the trained task, as well as the WM outcomes are crucial in determining the effectiveness of the interventions (Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016; Redick et al., 2015).

Five studies implemented a physical activity intervention with typically developing children aged 8–10 years. None of these referred to WM models or cognitive processing frameworks in their rationale; rather they referred to neuro-developmental evidence for the underlying involvement of the cerebellum and prefrontal cortex in both motor and cognitive tasks. Examining the results of these studies means looking at the exact nature of the trained tasks (ingredients), and in doing so, an important distinction can be drawn between activities that mostly challenge: (a) physical fitness i.e., they raise the heart rate but require limited attentional resources under executive control because they are already learned skills with a degree of automaticity such as running; and (b) motor planning skills i.e., they require considerable executive control due to the novelty of the task, but have low cardiovascular impact such as dribbling a ball while avoiding obstacles; or (c) both physical fitness and motor planning skills which includes many sports.

All of these interventions appeared to involve novel motor planning tasks. Thus, they have been defined here as executive-loaded interventions, although in most cases the study authors did not define them in this way or specify the motor planning requirements of the intervention tasks. For example, Davis et al. (2007) described their intervention as an aerobic exercise program but on closer inspection of the treatment ingredients, they included the teaching of novel motor skills. This intervention was conducted with overweight children (n = 94) and found no significant weight reduction. Van der Niet, Smith, Oosterlaan, and Scherder (2016) did not find any improvements on children's physical fitness following their intervention, described as a cognitively demanding exercise program and they did not measure the children's motor skills. Three studies did report significant improvements on the trained physical activities. Kamijo et al. (2011) reported improvements on physical fitness and Alesi, Bianco, Palma, and Pepi (2016) found significant improvements on agility following a football intervention. Koutsandréou, Wegner, Niemann, and Budde (2016) was the only study that directly compared the effects of physical activity with and without an executive skills element. Both groups (cardiovascular and motor exercise) showed specific improvements from the intervention compared to a no-intervention control group.

Looking at the effects of these physical activity interventions on WM, Davis et al. (2007) found no significant WM gains (though they report positive effects on other aspects of cognitive functioning). Van der Niet et al. (2016) reported significant improvements on VELWM (backward digit span task) but not on VSELWM (visual memory span). The study authors suggested improvements in WM skills, in the absence of enhanced physical fitness, were owed to the cognitively engaging aspect of the trained task. Kamijo et al. (2011) reported mixed findings on VELWM outcomes depending on the complexity of the task. Alesi et al. (2016) also found mixed effects on WM measures, with gains observed on a visuospatial STM task, but not on verbal STM or ELWM measures. Koutsandréou et al. (2016) found positive effects on WM following both the cardiovascular and the motor exercise programs, but to a larger degree from the motor exercise intervention.

To summarise, all of the physical activity interventions reviewed included tasks requiring novel motor planning. Three out of the five studies reported improvements on these executive-loaded skills. The WM outcomes measured varied greatly between studies and verbal ELWM skills were measured most frequently. Four out of the five papers reviewed found significant gains on these outcomes.

(b) Training skills which may indirectly impact on WM: phonological awareness

Two studies investigated the effects of training phonological awareness on WM and both used the Baddeley and Hitch (1974) model as

Table 4
Direct WM training with strategy instruction: tasks and taught strategies.

Study author and year	Trained WM tasks	Taught strategies
Caviola et al. (2009)	VSSTM, specifically, sequential-spatial tasks.	– Coding stimuli and analysing information - looking closely at figures, naming and rehearsing labels when following a path. – Chunking visuospatial stimuli. – Using mental images to execute a task. – Verbalising mental images.
Comblain (1994)	VSTM tasks: Digit span Word span Letter span	Described as rehearsal
Cornoldi et al. (2015)	VELWM: variations of classical WM tests e.g. listening span VELWM – recall plus a secondary task	Meta-cognitive strategies focusing on those related to: (1) understanding the wording of a problem (2) improving the visual-schematic representation of problems
Peng and Fuchs (2015)	VELWM tasks: Counting figures Calculation span Operation span Puzzles	Rehearsal strategy training
Witt (2011)	VSTM: Word list recall forwards VELWM: Backward digit recall VELWM: Updating task VELWM: Counting recall	– Imagine a story – Sub-vocal rehearsal – strategies for preventing distraction

their theoretical framework, hypothesising about the role of phonological processing and memory in language learning (see Table 3). Melby-Lervåg and Hulme (2010) compared the effects of phoneme awareness training, rhyme training and vocabulary training on these trained skills and on WM (serial recall and free recall). Phoneme awareness training improved phoneme awareness skills, benefitted serial recall and had a smaller positive effect on free recall. Rhyme training improved rhyme generation skills but had no impact on serial or free recall. Vocabulary training improved children's ability to define the trained words. It improved free recall and had a smaller positive effect on serial recall, but again only for the trained words. Van Kleeck, Gillam, and Hoffman (2006) reported WM outcomes for children with language impairment (n = 24) who had taken part in an intervention targeting phoneme awareness and rhyme skills (see Van Kleeck, Gillam, & McFadden, 1998). The original paper reported that children made significant gains from pre- to post-intervention assessment on rhyme and phoneme awareness tasks, but when comparisons were made with the control group, the gains on rhyme could not be attributed to the intervention. In the earlier paper, the study authors reported significant pre- to post-intervention improvements on VSTM measures but in the more recent paper there was no comparison with a control group. When taken together, the results of these two studies suggest that rhyme and vocabulary training do not improve VSTM skills but phoneme awareness training produced positive effects.

(c) Training skills which may indirectly impact on WM: play and inhibition

Two studies implemented small group interventions with 4–5 year olds. Thibodeau et al. (2016) studied the effects of a fantastical play intervention and Volckaert and Noël (2015) investigated the effects of training exercises that tapped into four aspects of inhibitory control: interruption of an ongoing response; impulsivity control; inhibition of a predominant response; and inhibition of external factors. Both studies reported significant improvements on the trained tasks (fantastical play and inhibition). Thibodeau et al. (2016) found positive effects on VSTM and Volckaert and Noël (2015) reported gains on a factor analysis combining three WM outcomes (VSSTM, VELWM and VSSTM). They also included far-transfer measures of children's externalising behaviours and reported significant effects including a reduction in children's negative and inattentive behaviours. The study authors suggested that a meta-cognitive element to the intervention may have supported transfer to attention behaviours. To summarise, these studies suggest that children's fantastical play skills can be improved by intervention and that this can strengthen VSTM skills. Inhibitory control was improved by training and produced effects on WM, attention and behaviour.

Synthesized findings; active ingredients, dosage, transfer effects and maintenance

The current section provides a synthesis of the results for: the primary outcomes (effects on trained aspects of WM, research objective 2); the secondary outcomes (near- and far-transfer effects, research objective 3); and durability over time (research objective 4). Table 5 presents the intervention ingredients extracted from those studies deemed to be effective, following the criteria outlined in the data analysis section.[4] The key finding is clearly demonstrated - in all of the effective interventions, the trained tasks were executive-loaded. Overall, the evidence for near- and far-transfer effects from WM interventions within the child's environment was limited to three studies (see Table 5: Henry et al., 2014; Volckaert & Noël, 2015; Witt, 2011), although the evidence was constrained by the lack of near-transfer effects being measured in some studies. For example, Peng and Fuchs (2015), Cornoldi et al. (2015) and Passolunghi and

[4] Comprehensive summaries of the training effects for these outcomes can be found in the supplementary materials (Tables B1–B5).

Costa (2016) reported significant far transfer effects following training, but had not measured near-transfer effects.

There was less consistency regarding the findings on intervention dosage. When they were reported, there was considerable variation between studies. Dose/number of trials per intervention session was only reported in one paper (Henry et al., 2014). Despite this, Table 5 demonstrates that training effects can be observed following relatively short interventions of 5–8 weeks (albeit with varying intensity of sessions per week) (see Appendix A for full details).

The fourth research objective was to identify whether WM gains were durable over time. Only four of the included studies (Banales et al., 2015; Henry et al., 2014; Cornoldi et al., 2015; Comblain, 1994) included any follow-up period so the evidence here is limited. These studies were heterogeneous in their intervention approaches and in the length of time between post-intervention assessment and follow up but all demonstrated that WM gains had been maintained.

Risk of bias

The risk of bias in the included studies is significant due to methodological issues (see completed Cochrane risk of bias tool, Appendix B). Fewer than 50% of included studies were randomised controlled trials (n = 8) and none of the studies reported undertaking a power analysis, so small sample sizes may have resulted in inflated effects being reported (Button et al., 2013). Whether the children's teachers were aware of the purpose of the intervention was often unclear and without clear audit protocols being put in place this raises questions about the fidelity of implementation. There was also a lack of active control groups and blinding, which are important in WM research studies, especially with children whose familiarity with experimenters could affect their motivation and outcomes (Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016; Redick et al., 2015). Reporting issues were also identified by the CONSORT (Schulz et al., 2010) and TREND (Des Jalais et al., 2004) checklists especially in relation to randomisation and allocation processes which were consistently unreported. Publication bias may also threaten the validity of the findings because, although the grey literature was comprehensively searched, only published papers met the review criteria. On balance, the review findings for the effectiveness of non-computerised WM interventions in children's everyday contexts should be considered as suggestive evidence and viewed with some caution until further evidence is obtained from more robust studies.

Discussion

The aim of this review was to examine systematically the effectiveness of interventions targeting WM in 4–11 year olds applied within their everyday contexts. The first research objective was to identify both the types of WM interventions implemented and their theoretical underpinnings. A systematic search of the literature resulted in eighteen studies being reviewed, encompassing a range of intervention approaches including: adapting the environment to reduce WM loads; direct WM training without strategy instruction; direct WM training with strategy instruction; and training skills that may indirectly impact on WM (physical activity, phonological awareness, fantastical play and inhibition). Many of the included studies lacked a clear theoretical account of why the intervention should impact WM. In particular, the studies looking at indirect training of WM through physical activity, fantastical play (Thibodeau et al., 2016), or inhibition (Volckaert & Noël, 2015) were not explicitly underpinned by theoretical models of WM.

The second research question was to identify the effects of interventions targeting WM in children's everyday contexts on each aspect of WM. Answering this question was challenging because in the majority of studies, the aspect of WM being trained or measured was not elucidated, and there was often no clear distinction between STM and ELWM tasks. Nonetheless, a significant outcome of this review is that WM skills can be altered through diverse interventions, particularly in relation to verbal WM skills which were more frequently measured than the visuospatial domain. ELWM skills appear to be more amenable to change than STM skills.

The third and fourth research questions were to identify any near-and far-transfer effects and the durability of WM gains over time. The evidence here was limited because few studies measured these outcomes. However, there is preliminary evidence suggesting that certain direct and indirect WM tasks applied within children's everyday contexts have the potential to produce: near-transfer effects on similar WM tasks (Henry et al., 2014; Witt, 2011); and far-transfer effects on areas such as reading comprehension (Henry et al., 2014), numeracy skills (Witt, 2011), attention and behaviour (Volckaert & Noël, 2015).

Reflection on the potential of these varied interventions to produce training and transfer effects leads to questions about which children may benefit most and the impact of individual differences. The age of participants varied within each intervention type, making it difficult to draw strong conclusions about age effects. A number of the interventions reviewed showed significant benefits for younger children (4–5 year olds) (Passolunghi & Costa, 2016; Thibodeau et al., 2016; Van Kleeck et al., 2006; Volckaert & Noël, 2015), reinforcing the idea that non-computerised approaches might be more suitable for younger children. The majority of studies were with typically developing children, meaning it was not possible to evaluate the effectiveness of the interventions for children with identified WM difficulties, neurodevelopmental difficulties or at-risk groups such as those from low-socioeconomic backgrounds persist. Nonetheless, it would be beneficial in future reviews to evaluate the effects of differences in baseline abilities and other individual differences.

The final research question concerned the active ingredients and optimum dosage requirements for WM interventions applied in children's everyday contexts. Here the synthesized data from those studies demonstrating effects on WM indicated that the most effective tasks were executive-loaded i.e., they tap into attentional resources under executive control. The effective ELWM tasks were: listening recall, odd one out, backward digit recall, verbal and visuospatial dual tasks, and word list updating. When considering indirect WM tasks, there is suggestive evidence that cognitively-demanding physical activity (motor planning), fantastical play (Thibodeau et al., 2016) and inhibition training (Volckaert & Noël, 2015) are beneficial to ELWM. In these effective interventions, it is perhaps the overlapping nature of the trained activities, WM and real-world skills that is the active ingredient resulting in promising positive effects (Gathercole et al., 2018).

Table 5
Synthesized findings for effective interventions on trained aspects of WM, near- and far-transfer effects.

Outcomes measured	Intervention demonstrating positive effects			Dosage			
				Dose	Dose frequency		Total intervention duration
	Trained task	Executive-loaded?	Study author and year		Session duration (min)	Session frequency (times per week)	
Trained aspects of working memory	Direct ELWM training: Odd one out and listening recall	✓	Henry et al. (2014)	22 trials (11 of each task)	10	3	6 weeks
	Direct ELWM training: Verbal and visuospatial dual tasks	✓	Passolunghi and Costa (2016)	?	60	2	5 weeks
	Direct ELWM training: word list updating	✓	Cornoldi et al. (2015)	?	60	1	8 weeks
	Direct ELWM training with strategy instruction: backward digit recall with rehearsal	✓	Witt (2011)	?	15	?	6 weeks
	Phoneme awareness	✓	Melby-Lervåg and Hulme (2010)	?	7	1	10 consecutive school days
		✓	Van Kleeck et al. (2006)	?	15	2	12 weeks
WM impacted indirectly by training other skills	Cognitively-demanding physical activity	✓	Alesi et al. (2016)	?	75	2	6 months
		✓	Kamijo et al. (2011)	?	120	1	150 days (9 months)
		✓	Koutsandréou et al. (2016)	?	45	3	10 weeks
		✓	Van der Niet et al. (2016)	?	45	3	10 weeks
	Fantastical play	✓	Thibodeau et al., 2016	?	15	5	5 weeks
	Inhibition	✓	Volckaert and Noël (2015)	?	15	?	6 weeks
Near-transfer measures[a]	Direct ELWM training: Odd one out and listening recall. Near-transfer to another ELWM task (counting recall)	✓	Henry et al. (2014)	22 trials (11 of each task)	10	3	6 weeks
	Direct ELWM training with strategy instruction: backward digit recall with rehearsal. Near-transfer to VSSTM.	✓	Witt (2011)	?	15	?	6 weeks
Far-transfer measures	Direct ELWM training: Odd one out and listening recall Improvements on one measure of reading comprehension.	✓	Henry et al. (2014)	22 trials (11 of each task)	10	3	6 weeks
	Direct ELWM training with strategy instruction: backward digit recall with rehearsal. Far-transfer to numeracy skills (addition).	✓	Witt (2011)	?	15	?	6 weeks
	Inhibition. Far-transfer - a reduction in inattention levels and negative reactions in games.	✓	Volckaert and Noël (2015)	?	15	?	6 weeks

[a] Caviola et al. (2009) reported gains on one of the four untrained WM skills they measured (backward Corsi task, VSEWLM) but there were no effects on the trained VSTM skill.

The optimum dosage required to produce training effects remains uncertain because dosage variables were often unreported or showed significant variation across studies. However, relatively short interventions of 5–6 weeks in total duration (albeit with different frequency of sessions) were shown to be effective (e.g., Henry et al., 2014; Thibodeau et al., 2016; Volckaert & Noël, 2015). There is still a great deal to learn about optimal levels of dosage for interventions in the area of child language and development (Justice, 2018). Clearly, this is an area requiring more detail and rigour in intervention studies to better inform our understanding of dosage and increase applicability of interventions to clinical contexts (Sugden, Baker, Munro, Williams, & Trivette, 2018).

Limitations

Several methodological factors may limit confidence in the findings of this review, including the risk of bias in individual studies due to the frequent lack of control of confounding variables, small samples sizes and an absence of blinding of participant and outcome assessors. Only two of the included studies incorporated active control groups in their design. This highlights a significant weakness that has also impacted on empirical research into computerised WM training (Melby-Lervåg & Hulme, 2013). The lack of an active control group means that training effects could be attributed to other variables that differ between experimental and passive control groups (Redick et al., 2015).

The absence of a clear theoretical framework in many of the included studies has limited the evidence found in this review. The lack of a sound theoretical underpinning leads to ambiguous predictions and unclear conclusions about training effects, which then impact on outcome measurement. The distinction between STM and ELWM tasks is widely accepted across both componential and attentional models of WM (Baddeley & Hitch, 1974; Baddeley, 2000; Cowan, 2005). However, in many studies the trained tasks and outcomes measured were not clearly defined. For example, none of the physical activity studies measured VSELWM which, given Baddeley (2000, 2007) hypothesis that kinaesthetic memory is managed within the visuospatial sketchpad, may also be expected to show associations with motor planning. Unspecified causal pathways also resulted in near-transfer effects being measured inadvertently or, in many cases, not measured at all. The lack of recognition of near-transfer effects subsequently impacts on conclusions about far-transfer. It is difficult to attribute far-transfer effects to interventions if near-transfer effects have not been demonstrated (Redick et al., 2015). Only one study explicitly recognised this (Henry et al., 2014), with three others measuring far-transfer effects without measuring near-transfer (Banales et al., 2015; Cornoldi et al., 2015; Passolunghi & Costa, 2016).

The clinical diversity of the included interventions is both a limitation and a strength of this review. The heterogeneity of the interventions implemented and the study design (randomised and non-randomised) means that a meta-analysis was not appropriate in this review. This may have limited the strength of the evidence presented but synthesizing study effects in a meta-analysis would have produced misleading findings. The diverse nature of the interventions reviewed has enabled the identification of key ingredients, notably training ELWM, as well as developing recommendations that can help inform novel methodologies (Reeves et al., 2008) and significantly enhance thinking to support the third wave of WM research (Morra & Borella, 2015).

Future directions

From both theoretical and applied perspectives, many questions about the utility of WM training approaches remain unanswered. We must therefore consider whether it is overly optimistic to continue developing and testing diverse, WM intervention approaches with the aim of impacting on real world skills, and indeed whether this is a worthy goal for applied research. This review provides suggestive evidence for the effectiveness of diverse WM interventions applied within children's everyday context, when the trained tasks are executive-loaded. Evidence has emerged of what might be possible and there are several advantages to the types of interventions reviewed here in comparison to computerised WM training. These include: greater flexibility in how the tasks are presented; less of a requirement for young children to sit still for long periods of time; and opportunities to promote social and emotional development in activities embedded within the child's own environment (Diamond & Lee, 2011) (which may be appealing to education practitioners). It has also been speculated that young children may not be motivated by this approach (Jaeggi et al., 2012; Wass et al., 2012).

The considerable challenges of conducting further research in applied settings must also be acknowledged. Although computerised WM training lacks the ecological validity of WM interventions provided within the child's everyday context, it allows for tighter control over both the training environment and paradigms. The manipulation of WM loads on a trial-by-trial basis may be important for improving WM (Klingberg, 2010), and this is easier with computerised programmes. Ensuring that children are working at capacity is much harder to achieve in real-life contexts, particularly when working with groups. Conversely, there is some evidence to suggest that the incremental increases automatically prescribed during computerised training can be too great, thereby lessening children's motivation (Jaeggi, Buschkuehl, Jonides, & Shah, 2011). Controlling the level of distraction in the environment is also difficult in non-laboratory training environments. However, the occurrence of distraction alongside training may indeed enhance its ecological validity and support transfer effects (De Simoni & von Bastian, 2018). Of course, it may eventually be possible to develop a hybrid intervention approach that integrates the benefits of computerised training in everyday contexts. There may be potential for the utilisation of technology to monitor children's responses and continually adapt the difficulty level of training trials delivered face-to-face. For example, education professionals could deliver practice trials on ELWM tasks in schools and record responses on a portable device (laptop or tablet) with software informing the facilitator about levels of difficulty.

The strength of evidence found in this review is compromised by inter-related theoretical and methodological issues, a lack of clear empirical evidence does not necessarily equate to ineffectiveness and says nothing about the potential for future interventions (Shipstead et al., 2012). In future research, there needs to be greater recognition that all interventions are based on causal assumptions (Moore & Evans, 2017). Future studies need to present a clear theoretical account of how and why the intervention should impact WM in hypothesis-driven research. It will be important also to apply greater rigour in study methodology, including the use of active control groups and randomised controlled designs. In order to develop a greater understanding of the relationship between intervention ingredients, WM outcomes and real world skills, outcome measurement must be comprehensive. Greater attention must also be paid to intervention dosage. There is a need to look more closely within interventions, to distil them and identify exactly which ingredients and dosages act as optimal mechanisms of change. This will require replicating specific tasks or subgroups of tasks embedded in successful interventions and varying the doses delivered in treatment sessions, frequency of intervention sessions, and overall duration of intervention in comparative studies (Warren et al., 2007).

Clarifying for whom non-computerized WM interventions may be most effective, and in what circumstances, should be a goal of further research. Future studies should target children from understudied sub-groups such as those with identified WM difficulties, neurodevelopmental difficulties or at-risk groups such as those from low-socioeconomic backgrounds. Greater consideration should be given to the role of individual differences that could influence the effectiveness of interventions e.g., cognitive level, motivation (Melby-Lervåg et al., 2016). It may also be pertinent to consider the context in which the intervention is implemented such as the influence of the child's environment (Hawe, 2015; McLeroy, Bibeau, Steckler, & Glanz, 1988).

Conclusions

Diverse interventions applied within young children's everyday contexts, have produced improvements on their WM skills and have the potential to produce near- and far-transfer effects. Both direct training on WM tasks and practicing certain skills that may indirectly impact on WM (physical activity, fantastical play and inhibition) were beneficial. The common ingredient across effective interventions was the executive-loaded nature of the trained task i.e., training on a task that taps into attentional and processing resources under executive control not just the storage of information. The strength of the evidence is tempered by a lack of clear theoretical underpinnings, rigorous methodology and consideration of dosage. Further well-designed and controlled studies with sound theoretical underpinnings and comprehensive outcome measurement, comparing carefully-considered dosages, are required to expand and enhance the evidence base.

Funding

This systematic review was undertaken as part of a doctoral research study funded by the Research and Development Division of the Public Health Agency, Northern Ireland. The funder has not been involved at any stage of the review process. The authors alone have been responsible for the design, conduct of the review, analysis and interpretation of the findings, writing of the report and the decision to submit this article for publication. Open access was paid for by the Medical Research Council of the United Kingdom, grant code RG91365.

Declaration of interest

None.

Appendix A. Dosage implemented in included studies following Warren et al. (2007)

Non-computerised WM intervention approach	Paper	Rationale provided for dosage	Dosage				Do study authors reflect on dosage in their discussion?
			Dose	Dose frequency		Total intervention duration	
				Session duration (mins)	Session frequency (times per week)		
Adapting environment	Elliott et al. (2010)	No	No details provided to quantify amount of teacher training provided. Specifying dosage for the children in this study is not applicable due to the nature of the intervention			8–11 months	No
Direct WM without strategy training	Banales et al. (2015)	No	?	30	3	8 weeks	They question if the amount of training was sufficient but do not comment on the impact of the intervention being delivered via Skype
	Henry et al. (2014)	Yes. Number of sessions chosen to conform to computerised training studies	22 trials (11 of each task)	10	3	6 weeks	Yes. They suggest the brevity of each session supported children's compliance, enjoyment and motivation and contributed to effectiveness of the intervention
	Passolunghi and Costa (2016)		?	60	2	5 weeks	No

Direct WM training with strategy training	Caviola et al. (2009)	No	?	40 (plus 10 min discussion)	2	4 weeks (7 sessions)	No
	Comblain (1994)	Yes. Inspired by methodology in a previous study	?	30	1	8 weeks	No
	Cornoldi et al. (2015)	No	?	60	1	8 weeks	No
	Peng and Fuchs (2015)	No	?	35	1 per day	10 consecutive days	Yes. They question if the amount of training was sufficient
	Witt (2011)	No	?	15	?	6 weeks	No
Training skills which may indirectly impact on WM: phonological awareness	Melby-Lervåg and Hulme (2010)	No	?	7	1	10 consecutive days (Mon- Fri for 2 school weeks)	No
	Van Kleeck et al. (2006) Dosage data extracted from intervention study (Van Kleeck et al. (1998))	No.	?	15	2	12 weeks each of rhyme & phoneme awareness training (24 weeks total)	The authors suggest the brevity of the brevity of the intervention sessions make it attractive and replicable. No discussion on the effectiveness of the dosage provided
Training skills that may indirectly impact on WM: physical activity	Alesi et al. (2016)	No	?	75	2	6 months	No
	Davis et al. (2007)	Yes. Inspired by methodology in a previous study	?	Low dose – 20 High dose – 40	5	15	Yes. They suggest that the total intervention duration may have been too short and reported that the high dose condition was more effective
	Kamijo et al. (2011)	No	?	120	1	150 days (9 months)	No
	Koutsandréou et al. (2016)	No	?	45	3	10 weeks	No
	Van der Niet et al. (2016)	No	?	30	2	22 weeks	Yes. Authors suggest that lack of effect on physical fitness may be related to the frequency or intensity of the intervention
Training skills that may indirectly impact on WM: play	Thibodeau et al. (2016)	Yes. Number of sessions chosen to conform to computerised training studies	?	15	5	5 weeks	No
Training skills that may indirectly impact on WM: inhibition	Volckaert and Noël (2015)		?	45	2	8 weeks	Yes. The authors reported moderate effect sizes and suggest that more than 16 sessions may be required to obtain larger effects

Note: Cumulative intervention intensity (dose × dose frequency × total intervention duration) was omitted from this table as it was only calculable for one study (Henry et al., 2014) which provided the number of trials per session (dose). Cumulative intensity for Henry et al. (2014) = 396 (22 × 3 × 6).

Appendix B. Summary risk of bias table for primary outcomes across all studies

Study author and year	Random sequence generation (RCTs)/Allocation	Allocation concealment	Blinding of participants an personnel	Blinding of outcome assessment	Incomplete outcome data – trained WM	Selective reporting
Elliott et al. (2010)	High	Unclear	High	Unclear	Unclear	Unclear
Banales et al. (2015)	High	Unclear	Low	High	Low	Unclear
Henry et al. (2014)	Unclear	Unclear	Low	Low	Low	Low
Passolunghi and Costa (2016)	Unclear	Unclear	Low	Low	Low	Unclear
Caviola et al. (2009)	High	Unclear	Low	Low	Unclear	High
Comblain (1994)	High	Unclear	Unclear	High	Unclear	Unclear
Cornoldi et al. (2015)	High	Unclear	High	Unclear	Low	Unclear
Peng and Fuchs (2015)	Unclear	Unclear	Unclear	Low	High	Unclear
Witt (2011)	High	Unclear	High	Unclear	Unclear	Unclear
Melby-Lervåg and Hulme (2010)	High	Unclear	Unclear	Unclear	High	Unclear
Van Kleeck et al. (2006)	High	Unclear	Unclear	Unclear	High	High
Alesi et al. (2016)	High	Unclear	Unclear	Unclear	Low	Unclear
Davis et al. (2007)	Unclear	Unclear	Unclear	Low	Low	Unclear
Kamijo et al. (2011)	Unclear	Unclear	Unclear	Unclear	High	Unclear

Koutsandréou et al. (2016)	Unclear	Unclear	Unclear	Low	Unclear	Unclear
Van der Niet et al. (2016)	High	Unclear	Unclear	Low	Low	Unclear
Thibodeau et al. (2016)	Unclear	Unclear	Low	Low	Unclear	Unclear
Volckaert and Noël (2015)	High	Unclear	Unclear	Low	N/A	Unclear

Appendix C. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dr.2019.02.001.

References

Alesi, M., Bianco, G. L., Palma, A., & Pepi, A. (2016). Improving children's coordinative skills and executive functions: The effects of a football exercise program. *Perceptual and Motor Skills, 122*(1), 27–46. https://doi.org/10.1177/0031512515627527.

Allen, R. J., Hitch, G. J., & Baddeley, A. D. (2009). Cross-modal binding and working memory. *Visual Cognition, 17*(1–2), 83–102. https://doi.org/10.1080/13506280802281386.

Alloway, R. G., & Alloway, T. P. (2015a). *Understanding working memory* (2nd ed.). Los Angeles: Sage.

Alloway, R. G., & Alloway, T. P. (2015b). The working memory benefits of proprioceptively demanding training: A pilot study. *Perceptual and Motor Skills, 120*, 766–775. https://doi.org/10.2466/22.PMS.120v18x1.

Alloway, T. P., & Archibald, L. M. (2008). Working memory and learning in children with Developmental Coordination Disorder and Specific Language Impairment. *Journal of Learning Disabilities, 41*, 251–262. https://doi.org/10.1177/0022219409335214.

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The cognitive and behavioural characteristics of children with low working memory. *Child Development, 80*(2), 606–621. https://doi.org/10.1111/j.1467-8624.2009.01282.x.

Archibald, L. M. D. (2017). Working memory and language learning: A review. *Child Language Teaching and Therapy, 33*(1), 5–17. https://doi.org/10.1177/026565901665420.

Archibald, L. M., & Gathercole, S. E. (2007). Nonword repetition in specific language impairment: More than a phonological short-term memory deficit. *Psychonomic Bulletin & Review, 14*, 919–924. https://doi.org/10.3758/BF03194122.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417–423. https://doi.org/10.1016/S1364-6613(00)01538-2.

Baddeley, A. (2007). *Oxford psychology series: Vol. 45. Working memory, thought, and action.* New York, NY, US: Oxford University Press.

Baddeley, A. D., Gathercole, S. E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*, 158–173. https://doi.org/10.1037/0033- 295X.105.1.158.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Vol. Ed.), *The psychology of learning and motivation: Vol. 8*. London: Academic Press.

Banales, E., Kohnen, S., & McArthur, G. (2015). Can verbal working memory training improve reading? *Cognitive Neuropsychology, 32*(3–4), 104–132. https://doi.org/10.1080/02643294.2015.1014331.

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin, 128*, 612–637. https://doi.org/10.1037/0033-2909.128.4.612.

Bishop, D. V. M., Snowling, M. J., Thompson, P. A., & Greenhalgh, T. The CATALISE Consortium. (2016). CATALISE: A multinational and multidisciplinary Delphi consensus study. Identifying language impairments in children. *PLOS One, 11*(7), https://doi.org/10.1371/journal.pone.0158753.

Bjorkland, D. F., & Douglas, R. N. (1997). The development of memory strategies. In N. Cowan, & C. Hulme (Eds.). *The development of memory in childhood.* Sussex: Psychology Press.

Booth, A., & Fry-Smith, A. (2004). *Developing a research question. systematic reviews in the social sciences.* Oxford: Blackwell.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis.* West Sussex, UK: John Wiley and sons Ltd.

Broadbent, D. E. (1975). The magic number seven after fifteen years. In A. Kennedy, & A. Wilkes (Eds.). *Studies in long-term memory*. Oxford, England: Wiley.

Bunting, M. F., & Cowan, N. (2005). Working memory and flexibility in awareness and attention. *Psychological Research, 69*, 412–419. https://doi.org/10.1007/s00426-004-0204-7.

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., & Munafò, M. R. (2013). Power failure: Why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience, 14*, 365–376. https://doi.org/10.1038/nrn3475.

Caviola, S., Mammarella, I. C., Cornoldi, C., & Lucangeli, D. (2009). A meta-cognitive visuospatial working memory training for children. *International Electronic Journal of Elementary Education, 2*(1), 122–136. https://www.iejee.com/index.php/IEJEE/article/view/261.

Cogmed (2005). *Cogmed working memory training.* Pearson Assessment.

Comblain, A. (1994). Working memory in Down's syndrome: Training the rehearsal strategy. *Down's Syndrome Research and Practice, 2*(3), 123–126. https://doi.org/10.3104/reports.42.

Cornoldi, C., Carretti, B., Drusi, S., & Tencati, C. (2015). Improving problem solving in primary school students: The effect of a training programme focusing on meta-cognition and working memory. *British Journal of Educational Psychology, 85*, 424–439. https://doi.org/10.1111/bjep.12083.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behav. Brain Sci. 24*, 87–185 [PubMed: 11515286].

Cowan, N. (2005). *Working memory capacity.* New York: Psychology Press.

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Prog Brain Res. 169*, 323–338. https://doi.org/10.1016/S0079-6123(07)00020-9.

Cowan, N., Fristoe, N. M., Elliott, E. M., Brunner, R. P., & Saults, J. S. (2006). Scope of attention, control of attention and intelligence in children and adults. *Memory and Cognition, 34*(8), 1754–1768. https://doi.org/10.3758/BF03195936.

Cragg, L., Richardson, S., Hubber, P. J., Keeble, S., & Gilmore, C. (2017). When is working memory important for arithmetic? The impact of domain, strategy and age. *PLOS ONE, 12*(12), e0188693. https://doi.org/10.1371/journal.pone.0188693.

Danielsson, H., Zottarell, V., Palmqvist, L., & Lanfranchi, I. (2015). The effectiveness of working memory training with individuals with intellectual disabilities–a meta-analytic review. *Frontiers in Psychology, Developmental Psychology, 6*, 1230. https://doi.org/10.3389/fpsyg.2015.01230.

Davis, C. L., Tomporowski, P. D., Boyle, C. A., Waller, J. L., Miller, P. H., Naglieri, J. A., & Gregoski, M. (2007). Effects of aerobic exercise on overweight children's cognitive functioning: A randomized controlled trial. *Research Quarterly for Exercise and Sport, 78*(5), 510–519. https://doi.org/10.1080/02701367.2007.10599450.

De Simoni, C., & von Bastian, C. C. (2018). Working memory updating and binding training: Bayesian evidence supporting the absence of transfer. *Journal of Experimental Psychology: General, 147*(6), 829–858. https://doi.org/10.1037/xge0000453.

Deeks, J. J., Higgins, J. P. T., & Altman, D. G. (2008). Chapter 9: Analysing data and undertaking meta-analyses. In J. P. T. Higgins, & S. Green (Eds.). *Cochrane*

handbook for systematic reviews of interventions. Chichester, UK: John Wiley & Sons.
Des Jalais, D. C., Lyles, C., & Crepaz, N. the TREND Group. (2004). Improving the reporting quality of nonrandomized evaluations of behavioural and public health interventions. *American Journal of Public Health, 94*(3), 361–366. https://doi.org/10.2105/AJPH.94.3.361.
Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science, 21*(5), 335–341. https://doi.org/10.1177/0963721412453722.
Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959–964 https://www.ncbi.nlm.nih.gov/pubmed/21852486.
Dunning, D., & Holmes, J. (2014). Does working memory training promote the use of strategies on untrained working memory tasks? *Memory and Cognition, 2*, 854–862. https://doi.org/10.3758/s13421-014-0410-5.
Dunning, D., Holmes, J., & Gathercole, S. E. (2013). Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial. *Developmental Science, 16*(6), 915–925. https://doi.org/10.1111/desc.12068.
Elliott, J. G., Gathercole, S. E., Alloway, T. P., Holmes, J., & Kirkwood, H. (2010). An evaluation of a classroom-based intervention to help overcome working memory difficulties and improve long-term academic achievement. *Journal of Cognitive Education and Psychology, 9*(3), 227–250. https://doi.org/10.1891/1945-8959.9.3.227.
Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19–23. https://doi.org/10.1111/1467-8721.00160.
Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual differences in working memory for comprehension and following directions. *Journal of Educational Research, 84*, 253–262. https://doi.org/10.1080/00220671.1991.10886025.
Ericsson, K. A., & Chase, W. G. (1982). Exceptional memory: Extraordinary feats of memory can be matched or surpassed by people with average memories that have been improved by training. *American Scientist, 70*(6), 607–615. http://www.jstor.org/stable/27851732.
Fletcher, A., Jamal, F., Moore, G., Evans, R. E., Murphy, S., & Bonell, C. (2016). Complex intervention science: Applying realist principles across all phases of the Medical Research Council framework for developing and evaluating complex interventions. *Evaluation, 22*(3), 286–303. https://doi.org/10.1177/1356389016652743.
Gathercole, S. E. (1998). The development of memory. *Journal of Child Psychology and Psychiatry, 39*, 3–27. https://doi.org/10.1017/S0021963097001753.
Gathercole, S. E., Alloway, T. P., Willis, C. S., & Adams, A. M. (2006). Working memory in children with reading disabilities. *Journal of Experimental Child Psychology, 93*, 265–281. https://doi.org/10.1016/j.jecp.2005.08.003.
Gathercole, S. E., & Baddeley, A. D. (1993). Phonological working memory: A critical building block for reading development and vocabulary acquisition. *European Journal of Psychology and Education, 8*, 259. https://doi.org/10.1007/BF03174081.
Gathercole, S. E., Dunning, D. L., Holmes, J., & Norris, D. (2019). Working memory training involves learning new skills. *Journal of Memory and Language, 105*, 19–42. https://doi.org/10.1016/j.jml.2018.10.003.
Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *The British Journal of Educational Psychology, 70*(2), 177–194. https://doi.org/10.1348/000709900158047.
Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology, 40*, 177–190. https://doi.org/10.1037/0012-1649.40.2.177.
Gathercole, S. E., Woolgar, F., Kievit, R. A., Astle, D., Manly, T., & Holmes, J. (2016). How common are WM deficits in children with difficulties in reading and mathematics? *Journal of Applied Research in Memory and Cognition, 5*, 384–394. https://doi.org/10.1016/j.jarmac.2016.07.013.
Geary, D. C., Hoard, M. K., Byrd-Craven, J., & DeSoto, M. C. (2004). Strategy choices in simple and complex addition: Contributions of working memory and counting knowledge for children with mathematical disability. *Journal of Experimental Child Psychology, 88*, 121–151. https://doi.org/10.1016/j.jecp.2004.03.002.
Gough, D., Thomas, J., & Oliver, S. (2012). Clarifying differences between review designs and methods. *Systematic Reviews, 1*(1), https://doi.org/10.1186/2046-4053-1-28.
GRADE working group (2004). Grading quality of evidence and strength of recommendations. *British Medical Journal, 328*(1490), https://doi.org/10.1136/bmj.328.7454.1490.
Guye, S., & von Bastian, C. C. (2017). Working memory training in older adults: Bayesian evidence supporting the absence of transfer. *Psychology and Aging, 32*(8), 732–746. https://doi.org/10.1037/pag0000206.
Halperin, J. M., Marks, D. J., Bedard, A. C., Chacko, A., Curchack, J. T., & Yoon, C. A. (2015). Training executive, attention, and motor skills: A proof-of- concept study in preschool children with ADHD. *Journal of Attention Disorders, 17*(8), 711–721. https://doi.org/10.1177/1087054711435681.
Hart, T., Tsaousides, T., Zanca, J. M., Whyte, J., Packel, A., Ferraro, M., & Dijkers, M. P. (2014). Toward a theory-driven classification of rehabilitation treatments. *Archives of Physical and Medical Rehabilitation, 95*(1 Suppl. 1), S33–S44. https://doi.org/10.1016/j.apmr.2013.05.032.
Hawe, P. (2015). Lessons from complex interventions to improve health. *Annual Review of Public Health, 36*, 307–323. https://doi.org/10.1146/annurev-publhealth-031912-114421.
Henry, L. (2012). *The development of working memory in children.* London: SAGE.
Henry, L., & Botting, N. (2017). Working memory and developmental language impairments. *Child Language Teaching and Therapy, 33*(1), 19–32. https://doi.org/10.1177/0265659016655378.
Henry, L. A., Messer, D. J., & Nash, G. (2014). Testing for near and far transfer effects with a short, face-to-face adaptive working memory training intervention in typical children. *Infant and Child Development, 23*(1), 84–103. https://doi.org/10.1002/icd.
Higgins, J. P. T., & Altman, D. G. (2008). Assessing risk of bias in included studies. In J. P. T. Higgins, & S. Green (Eds.). *Cochrane handbook for systematic reviews of interventions*. Chichester, UK: John Wiley & Sons.
Hoffman, J. I. E. (2015). *Biostatistics for medical and biomedical practitioners.* Cambridge, MA: Academic Press. https://doi.org/10.1016/B978-0-12-802387-7.00036-6.
Hoffmann, T. C., Glasziou, P. P., Broutron, I., Milne, R., Perera, R., Moher, D., ... Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *British Medical Journal, 348*(g1687), https://doi.org/10.1136/bmj.g1687.
Holmes, J., & Adams, J. (2006). Working Memory and Children's Mathematical Skills: Implications for mathematical development and mathematics curricula. *Educational Psychology, 26*(3), 339–366. https://doi.org/10.1080/01443410500341056.
Holmes, J., Butterfield, S., Cormack, F., Loenhoud, A. V., Ruggero, L., Kashikar, L., & Gathercole, S. (2015). Improving working memory in children with low language abilities. *Frontiers in Psychology, 6*, 519. https://doi.org/10.3389/fpsyg.2015.00519.
Jaeggi, S. M., & Buschkuehl, M. (2014). Working memory training and transfer: Theoretical and practical considerations. In B. Toni (Vol. Ed.), *New frontiers of multidisciplinary research in STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health). Springer proceedings in mathematics & health: Vol. 90*. Cham: Springer.
Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Shah, P. (2011). Short- and long-term benefits of cognitive training. *Proceedings of the National Academy of Sciences, USA, 108*, 10081–10086.
Jaeggi, S. M., Buschkuel, M., Jonides, J., & Shah, P. (2012). Cogmed and working memory training-Current challenges and the search for underlying mechanisms. *Journal of Applied Research in Memory and Cognition, 1*(3), 185–193. https://doi.org/10.1016/j.jarmac.2012.06.003.
Janneke, C. A. W., Peijnenborgh, J. C. A. W., Hurks, P. M., Aldenkamp, A. P., Vles, J. S. H., & Hendriksen, J. G. M. (2016). Efficacy of working memory training in children and adolescents with learning disabilities: A review study and meta-analysis. *Neuropsychological Rehabilitation, 26*(5–6), 645–672. https://doi.org/10.1080/09602011.2015.1026356.
Jaroslawska, A. J., Gathercole, S. E., Allen, R. J., & Holmes, J. (2016). Following instructions from working memory: Why does action at encoding and recall help? *Memory and Cognition, 44*, 1183–1191. https://doi.org/10.3758/s13421-016-0636-5.
Jaroslawska, A. J., Gathercole, S. E., Logie, M. R., & Holmes, J. (2016). Following instructions in a virtual school: Does working memory play a role? *Memory and Cognition, 44*, 580–589. https://doi.org/10.3758/s13421-015-0579-2.
Jeffries, S. A., & Everatt, J. E. (2003). Differences between dyspraxics and dyslexics in sequence learning and working memory. *Dyspraxia Foundation Professional*

Journal, 2, 12–21.
Jeffries, S., & Everatt, J. (2004). Working memory: Its role in dyslexia and other specific learning difficulties. *Dyslexia, 10*, 196–214. https://doi.org/10.1002/dys.278.
Justice, L. M. (2018). Conceptualising "dose" in paediatric language interventions: Current findings and future directions. *International Journal of Speech-Language Pathology, 20*(3), 318–323. https://doi.org/10.1080/17549507.2018.1454985.
Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science, 14*(5), 1046–1058. https://doi.org/10.1111/j.1467-7687.2011.01054.x.
Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences, 14*, 317–324 https://www.ncbi.nlm.nih.gov/pubmed/30719000.
Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology, 24*, 781–791. https://doi.org/10.1076/jcen.24.6.781.8395.
Koutsandréou, F., Wegner, M., Niemann, C., & Budde, H. (2016). Effects of motor versus cardiovascular exercise training on children's working memory. *Medicine & Science in Sports & Exercise, 48*(6), 1144–1152. https://doi.org/10.1249/MSS.0000000000000869.
Kudo, M. F., Lussier, C. M., & Swanson, H. L. (2015). Reading disabilities in children: A selective meta-analysis of the cognitive literature. *Research in Developmental Disabilities, 40*, 51–62. https://doi.org/10.1016/j.ridd.2015.01.002.
Leonard, H. C., Bernardi, M., Hill, E. L., & Henry, L. A. (2015). Executive functioning, motor difficulties, and developmental coordination disorder. *Developmental Neuropsychology, 40*(4), 201–215. https://doi.org/10.1080/87565641.2014.997933.
McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education and Behaviour, 15*, 351–377. https://doi.org/10.1177/109019818801500401.
Melby-Lervåg, M., & Hulme, C. (2010). Serial and free recall in children can be improved by training: Evidence for the importance of phonological and semantic representations in immediate memory. *Psychological Science, 21*(11), 1694–1700. https://doi.org/10.1177/0956797610385355.
Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology, 49*(2), 270–291. https://doi.org/10.1037/a0028228.
Melby-Lervåg, M., Redick, T. S., & Hulme, C. (2016). Working memory Training does not improve performance on measures of intelligence or other measures of "far transfer": Evidence from a meta-analytic review. *Perspectives on Psychological Science, 11*(4), 512–534. https://doi.org/10.1177/1745691616635612.
Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*, 81–97 [PubMed: 13310704].
Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7), e1000097. https://doi.org/10.1371/journal.pmed1000097.
Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., ... Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews, 4*(1), 1. https://doi.org/10.1186/2046-4053-4-1.
Moore, G., & Evans, R. (2017). What theory, for whom and in which context? Reflections on the application of theory in the development and evaluation of complex population health interventions. *SSM Population Health, 3*, 132–135. https://doi.org/10.1016/j.ssmph.2016.12.005.
Morra, S., & Borella, E. (2015). Working memory training: From metaphors to models. *Frontiers in Psychology, 6*, 1097.
Morrison, A., & Chein, J. (2012). The controversy over Cogmed. *Journal of Applied Research in Memory and Cognition, 1*, 208–210. https://doi.org/10.1016/j.jarmac.2012.07.005.
Noack, H., Lövdén, M., Schmiedek, F., & Linderberger, U. (2009). Cognitive plasticity in adulthood and old age: Gauging the generality of cognitive intervention effects. *Restorative Neurology and Neuroscience, 27*, 435–453. https://doi.org/10.3233/RNN-2009-0496.
Otero, T. M., Barker, L. A., & Naglieri, J. A. (2014). Executive function treatment and intervention in schools. *Applied Neuropsychology: Child, 3*, 205–214. https://doi.org/10.1080/21622965.2014.897903.
Ottem, E., Lian, A., & Karlsen, P. (2007). Reasons for the growth of traditional memory span across age. *European Journal of Cognitive Psychology, 19*, 233–270. https://doi.org/10.1080/09541440600684653.
Passolunghi, M. C., & Costa, H. M. (2016). Working memory and early numeracy training in preschool children. *Child Neuropsychology, 22*(1), 81–98. https://doi.org/10.1080/09297049.2014.971726.
Pawson, R. (2006). *Evidence-based policy: A realist perspective.* London: SAGE.
Pawson, R., & Tilly, N. (1997). *Reaslistic evaluation.* London: SAGE.
Peng, P., & Fuchs, D. (2015). A Randomized control trial of working memory training with and without strategy instruction: Effects on young children's working memory and Comprehension. *Journal of Learning Disabilities, 50*(1), 62–80. https://doi.org/10.1177/0022219415594609.
Petticrew, M. (2015). Time to rethink the systematic review catechism? Moving from 'what works' to 'what happens'. *Systematic Reviews, 4*(1), https://doi.org/10.1186/s13643-015-0027-1.
Redick, T. S., Shipstead, Z., Wiemers, E. A., Melby-Lervåg, M., & Hulme, C. (2015). What's working in working memory training? An educational perspective. *Educational Psychology Review, 27*, 617–633. https://doi.org/10.1007/s10648-015-9314-6.
Reeves, B. C., Deeks, J. J., Higgins, J. P. T., & Wells, G. A. (2008). Chapter 13: Including non-randomized studies. In J. P. T. Higgins, & S. Green (Eds.). *Cochrane handbook for systematic reviews of interventions*. Chichester (UK): John Wiley & Sons.
Sala, G., & Gobet, F. (2017). Working memory training in typically developing children: A meta-analysis of the available evidence. *Developmental Psychology, 53*(4), 671–685. https://doi.org/10.1037/dev0000265.
Schulz, K. F., Altman, D. G., & Moher, D. for the CONSORT Group. (2010). CONSORT 2010 statement: Updated guidelines for reporting parallel group randomized trials. *Annals of Internal Medicine, 152*, 726–732. https://doi.org/10.7236/0003-4819-152-11-201006010-00232.
Schwaighofer, M., Fischer, F., & Bühner, M. (2015). Does working memory training transfer? A meta-analysis including training conditions as moderators. *Educational Psychologist, 50*(2), 138–166. https://doi.org/10.1080/00461520.2015.1036274.
Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., & Shekelle, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *British Medical Journal, 349*, 7647. https://doi.org/10.1136/bmj.g7647.
Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Working memory training remains a work in progress. *Journal of Applied Research in Memory and Cognition, 1*, 217–219. https://doi.org/10.1016/j.jarmac.2012.06.006.
Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., & Stine-Morrow, E. A. L. (2016). Do "Brain-Training" programs work? *Psychological Science in the Public Interest, 17*(3), 103–186. https://doi.org/10.1177/1529100616661983.
Soveri, A., Antfolk, J., Karlsson, L., Salo, B., & Laine, M. (2017). Working memory training revisited: A multi-level meta-analysis of n-back train-ing studies. *Psychonomic Bulletin & Review, 24*, 1077–1096. https://doi.org/10.3758/s13423-016-1217-0.
Sprenger, A. M., Atkins, S. M., Bolger, D. J., Harbison, J. I., Novick, J. M., Chrabaszcz, J. S., ... Dougherty, M. R. (2013). Training working memory: Limits of transfer. *Intelligence, 41*, 638–663. https://doi.org/10.1016/j.intell.2013.07.013.
St. Clair-Thompson, H. L., & Holmes, J. (2008). Improving short-term and working memory: Methods of memory training. In N. B. Johansen (Ed.). *New research on short-term memory*. New York: Nova Science.
St. Clair-Thompson, H. L., Stevens, R., Hunt, A., & Bolder, E. (2010). Improving children's working memory and classroom performance. *Educational Psychology, 30*, 203–220. https://doi.org/10.1080/01443410903509259.
Sugden, E., Baker, E., Munro, N., Williams, A. L., & Trivette, C. M. (2018). Service delivery and intervention intensity for phonology-based speech sound disorders. *International Journal of Language and Communication Disorders, 53*(4), 718–734.
Swanson, H. L. (1994). Short-term memory and working memory: Do both contribute to our understanding of academic achievement in children and adults with learning disabilities? *Journal of Learning Disabilities, 27*(1), 34–50. https://doi.org/10.1177/002221949402700107.
Swanson, H. L. (2003). Age-related differences in learning disabled and skilled readers' working memory. *Journal of Experimental Child Psychology, 85*, 1–31. https://doi.org/10.1016/S0022-0965(03)00043-2.
Swanson, H. L. (2017). Verbal and visual-spatial working memory: What develops over a life span? *Developmental Psychology, 53*(5), 971–995. https://doi.org/10.

1037/dev0000291.

Swanson, H. L., Jerman, O., & Zheng, X. (2008). Growth in working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology, 100*, 343–379. https://doi.org/10.1037/0022-0663.100.2.343.

Swanson, H. L., Xinhua, Z., & Jerman, O. (2009). Working memory, short-term memory, and reading disabilities: A selective meta- analysis of the literature. *Journal of Learning Disabilities, 42*(3), 260–287. https://doi.org/10.1177/0022219409331958.

Szucs, D., Devine, A., Soltesz, F., Nobes, A., & Gabriel, F. (2013). Developmental dyscalculia is related to visuo-spatial memory and inhibition impairment. *Cortex, 49*(10), 2674–2688. https://doi.org/10.1016/j.cortex.2013.06.007.

Thibodeau, R. B., Gilpin, A. T., Brown, M. M., & Meyer, B. A. (2016). The effects of fantastical pretend-play on the development of executive functions: An intervention study. *Journal of Experimental Child Psychology, 145*, 120–138. https://doi.org/10.1016/j.jecp.2016.01.001.

Van der Niet, A. G., Smith, J., Oosterlaan, J., & Scherder, E. J. A. (2016). Effects of a cognitively demanding aerobic intervention during recess on children's physical fitness and executive functioning. *Pediatric Exercise Science, 28*, 64–70. https://doi.org/10.1123/pes.2015-0084.

Van Kleeck, A., Gillam, R. B., & Hoffman, L. M. (2006). Training in phonological awareness generalizes to phonological working memory: A preliminary investigation. *The Journal of Speech and Language Pathology – Applied Behavior Analysis, 1*(3), 228–243.

Van Kleeck, A., Gillam, R. B., & McFadden, T. U. (1998). A study of classroom-based phonological awareness training for pre-schoolers with speech and/or language disorders. *American Journal of Speech-Language Pathology, 7*, 65–76. https://doi.org/10.1044/1058-0360.0703.65.

Volckaert, A. M. S., & Noël, M. (2015). Training executive function in preschoolers reduce externalizing behaviors. *Trends in Neuroscience and Education, 4*, 37–47. https://doi.org/10.1016/j.tine.2015.02.001.

Von Bastian, C. C., & Oberauer, K. (2014). Effects and mechanisms of working memory training: A review. *Psychological Research, 78*, 803–820. https://doi.org/10.1007/s00426-013-0524-6.

Warren, S. F., Fey, M. E., & Yoder, P. J. (2007). Differential treatment intensity research: A missing link to creating optimally effective communication interventions. *Mental Retardation and Developmental Disabilities Research Reviews, 13*, 70–77. https://doi.org/10.1002/mrdd.20139.

Wass, S. V., Scerif, G., & Johnston, M. H. (2012). Training attentional control and working memory- is younger better? *Developmental Review, 32*, 360–387. https://doi.org/10.1016/j.dr.2012.07.001.

Weiland, C., Barata, M. C., & Yoshikawa, H. (2014). The co-occurring development of executive function skills and receptive vocabulary in preschool-aged children: A look at the direction of developmental pathways. *Infant and Child Development, 23*, 4–21. https://doi.org/10.1002/icd.1829.

Witt, M. (2011). School based working memory training: Preliminary finding of improvement in children's mathematical performance. *Advances in Cognitive Psychology, 7*(1), 7–15. https://doi.org/10.2478/v10053-008-0083-3.

Wong, G., Greenhalgh, T., Westhorp, G., & Pawson, R. (2014). Development of methodological guidance, publication standards and training materials for realist and meta-narrative reviews: The RAMESES (Realist and Meta-narrative Evidence Syntheses – Evolving Standards) project. *Health Services and Delivery Research, 2*(30), https://doi.org/10.3310/hsdr02300.

Worthen, E. (2010). Sensory- based interventions in the general educational classroom: A critical appraisal of the topic. *Journal of Occupational Therapy, Schools and Early Intervention, 3*(1), 76–79. https://doi.org/10.1080/19411241003684217.

4.3 Summary of implications for intervention development

Based on the findings of the systematic review, the following implications for the development and testing of the novel intervention were identified:

1. All of the trained tasks should be executive-loaded and may include: direct ELWM training; and training on tasks to impact on WM indirectly such as phoneme awareness training, cognitively-demanding physical activity, fantastical play, or activities targeting inhibitory control.
2. Two of the reviewed interventions that targeted WM indirectly via phoneme awareness training (van Kleeck *et al.* 1998, 2006) and fantastical play (Thibodeau *et al.* 2016), showed positive effects on verbal short-term memory (VSTM) (see Tables A and B1 in Appendix I). Therefore, by including these components, it may be possible to maximise the intervention's effects on functional language skills by harnessing the links between VSTM and language learning (e.g., Baddeley *et al.* 1998) (see Chapter 2).
3. The findings should be considered in the light of current theorising around training and transfer effects (discussed in Chapter 2). All of the potential intervention components should be scrutinised to ensure they have a sound theoretical underpinning regarding how and why they should improve WM and produce transfer effects to attention and language (Melby-Lervåg and Hulme 2013, Redick *et al.* 2015). This should be triangulated with the qualitative evidence regarding the contextual factors that may facilitate or impede their implementation in the classroom setting (Chapter 5). This approach is consistent with the realist paradigm, complexity theory and ecological perspective underpinning this doctoral study (Bhaskar 1997, Byrne 1998, McLeroy 1998).

4. In order to avoid the methodological issues that constrained the strength of the evidence in the studies included in the review, the feasibility trial should have an active control group that receives an intervention of comparable format and intensity to the experimental condition; and the blinding of participants and outcome assessors.

Chapter 5 - Qualitative Study

5.1 Introduction

Chapter 5 relates to step 2 of the Six Steps in Quality Intervention Development (6SQuID) model (Wight *et al.* 2016) that aims to clarify which *causal and contextual factors* are malleable. The systematic review (Chapter 4) examined the malleability of working memory (WM), which, due to its associations with attention (Bunting and Cowan 2005, Cowan *et al.* 2006) and language learning (Baddeley *et al.* 1998), is considered to be the *causal mechanism* within to be embedded in the novel intervention. The qualitative study presented in the current chapter explored the *contextual factors* that may impact on the intervention implementation. As outlined in Chapter 1, the context for the doctoral study is conceptualised as the complex interacting systems of the Regional Integrated Support for Education (RISE) teams and mainstream primary schools in Northern Ireland.

This chapter presents the findings of the qualitative study as a paper that has been submitted to the *Journal of Educational Psychology*. The next section includes the pdf. version of the submitted manuscript in its entirety, including the appendices referred to in the text (the focus group schedule and thematic maps). The paper is formatted according to the journal guidelines with regards to the font, margins, headings and referencing style and the inclusion of an 'Educational Impact and Implications' statement. Ethical approval for this study was granted by the Institute of Nursing and Health Research Ethics Filter Committee at Ulster University (see Appendix A at the end of this volume of the thesis). The chapter ends with a summary of the implications of the study findings for the development and testing of the to-be-developed intervention.

5.2 An exploration of health professionals' and teachers' knowledge, perceptions and practice in relation to working memory when delivering services to children in the classroom (Paper 2)

Author details and title

Rowe, A., Titterington, J. and Taggart, L. An exploration of health professionals' and teachers' knowledge, perceptions and practice in relation to working memory when delivering services to children in the classroom (submitted to the *Journal of Educational Psychology*).

PhD researcher's contribution to the paper

The PhD researcher was responsible for every aspect of conducting the study including: applying for ethical approval; recruiting participants; facilitating the focus groups and analysing the data. The PhD researcher derived the initial themes from the data that were checked subsequently through consultation with the co-authors (the supervisory team) as part of enhancing the trustworthiness of the work. The PhD researcher wrote the first draft of the manuscript, revised it based on the co-authors' feedback, submitted the paper to the journal and is the first and corresponding author.

An exploration of health professionals' and teachers' knowledge, perceptions and practice in relation to working memory when delivering services to children in the classroom

Abstract

Working memory (WM) is associated with attention, language, motor skills and academic achievement. It is important that health professionals (HPs) and teachers working with school-aged children in mainstream schools understand WM. This qualitative study explores HPs' and teachers' knowledge, perceptions and practice in relation to WM and how context influences decision-making when supporting school-aged children. It included: HPs (speech-language pathologists, occupational therapists, physical therapists and social, emotional and behavioral specialists) (*n*= 13) from teams providing services to schools in Northern Ireland; and teachers (n= 10) whom they support from schools in areas of social disadvantage. Data were collected using 5 focus groups and analyzed using thematic analysis. HPs and teachers had limited awareness of WM or the implications of low WM for children's learning. Eclectic practice is underpinned by lay theories including: a belief in a transdisciplinary model (interventions combining motor, sensory and language tasks); and a belief that children learn when tasks are functional and fun. HPs' and teachers' intervention approaches and dosage are based on contextual factors, especially the demands of the curriculum and the classroom environment. Children with low WM may go undetected and the potential to address this may be missed. The influence of lay theories and context means that classroom interventions may (or may not) work. The lay theories adopted by practitioners may be consistent with scientific theory/evidence but the lack of an explicit theoretical underpinning is a barrier to evidence-based practice. HPs and teachers require training on WM and the importance of dosage.

Educational Impact and Implications Statement

Working memory is the ability to hold and process information in mind. Children with weak working memory struggle to pay attention in the classroom and are at risk of underachievement so it is important that health professionals and teachers working with school-aged children understand working memory. This study found that health professionals and teachers are uncertain about the theory of working memory and how it impacts on learning. This means children with working memory problems may not be identified and the interventions used to support children's learning may, at times, be less effective than if they were grounded in sound theoretical thinking.

Keywords: working memory, theory, transdisciplinary, classroom interventions

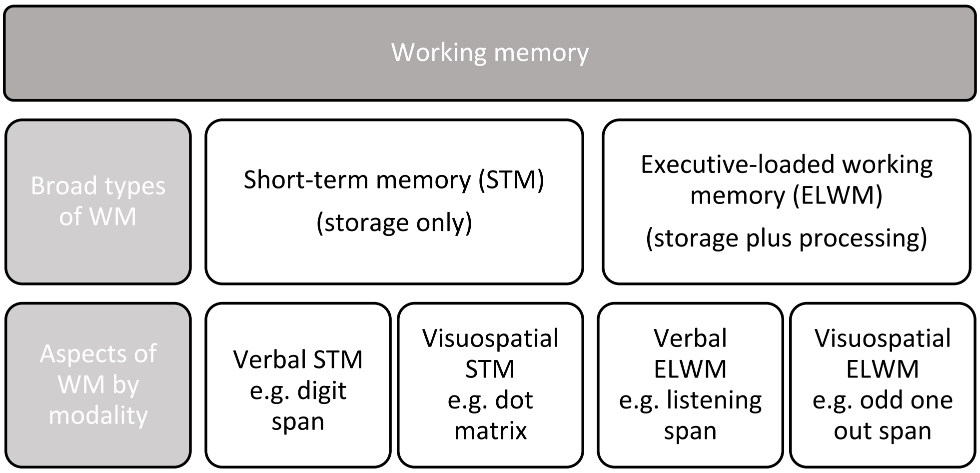
Introduction

Working memory

Working memory (WM) is the ability to hold in mind and mentally manipulate information over short periods of time in the face of distraction (Baddeley & Hitch, 1974; Cowan, 2008). WM supports many everyday activities such as reading and following instructions (Henry, 2012). Various theories have been put forward to account for the structure and function of WM. Baddeley and Hitch's (1974) multicomponent model of WM (and its subsequent revisions e.g., Baddeley, 2000) has been most influential and has yielded rich information about how children learn and acquire language (e.g. Baddeley *et al.,* 1998; Gathercole and Baddeley, 1993; Holmes & Adams 2006; Swanson, 1994).

According to the WM model, memory tasks can be differentiated in two ways: 1) whether the to-be-remembered information is verbal or visuospatial in nature; and 2) whether they involve the simple *storage* of information (short-term memory), or the *concurrent storage and processing of information.* Tasks that require concurrent storage and processing of information rely on attentional resources under executive control and can therefore be defined as executive-loaded WM (ELWM) (Henry, 2012). Thus, four aspects of WM can be delineated (verbal and visuospatial STM and verbal and visuospatial ELWM). Figure 1 denotes this and provides examples of tasks representing each aspect of WM.

Figure 1. Differentiation of WM tasks



The distinction between ELWM and STM measures is important because ELWM measures are more strongly associated with other higher-order cognitive (executive) functions than STM tasks (e.g., Engle, 2002; Gathercole *et al.*, 2004). STM and ELWM skills also function differently in relation to how they support language learning and processing. Verbal STM skills play a crucial role in word learning (Baddeley *et al.*, 1998), whereas verbal ELWM is associated more with sentence comprehension and particularly supports the processing of sentences with high morphosyntatic demands (Engel de Abreu *et al., 2*011; Ellis Weismer *et al.,* 2017; Frizelle *et al., 2*007). The difference between STM and ELWM may also have therapeutic implications since there is suggestive evidence that repeated practice on ELWM tasks (rather than on STM tasks) may improve the efficiency of processing or perhaps even facilitate the storage of information in WM (e.g., Henry *et al.*, 2014; Rowe *et al.*, 2019).

The relevance of WM to health professionals and teachers in mainstream schools

WM is associated with attention (e.g., Bunting & Cowan, 2005) and language acquisition (Baddeley *et al.*, 1998). Low WM is associated with developmental disorders including: Attention Deficit Hyperactivity Disorder (Martinussen & Tannock, 2006), Specific Language Impairment (now encompassed within the term Developmental Language Disorder (DLD), Bishop *et al.*, 2016); and motor impairments, such as Developmental Coordination Disorder (Rodak & Alloway, 2018). It is widely recognized that children with weak WM typically present as inattentive and distractible in the classroom and have difficulty completing learning tasks (see Box 1). This may explain why WM is a strong predictor of academic achievement (e.g., Gathercole *et al.*, 2016).

Box 1. Typical classroom behaviors associated with low WM

Children with weak WM struggle in the classroom with:

- Remembering and carrying out instructions (Engle *et al.*, 1991)
- Problem-solving (Swanson *et al.*, 2008)
- Planning, organizing and keeping track of tasks (Alloway *et al.*, 2009; Gathercole *et al.*, 2008)

There is still a lot to learn about how WM relates to other developmental skills and neurodevelopmental disorders. For example, the relationship between WM and language appears to be somewhat reciprocal: where WM supports language learning and processing; and elaborate linguistic knowledge supports WM (see Archibald, 2018 for a review). However, the closeness of the relationship between WM and other developmental skills is clear and any school-aged child presenting with inattentive behavior, DLD, motor impairments and/or failure to learn is at risk of also having underlying WM difficulties (Rodak & Alloway, 2018; Baddeley *et al*., 1998; Gathercole *et al.*, 2016). Therefore, all professionals working with this population should be aware of how to identify and best support children with WM deficits. Teachers need to recognise that children's behavior in the classroom may indicate underlying WM difficulties and serve as a prospective indicator (red flag) for poor academic progress (Gathercole, 2008). Health professionals (HPs) [1] working with school-aged children may be uniquely acquainted with the importance of WM and may be best placed to provide training and support for teachers. For example, speech and language therapists (SLTs) have an important role in enhancing teachers' understanding of the ways in which WM constrains language learning and how to evaluate and reduce the WM demands of the classroom (Singer & Bashir, 2018).

Despite the relevance of WM to HPs and teachers working with school-aged children in mainstream schools, little is known about their knowledge and perceptions of WM. Following thorough searches of key databases (British Education Index, CINAHL, ERIC, LLBA, PsycInfo, and Medline Ovid), no previous studies of HPs' perceptions and practice in relation to WM with school-aged populations were found. Regarding teachers' perceptions of WM difficulties, it has been suggested that teachers may interpret the inattentive behavior of children with low WM as being due to low motivation (Gathercole *et al.*, 2006; Gathercole *et al.*, 2008). However, the database searches conducted as part of the current investigation found only one study that explicitly investigated teachers' perceptions of WM. Alloway *et al.* (2012) carried out semi-structured interviews with

[1] The abbreviation HP is used throughout this paper (rather than the standard use of AHP for allied health professionals) because this study includes Social, Emotional and Behavior Specialists who are not designated AHPs.

teachers (*n*= 14) of 5-10-year-old children in Scotland. The teachers' responses to questions about WM were scored to assess their: knowledge of WM; awareness of WM deficits in children; and ability to identity strategies to support children with low WM. They had limited awareness of WM and did not identify it as a potential contributory factor to inattentive behavior in the classroom.

Alloway *et al.*'s (2012) findings have not been replicated so there is a need for further research that also includes an exploration of the factors contributing to this apparent lack of awareness. The authors of this paper know that a large scale (online) survey of teachers' awareness of WM has been conducted recently by researchers in the United Kingdom (UK) (unpublished work, personal communication). The results should provide useful insights into teachers' practice but it does not include other professional groups such as HPs who increasingly provide school-based interventions to support children at risk of academic underachievement (Ebbels *et al.*, 2019).

Current collaborative service provision for school-aged children

In one region of the UK, school-aged children are currently supported through a collaborative model of service provision between health and education services. The Regional Integrated Support for Education (RISE) teams are based in the Health and Social Care Trusts (HSCTs) in Northern Ireland (NI) and include SLTs, occupational therapists (OTs), physical therapists (PTs) and social, emotional and behavioral specialists (SEBs). They support mainstream primary schools through a three-tiered model of service delivery: individualized (specialist) support for referred children; and whole class (targeted and universal) interventions that aim to prevent potential future difficulties for at risk children (Ebbels *et al.*, 2019). The majority of referred children are 4-5 year olds from schools in areas of social disadvantage (SD), for whom attention difficulties are most frequently cited as the reason for referral (Harron & Dickson, 2013). For this population, family-level factors (e.g., parental education and maternal wellbeing) is likely to contribute to emotional problems and behavioural issues such as inattentiveness in the classroom (see Box 1) (Chowdry & McBride, 2017). Furthermore, the higher-order cognitive skills (executive functions) associated with attention control are likely to develop more in these children and in those raised in economic advantage (Noble *et al., 2*007). To address their needs, the RISE teams work within a transdisciplinary model in which professionals jointly plan and deliver interventions. This aims to maximize clinical and cost effectiveness by enhancing the holistic nature of interventions and streamlining the clinical pathway for children through professionals sharing their expertise (Gascoigne, 2006).

Despite the significant investment in the type of collaborative classroom-based intervention approaches employed by services such as the RISE teams, there is international recognition that these have not been robustly evaluated (e.g., Archibald, 2017; Ebbels *et al.*, 2019). There is also a lack of evidence for the transdisciplinary approach. Where research evidence is weak or does not exist, treatment choices should (at the very least) be underpinned by a sound rationale for why and how they should lead to a change in behavior (Roulstone, 2015). In other words, there should be a clear treatment hypothesis. This has been referred to as reason-based practice i.e., the implementation of scientific thinking in practice (Stanovich & Stanovich, 2003).

However, research has tended to focus on the implementation of *evidence-based* practice (EBP) and there has been limited research into decision-making at the *theoretical* level (Roulstone, 2015). The E^3BP model (Dollaghan, 2007) was based on the influential model of EBP proposed by Sackett *et al.*, (1996). As the name implies, it constructs EBP with three components: research evidence; clinical experience; and patient preferences. There is consistent evidence that, despite recognising the importance of EBP, HPs base their treatment decisions primarily on patient preferences, clinical experience (seeing 'what works' in practice) and pragmatic factors rather than on research evidence (Bennett *et al.*, 2003; Joffe & Pring, 2008; McLeod & Baker, 2014; McCurtin & Carter, 2015; McCurtin & Clifford 2015; Nail-Chiwetalu & Bernstein-Ratner, 2007; Zipoli & Kennedy, 2006). The research-practice gap is now acknowledged as a significant issue for HPs. The dissonance between what HPs say about EBP and what they actually do, and the reasons for it, have been discussed widely (see McCabe, 2018 for a review). However, very little is known about how clinicians apply *theory* to practice (Law *et al.*, 2008; Roulstone, 2015). The need for research in this area has been underscored by the suggestion that, without the clear application of theory, there is a risk of practice being based on pseudoscience (Lof, 2011).

In relation to service delivery issues in school-based collaborative practice, there is increasing recognition that the delivery of services, for example SLT provision, is impacted by local contexts (ICAN/RCSLT, 2018). Researchers interested in health and education practice are beginning to value and to adopt principles from implementation science that emphasizes the need for systems thinking to fully understand the barriers and facilitators to EBP and service delivery issues (Olswang & Prelock, 2015). However, the literature search conducted for the current study found no previous empirical studies of how context (e.g., the local environment and organizational features) actually influences decision-making and impacts on service delivery for school-aged children. The necessity to explore this is underscored by the need to maximize the effectiveness and efficiency of limited health and education resources for school-aged children (Law, 2019; Murphy, 2019).

The Present Study

The present study addresses gaps in what is known about HPs' and teachers' perceptions and knowledge of WM theory and if (or how) this influences their treatment choices. It also responds to calls for research into how local contexts influence decision-making and impact on service delivery for school-aged children (Law, 2019; Murphy, 2019). To address this, we adopt a realist perspective (Bhaskar, 1997) (described later) to explore the factors that impact on intervention implementation in children's everyday classroom context.

Aim

To explore health professionals' (SLTs, OTs, PTs, and SEBs) and teachers' knowledge, perceptions and practice in relation to WM and how context influences decision-making and service delivery for school-aged children at risk of low WM in mainstream schools.

Objectives

1) What are HPs' and teachers' knowledge and perceptions of WM?
2) What is the current practice of HPs and teachers when supporting children who are at risk of low WM (Box 1), and what rationale underpins this practice?
3) How does context (the interacting systems of HP services and schools) influence practitioners' decision-making and impact on service delivery for school-aged children in their everyday classroom?

Method

Study design and philosophical perspective

This was a qualitative study conducted as part of a wider research study seeking to develop a novel classroom-based intervention to support children with WM difficulties. It involved 5 focus groups from across NI: three groups of HPs (one from each of three participating HSCTs across NI); and two groups of teachers (from 5 different schools that the RISE teams support). A realist paradigm underpins this study, recognizing that interventions are based on causal assumptions (e.g., if we do x then y will change) that are influenced by context (Bhaskar, 1997). Causal mechanisms may be tacit or invisible and, consequently, are often referred to in implementation science as a 'black box'. Interventions are viewed as events within complex systems that constantly evolve and interact with their causal mechanisms and outcomes (Moore *et al.*, 2019). In the current study, schools and HP services are seen as complex systems that interact with each other and constantly change in response to internal and external pressures e.g., staff knowledge and attitudes, changes in staffing levels, dynamics of the class/teacher/children, and alterations to the curriculum. This dynamic context can impact on service delivery (Moore *et al.*, 2019).

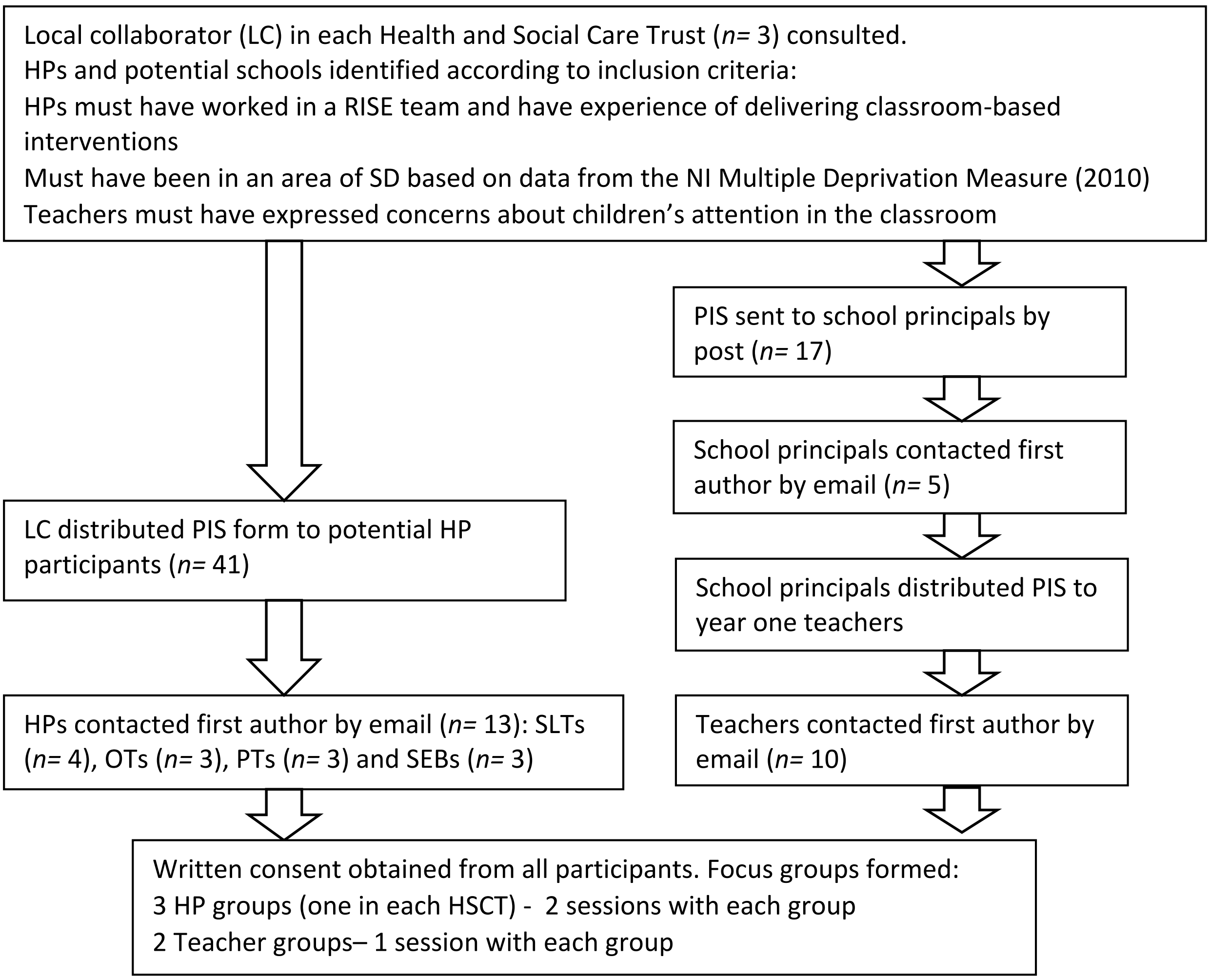
Participants and recruitment

As this study was part of a larger project, its scope was limited in terms of the clinical setting in which the HPs worked. The number of focus groups and participants involved was also restricted within the available time frame of the larger piece of work. The target population were: 1) HPs from the transdisciplinary RISE teams in three of the HSCTs in NI; and 2) teachers of year one children (4- 5 year olds) in mainstream primary schools in areas of SD supported by the teams.

Purposive sampling was used for both groups of participants. Figure 2 shows the recruitment flow chart. To recruit the HPs, a local collaborator in each of the three HSCTs distributed the participant information sheet (PIS) to potential participants (*n*= 41). Thirteen HPs (32% response rate) were recruited, with four disciplines represented: SLTs (*n*= 4); OTs (*n*= 3); PTs (*n*= 3); and SEBs (*n*= 3). To recruit teachers, mainstream primary schools in SD areas were identified according to data from the Northern Ireland Multiple

Deprivation Measure (NIMDM) 2010. Seventeen schools, in which teachers had raised concerns about children's attention in the classroom, were then identified in consultation with the local collaborators. The school principals (*n*= 17) were first approached in writing and five responded (29% response rate). The principals distributed the PIS to their year one teachers who contacted the first author by email. All those who responded (*n*= *10*) were included in the study.

Figure 2. Recruitment flow chart



Participant characteristics

Demographic details for each participant in terms of their background and years of experience are not provided here as, in the NI context, this could compromise their anonymity. Rather, an overview of their characteristics is provided. All of the participants were female. The HPs' clinical experience ranged from 4 to 37 years (mean = 21 years) with an average of 6 years' experience working in mainstream schools. The teachers' experience ranged from 2 to 25 years (mean = 15 years) and one participant had previously worked as a special educational needs co-ordinator (SENCO).

Data collection

Five focus groups were established: three groups of HPs (one in each HSCT); and two groups of teachers. Due to the close working relationship between the professionals in the RISE teams, the HPs were seen in focus groups that included participants from all four professional backgrounds (SLT, OT, PT and SEBs). The teachers were not included in the focus groups with the HPs. Separate focus groups were formed for them because one of the key objectives of this study was to explore how context (the interacting systems of HP services and schools) influences HPs' and teachers' decision-making and impacts on service delivery. It was reasoned that teachers and HPs may perceive each other as barriers or facilitators to collaborative practice and service delivery and a frank discussion may be enabled by conducting separate focus groups. Two meetings took place with each HP group and each teacher group met once. Focus groups lasted approximately one hour and were facilitated by the first author (A.R.), accompanied by the second author (J.T.) for one HP session.

Focus group schedule

The semi-structured focus group schedule consisted of pre-determined questions including key questions (asked in every session) and other items that were used as required (appendix 1). This meant the process was iterative and lines of questioning could follow the participants' responses to gather rich data around their understanding and perceptions of WM. The sessions opened with some general questions around the prevalence of children presenting with difficulties coping in the classroom setting. Participants were then given a description of the typical classroom behaviors that may be underpinned by low WM (see Box 1) and asked to identify the factors that might contribute to this presentation. Up to this point, WM was not mentioned by the researcher as this could have influenced the participants' responses. If the participants identified WM as a contributory factor, their understanding of it was explored. If they did not identify it, the researcher raised the topic and asked about what they understood of this term. The semi-structured nature of the schedule meant that if participants were unsure about WM, there was flexibility to probe around why this may be and the schedule included an optional question about whether they had ever received training on WM.

The sessions progressed onto discussion of how children with low WM are supported in the classroom. The first questions in this section focused on what types of activities and strategies the participants' frequently use and proceeded to explore the rationale for their choices. They were asked open-ended questions to see if they spontaneously referred to any theoretical or research-based evidence for their choices e.g., "*What informed your choice of these activities, strategies or interventions?"* (Appendix 1). To explore the contextual factors that may influence their thinking, participants were asked to identify *"what makes it easy/difficult to integrate activities into your practice?"*

The final part of the focus group sessions sought to look directly at participants' knowledge of WM theory. If it had not emerged already in the discussion, participants were asked if they were familiar with WM theory. The researcher then provided a brief explanation of the WM model (Baddeley & Hitch, 1974; Baddeley, 2000) and relevant research evidence on the effectiveness of WM training and participants were encouraged to reflect on this. The rationale for using the WM model is that it has been used most widely in applied WM research into WM deficits, especially in relation to neurodevelopmental disorders (Henry, 2012). Therefore, it is reasonable to assume that practitioners working with school-aged populations should know, or at least be aware of, the model. Furthermore, in relation to language difficulties, the clinical application of the model has been referred to in articles published in journals widely accessed by SLTs (e.g., Archibald 2018; Henry & Botting, 2017; Boudreau & Constanza-Smith, 2013).

Data analysis method

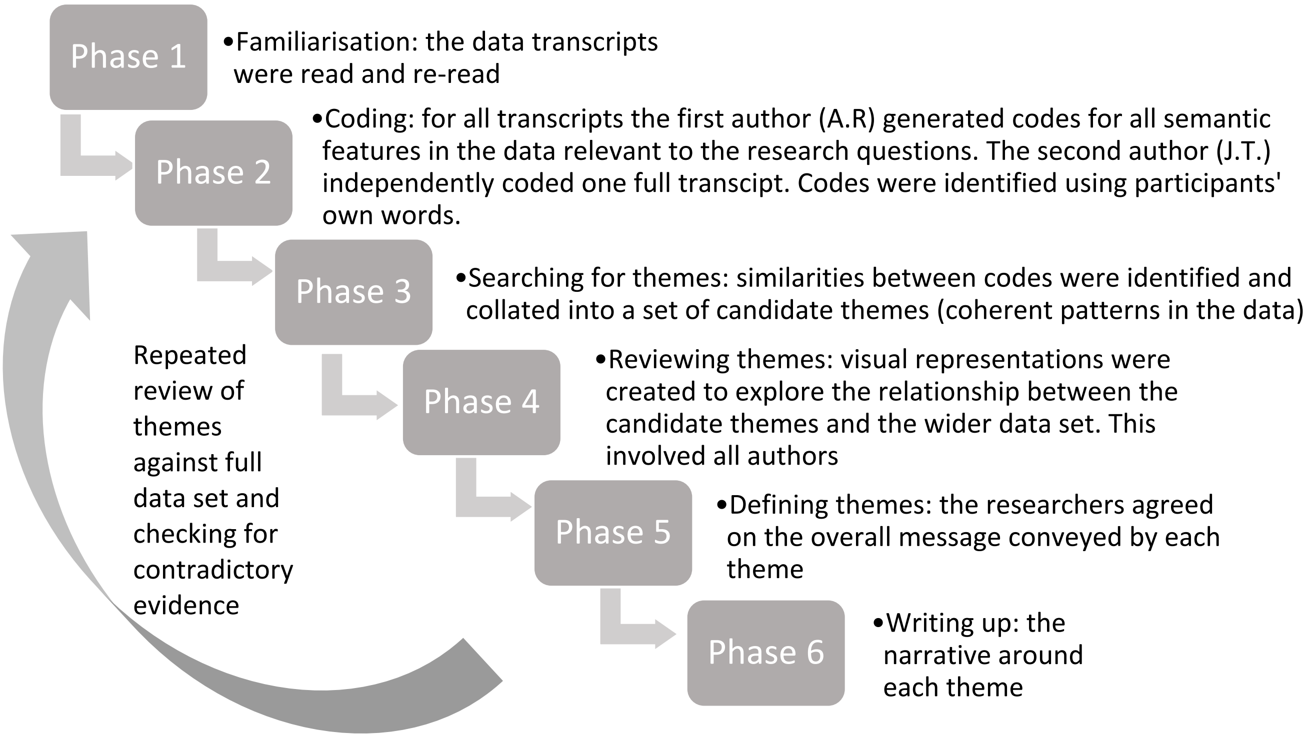
The data were audio-recorded (with participants' consent), transcribed verbatim and managed using the NVivo (2012) software package. The data were analyzed using a thematic content analysis (Braun & Clarke, 2006). This method is consistent with a realist paradigm because it can be used to understand people's perceptions of reality and the ways in which social contexts influence them (Braun & Clarke, 2006). Overall an inductive approach was taken to the analysis meaning that, although specific questions were asked of the data such as whether the participants identified WM theory as a rationale for their treatment choices, the researchers had no pre-specified notions around the themes that may be identified. Moreover, it was recognized that the rationale underpinning the participants' practice may be tacit (Law *et al.,* 2008, Van de Ven & Johnson, 2006). Therefore, applying thematic analysis in an inductive manner was advantageous as it enabled the identification of both explicit (semantic) and conceptual (latent) themes (Braun *et al*,. 2018).

Data interpretation: deriving themes

Figure 3 shows how the six phases of Braun and Clarke's (2006) thematic analysis method were followed to derive themes from the data. To summarize the approach taken, each transcript was read, re-read and coded systematically with semantic codes, generated using the participants' own words (phases 1 and 2). The first author (A.R.) coded all of the transcripts and the second author (J.T.) independently coded one complete transcript. The list of semantic codes was sorted into meaningful candidate themes (phase 3). Similarities between the codes were reviewed to identify candidate themes. The first author created visual representations (thematic maps) to examine the relationships between the candidate themes (Appendices 2 and 3). At this point, the initial list of codes was revisited and the full data set was consulted again. This indicated some latent codes that had not been previously identified and these were added to the thematic maps. The revised thematic maps were discussed amongst the research team on several occasions until a final set themes and sub-themes was agreed

Finally, during the writing up process, the wording of the themes was again revised by revisiting the full data set, initial codes and thematic maps in order to ensure the final interpretation of the data fully reflected the essence of the participants' views. This included looking for any cases that may contradict the codes themes especially in the case of those latent themes that had been identified. The original data transcripts were consulted on many occasions during this process.

Figure 3: Data interpretation phases (Braun & Clarke, 2006)



Trustworthiness

The first author (A.R.) had prior experience of working in one of the transdisciplinary school-based teams and was known to some of the HPs. Since insider insight can result in preconceptions being carried into any stage of a study, bracketing was applied to ensure rigor in the interpretation of the findings (Tufford & Newman, 2010). At the data collection stage, the following steps were taken: reflections on the research questions were recorded prior to the focus groups; field notes were written immediately after each session; and the second author (J.T.) attended one of the HP sessions to monitor the process. During the data analysis, the codes and themes generated were continually checked against the raw data transcripts to ensure the nuances of the participants' comments were captured accurately. Investigator triangulation was used to reach consensus on the key themes and sub-themes.

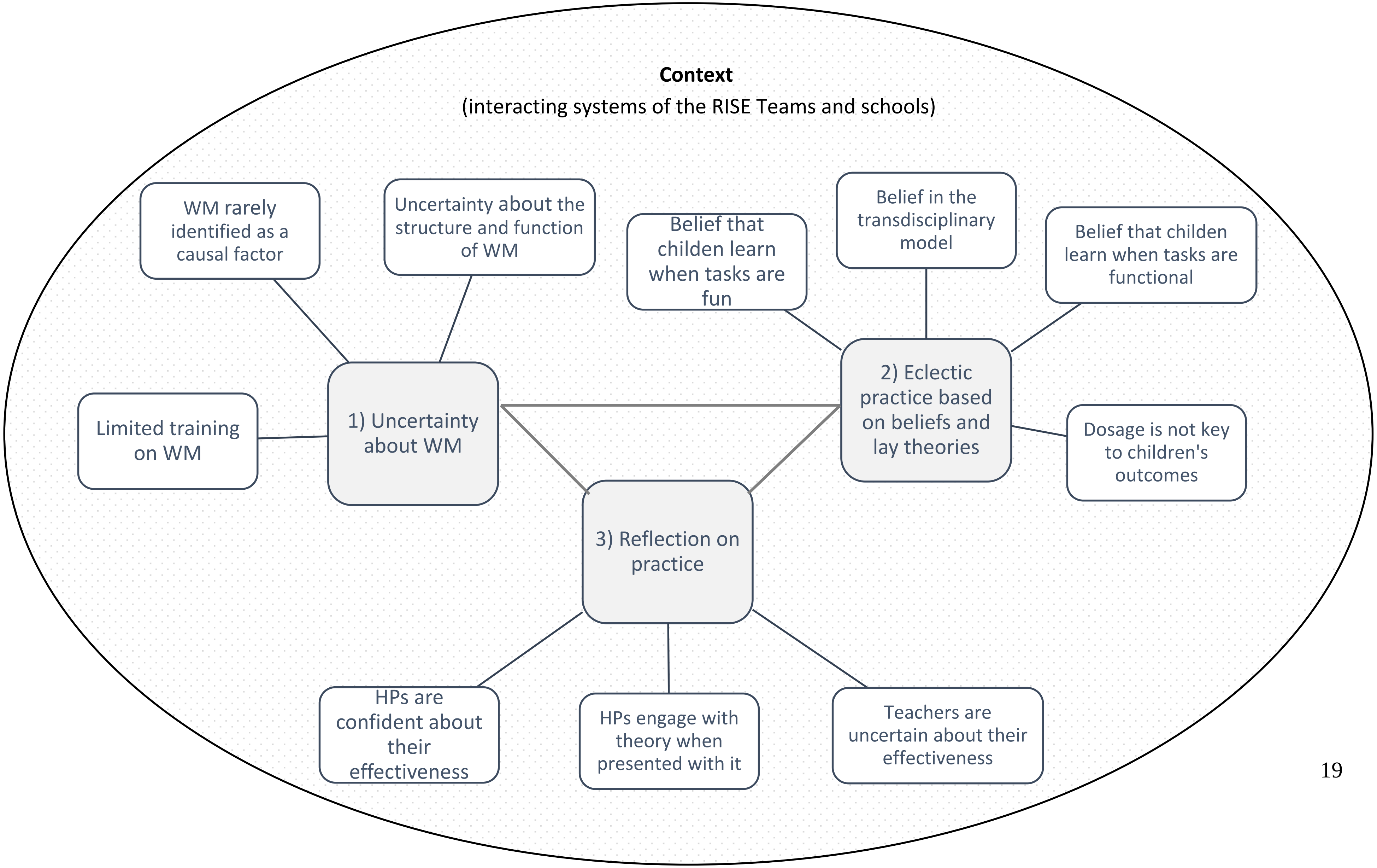
Ethics

Ethical approval was granted by the Institute of Nursing and Health Research's Ethics Committee at Ulster University. Approval was also obtained from the relevant HSCT research offices. Participants were given detailed PIS forms and provided written, informed consent prior to data collection. Responses were anonymized immediately at transcription. All data was stored securely according to Ulster University's data management policy and the General Data Protection Regulation (EU) 2016/679.

Findings

This section provides an overview of the set of themes and sub-themes identified in the data. Initially, the influence of context (the interacting systems of the RISE teams and schools) was identified as a single theme within the data. However, as the data analysis progressed, it became clear that this was in fact a more encompassing theme that influenced the entire set of themes. Figure 4 visually depicts the influence of context on the three key themes and 9 sub-themes identified in the data, and how they relate to each other. The three key themes are: 1) uncertainty about WM; 2) eclectic practice based on beliefs and lay theories; and 3) reflection on practice. Each theme is described below, supported by exemplar quotes from participants

Figure 4. Overview of qualitative themes and sub-themes depicted within the practice context of the RISE Teams and Schools



Theme 1: Uncertainty about WM

A predominant theme (identified through both semantic and latent codes generated from the data) was uncertainty about WM. This was demonstrated by a lack of recognition of WM as a potential causal factor for children's inattentive behavior in the classroom and a lack of clarity in describing the structure and function of WM.

Sub-theme: WM rarely identified as a causal factor

When given the description of the classroom behaviors typically associated with low WM (Box 1), the potential causes initially suggested by the HPs and teachers were external factors i.e., characteristics of the child's environment. Social history and family background were most frequently cited. The HPs proceeded to list many internal factors (relating to the child themselves) including; language, sensory, motor and social skills; attachment and emotional well-being; general health; and cognitive ability. They often referred to the interaction between skills, using words such as 'overlapping' and 'commonalities'. WM was sometimes implied in the participants' responses:

> *"In some ways I think they [the children] can't stay focused on what we told them. They can't keep that. They can't hold that because something else has come in and wiped that out."* (SLT4)

However, it was only explicitly identified as a causal factor by one HP:

> *"Poor processing speed. Low working memory. So children are unable to retain instructions and recall them and hold them in mind while they're progressing through a task."* (SEB3)

In comparison, the teachers identified fewer internal factors and the discussion often reverted back to social history and home life as causative. Again, at times WM was implied in a few responses, as reported by one teacher: *'Some of them just can't recall'*. However, it was not directly referred to by any of the teachers.

Sub-theme: Uncertainty about the structure and function of WM

Both the HPs and the teachers lacked confidence in defining WM and their responses demonstrated confusion around the distinction between WM, STM and ELWM skills. Throughout this segment of the discussions, both the HPs and the teachers frequently introduced or concluded their comments with qualifying remarks such as *'I could be wrong'* or *'but I don't know if it's right'*.

WM was often referred to as 'recalling' and 'holding information', suggesting confusion with STM skills. In a few cases, the definitions given by the HPs implied some understanding that WM involves executive aspects of cognition, through use of vocabulary such as *'processing'* and *'manipulating'*. For example, one SLT stated:

> *"Working memory is more just holding it in your head and being able to manipulate within your head…being able to hold it long enough, to change it, swap it round and give it back to you in some way." (SLT4)*

However, most of the HPs and teachers did not refer to higher level cognitive processing when talking about WM, and only one participant identified WM as an executive function and differentiated between WM and STM:

> *"I would see short-term memory as being more peripheral, just the ability to retain a piece of information for a short period of time….. but working memory is more like an executive function. So it's a more kind of in-depth level of processing…it's not just about retention, it's about the processing as well." (SLT2)*

All of the teachers reported that they had heard about WM but that *"it's not something we* *would talk about"*. Most teachers stated that they would not be able to define WM, but one participant suggested the following definition:

> *"I suppose working memory is more applying, I don't know, applying the memory, actually can you use what you remember? Rather than just, can you repeat back to me?"* (Teacher8)

A general confusion around the structure of WM was also evidenced by the inconsistent use of terminology to describe aspects of WM. Individual participants referred to 'auditory memory' in one comment and 'working memory' in another. There was also a difference across the professions. Rather than referring to verbal or visuospatial WM skills, the SLTs talked about 'auditory memory' and the OTs talked about 'visual memory'. This variation was noted by one of the HPs:

> *"Yes, it might be picking up working memory difficulties, but you might just call it something different."* (SEB3)

All of the participants were unsure about the function of WM and its associations with language, sensory and motor skills. The SLTs reported that it is difficult to differentiate between language impairment and poor WM, especially when interpreting individual assessment results or reviewing observations of a child in the classroom. They recognized the importance of WM for word learning and receptive language but did not elucidate its role in language acquisition:

> *"I think [WM] is over-arching every other speech and language skill really. For a child to be able to follow instructions. For a child to be able to learn vocabulary and everything, they need good memory, working memory skills to try and use that then effectively in tasks and activities in the classroom." (SLT3)*

The PTs reported they focus on motor skills and *"don't think much about the memory load"* (PT2). The OTs reported visual memory is a component that they include in the assessment of children's visual perceptual skills. When prompted, the teachers connected WM to literacy development but did not elaborate on the association between the two skills.

Sub-theme: Limited training on WM

Due to the participants' uncertainty about WM, they were asked about whether they had received training on this topic. At the undergraduate level, the SLT and SEB participants' reported that their courses included a component on WM but, for most, this was some years ago (since post-graduate experience was on average 20 years for the HPs). The PTs and OTs did not recall any training on WM. At the post-graduate level, none of the HPs had received any training on WM. One teacher said she had *'heard about WM during a course'* that she attended when working as a SENCO but the others all reported that they had never had an opportunity to learn about WM. When presented with the WM model (Baddeley, 2000), most participants reported it was new to them. None of the participants were aware that WM is a significant predictor of academic attainment or of the debate in the literature around the effectiveness of WM interventions. In terms of applying training to practice, the teachers reported that they learn best through practical demonstration in the classroom and that they do implement the approaches that are recommended and modelled by HPs in the classroom, as stated by one teacher:

> *"I think good training with new programs as well, is always seeing it in action…..as opposed to, you know, thinking and just talking about the theory." (Teacher4)*

Theme 2: Eclectic practice based on beliefs and lay theories

The data indicated that a broad and eclectic range of activities and strategies are used in the classroom to support children presenting with the types of behaviors associated with low WM (Box 1), including: behavioral approaches, visual supports, sensory strategies, adapting the classroom environment and listening games. The teachers favored the use of published materials and what they described as *"listening games".* Most agreed that these do not focus on memory, although they went on to describe a number of STM tasks.

The HPs described programs that they have developed themselves within their teams, integrating language, sensory and motor ingredients and identified these as transdisciplinary approaches. Activities included repeated practice on tasks that involve retaining an instruction whilst carrying out a specific motor movement e.g., the child might be told to *'walk on your tip toes, then put the big ball in the box'.* The role of WM appears to have had little consideration in the development of these programs:

> *"You do need the memory of the task to be able to practise it and complete it….I guess it's all in there [in interventions] but we don't really concentrate too much on memory. I guess I don't think of it as a memory task."* (PT1)

There was no clear link between WM theory and the eclectic approaches used by the HPs or teachers. When justifying their intervention choices, they used phrases such as *'because it works'* and *'it's just experience' and* no scientific theory was referred to. Hence, the explanations provided are labelled here as lay theories, defined as 'the informal, common sense explanations people give for behaviors' (Furnham, 1988, p.3). Lay theories are often tacit and include non-specific assumptions, whereas scientific theories are more formal, theoretically-underpinned, logical and coherent.

Sub-theme: Belief in the transdisciplinary model (interventions combining motor, sensory and language tasks).

The HPs reported that they had searched the literature, but had not been able to find research-based evidence for transdisciplinary interventions. Consequently, they developed their own programs, synthesizing their experience into tasks combining various components. They talked enthusiastically about how working closely with professionals from other disciplines had enhanced their skills:

> *"I think it* [working within a transdisciplinary team providing services into mainstream schools] *changes your professional practice almost beyond recognition…The way that you work with a child and the way that you work with parents, is completely impacted by the benefits of working alongside* [other disciplines]*, you know, that you just don't have as a speech and language therapist, even though you think, you think that you know it all – you don't."* (SLT2)

The HPs were confident in the effectiveness of their programs, suggesting that they work because they are more complex and present *'more of a challenge'* than working on various skills in isolation. They referred to the transdisciplinary model as being *'child-centered'* and *'holistic'*". The HPs appear to base their practice on the thinking that changing child outcomes arises from a marriage of differential input which addresses the complexity of the whole child.

Sub-theme: Belief that children learn when tasks are functional

Both the HPs and teachers believe that children's learning is maximized when tasks are *'functional'*. The HPs expressed the idea that their transdisciplinary tasks (combining motor, sensory and language components) have more ecological validity than practising skills in isolation. No scientific theory was pinpointed to account for this lay theory, rather they talked about the benefits of tasks that are more like *'real life'*:

> *"You're never really expected to just do one thing at one time. It kind of is what the classroom environment is like and what life is like, that you're expected to do more than one thing. So I feel it's beneficial in that sense, it's like real life." (OT3)*

Sub-theme: Belief that children learn when tasks are fun

All of the participants consistently spoke about the need to motivate and engage children in learning tasks and that children learn better when activities are fun:

> *"It has to be fun. They have to think almost, this isn't work. This is fun time. And that's what works for them. The same as I say, with practical hands on learning." (Teacher9)*

The HPs reported that tasks integrating language and motor ingredients are more motivating for children because they can be presented in a range of ways, thereby reducing the repetitive nature of intervention tasks.

Sub-theme: Dosage is not key to children's outcomes

This sub-theme was identified as a latent theme in the data during the later aspects of the data interpretation. Two factors contributed to this theme being derived from the data. Firstly, when discussing the classroom-based interventions that they had developed within their teams, the HPs were asked about how much input they provide to schools and what informed their decision–making around this. When discussing this, all of the reasons given related to the context of working in a school environment including the interpersonal relationship with the teacher and the structure of the school day/term. The amount of intervention provided (number of sessions) appears to *'depend on the teacher'* and the total intervention duration (number of weeks) is determined by what will fit within a school term/half-term. Likewise, the teachers' reported that they do as much practice as they can on the tasks described by fitting them in around other areas of the curriculum. Time and resources were the main factors affecting the amount of time spent on tasks to support children with the types of difficulties described in Box 1. They often referred to the challenges of delivering a broad and balanced curriculum due to large classes where there are high proportions of children needing additional support and limited availability of classroom assistants:

> *"It also depends on how many children you also have in your class…..it's just trying to get through the day, crowd control. I know things that would be good to do, but it's just really hard. It's actually trying to find the time and the resources to do what you want to do..…all schools in the foundation stage should definitely have assistants"* (Teacher6)

Secondly, when the groups were asked about the effectiveness of their practice and why they feel their interventions work (or don't work), neither the HPs nor the teachers referred to the any aspect of dosage amount (the amount or intensity of an intervention) the HPs did not refer to how this could impact on intervention effectiveness. These two factors imply a belief that dosage is not key to children's outcomes.

Theme 3: Reflection on practice

This theme addresses the HPs' and teachers' views on the effectiveness of their practice and the extent to which they engaged with WM theory when presented with it.

Sub-theme: HPs are confident about their effectiveness

The HPs expressed confidence in the effectiveness of their interventions although they were concerned about the lack of robust evidence for the effectiveness of the transdisciplinary model and classroom-based (universal) approaches to service provision in schools. They were aware that much of the evidence they have is anecdotal and that if they had the opportunity and appropriate validated measures, they would gather practice-based evidence and longitudinal data on children's outcomes to support their practice. They attributed instances of ineffectiveness to child-related and contextual factors, rather than the content or dosage of their interventions. Reasons given for ineffectiveness included: children's cognitive ability; teachers' expectations; the time of day or year that a program was delivered; and staffing levels/changes of staff:

> *"I don't doubt the program, but when it's a very difficult class with lots of problems, you kind of are thinking – this isn't as effective with this class as what it was with the class this morning. I think it's a whole load of combination factors that add into that." (SEB1)*

> *"The classroom is an ever-changing thing like staffing levels and busyness of the classroom, the different levels and abilities." (SLT3)*

Sub-theme: Teachers are uncertain about their effectiveness

In comparison to the HPs, the teachers were uncertain about the effectiveness of their practice, particularly for children with additional needs. They suggested that the approaches they use *"work for the majority'* (Teacher2) but talked about how the demands of the classroom make it difficult to adequately support those children who struggle to learn (such as those with attention difficulties and DLD):

"The majority it is working for, but I still have the small group that it's not doing anything for, no matter what you try with them." (Teacher2)

Sub-theme: HPs engage with theory when presented with it.

When the participants were presented with the WM theory and evidence, the HPs immediately began to reflect on the nature and effectiveness of their intervention ingredients. They were, as stated by one SLT, *'challenged'* by the distinction between ELWM and STM tasks and reflected on whether tasks are executive-loaded (tap into attentional resources) or not:

"I'm thinking already of the programs that we do and some of the strategies we use already. Are we actually strengthening that working memory? How are we impacting on this?...Are we actually doing anything to manipulate any level of this? Or are we only manipulating the short-term memory level?" (SLT4)

Following some debate with each other, the HPs appeared to reach consensus that targeting more than one skill in a task requires attentional resources:

"Once you start incorporating language and movement, and increasing waits and that kind of thing, then you're hopefully getting more into the executive." (SLT2)

In the teacher focus groups, there was less reflection on the evidence presented. They commented that the theory and evidence were *'interesting'* but the discussions reverted to more practical topics such as behaviour management in the classroom.

Overarching theme: the influence of context on practitioners' decision-making and service delivery for school-aged children in their everyday mainstream classroom

In the writing-up process, it became evident that contextual factors influenced the participants' views in relation to all of the other themes and sub-themes. Therefore, this was identified not just as a single theme in the data, but as an overarching theme that ties all the others together (see Figure 4.). From the realist perspective adopted in this study, the RISE Teams and schools are viewed as complex, dynamic systems that interact with each other (Moore *et al.,* 2019). The data indicated that the HPs' choice of interventions and their dosage (amount and intensity of treatment) is influenced primarily by working within the mainstream environment. They talked about *'relying'* on teachers and wanting to maintain a good working relationship with them. Therefore, they choose interventions that they perceive will be acceptable to teachers. In turn, teachers adopt activities and strategies that the HPs model for them in the classroom. The implications of this are discussed in the next section of this paper

Discussion

This is the first paper to explore HPs' and teachers' knowledge and perceptions of WM, and investigate how children who are at risk of low WM are supported in their everyday mainstream classroom. By adopting a realist paradigm, it provides insights into practice at the theoretical level; an area that has been under-researched (Roulstone, 2015). This study also responds to calls for investigation into how context (the interacting systems of health and education services) influences practitioners' decision-making and impacts on service delivery for school-aged children in their everyday classroom (Murphy, 2019). The key findings and their clinical implications are discussed below.

Health professionals' and teachers' knowledge and perceptions of WM

The present study highlights that HPs and teachers are uncertain about the structure and function of WM. Since there had been no previous studies of HPs' theoretical knowledge of WM this represents a first and novel discovery. With regards to teachers' knowledge and perceptions, this replicates the findings of Alloway *et al.* (2012) who found that teachers in Scotland had limited awareness of WM.

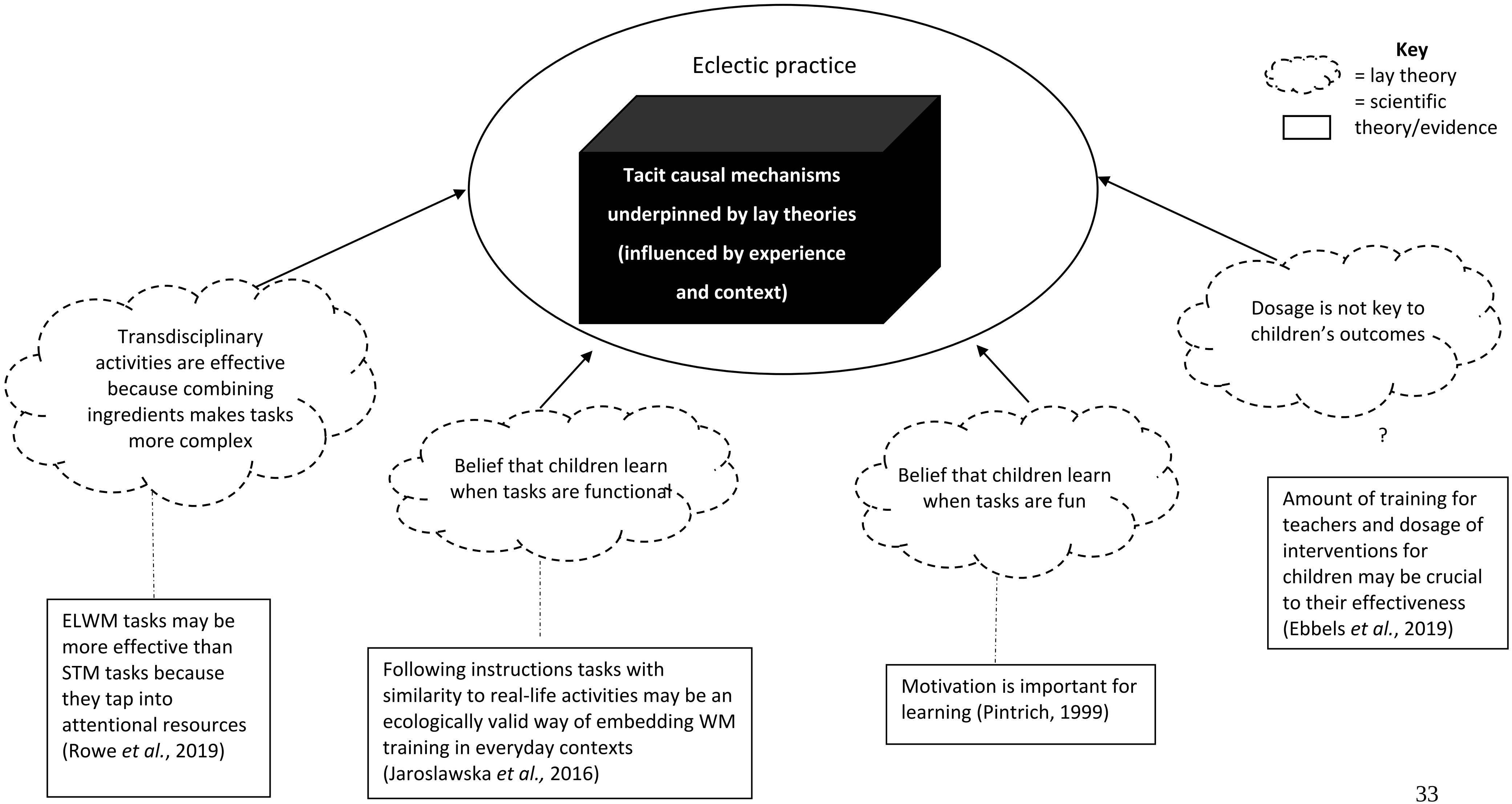
It is valuable that HPs and teachers readily identify poor attention as a key issue impacting on year one (4-5-year-old) children's learning potential in mainstream schools (Harron & Dickson, 2013). However, this study highlights that HPs and teachers are largely unaware that inattentive behavior is a potential indicator for low WM which has implications for language development, literacy difficulties and (ultimately) poor academic attainment. Therefore, children with low WM may go undetected and the possibility of addressing this potential cause is missed. The participants' difficulty in distinguishing between STM and ELWM skills has considerable implications for the accurate profiling of the strengths and weaknesses of children who struggle to learn (Henry & Botting, 2017).

There is a clear need to support HPs and teachers to enhance their practice in this area, especially in light of the limited training opportunities available to them that this study has highlighted. HPs and teachers need good pre and post-registration training on the structure and function of WM and how to apply WM theory to practice. Training should include how to differentiate tasks by their modality (verbal versus visuospatial) and by their storage/processing demands (STM versus ELWM) (Figure 1). The storage and processing (executive) demands of memory measures are often poorly specified in the academic literature (Rowe *et al.*, 2019). The use of clear and consistent definitions across academic and practice settings could support HPs' and teachers' understanding of the associations between WM, inattentive behavior and academic attainment. It is particularly important that HPs delivering services to mainstream schools receive high quality training on WM, since this study highlights the significant influence they have on teachers' practice.

The current practice of HPs and teachers when supporting children who are at risk of low WM

The findings of the present study are consistent with previous research, demonstrating that HPs favor eclectic intervention approaches (e.g., McCurtin & Carter, 2015; McCurtin & Clifford 2015). It also provides evidence that teachers similarly integrate a broad range of activities into their classroom practice, combining commercial programs targeting 'listening skills' alongside behavioral strategies. It is clear that WM theory does not underpin current practice. Indeed, no scientific theory or research-based evidence was referred to by any of the participants when accounting for their treatment choices. Rather, decision-making is underpinned by practice evidence ('seeing what works') and lay theories. According to Furnham (1988), lay theories (the informal common sense explanations people give for behaviors) are often tacit, and unconsciously influenced by scientific theories that are more formal, theoretical, logical and coherent. This leads to the question of whether the lay theories identified in the current study are consistent with scientific theory or research evidence. Each of the lay theories identified in the data has been examined in relation to existing scientific theory.

Figure 5. HP and teacher lay theories mapped to scientific theory/evidence



Lay theory 1: Belief in the transdisciplinary model

This study found that HPs believe in the effectiveness of transdisciplinary tasks combining language, sensory and motor ingredients, deemed effective because they are more challenging for the children than working on separate skills in isolation. This implies that the complexity of a task corresponds to its attentional demands i.e., novel, complex tasks are more attention-demanding (Archibald, 2017). Thus, the HPs' use of complex, transdisciplinary tasks may be supported by suggestive evidence that tapping into attentional resources (under executive control) could be an important ingredient in interventions for children who are at risk of low WM (Rowe *et al.*, 2019). Thus, whilst there may be limited research-based evidence to support the transdisciplinary approach, close working with other disciplines may have provided the HPs in the present study an opportunity to learn from each other and develop interventions that marry with evidence.

Lay theory 2: Belief that children learn when tasks are functional and fun

Both HPs and teachers believe that children learn when tasks are functional and map to the everyday demands of real-life (ecological validity). This is consistent with suggestions in the literature that it may be valuable to embed WM training within tasks that overlap with the way it is used in everyday life (e.g., Jaroslawska *et al.*, 2016). They also believe that children learn best when tasks are at an appropriate level for them and are presented to them in a fun way. This suggests an implicit recognition that children's learning is dependent on their motivation to complete a task. This thinking is consistent with theories proposed within educational research regarding the associations between motivation and self-regulated learning (e.g., Pintrich, 1999).

Overall, HPs and teachers may inadvertently use executive-loaded tasks to support children at risk of low WM and the lay theories underpinning their thinking may relate indirectly to scientific theory and emerging research evidence (Figure 5). Whilst this is reassuring, the lack of an explicit theoretical underpinning to practice is a significant issue for EBP, leaving practitioners open to the suggestion that their practice is unscientific (Lof, 2011). However, it is encouraging that, when presented with WM theory (Baddeley, 2000), the HPs immediately and spontaneously reflected on their practice. This implies that it is a lack of time and opportunity to engage in deep reflection on their practice that is impinging upon EBP. Consequently, if practitioners were given more time, they could easily be supported to become more skilled in articulating their clinical thinking in a way that explicitly refers to and is fully consistent with scientific theory (McCabe, 2018). Training on the methods employed in implementation and improvement science could support this work with individuals and teams wishing to generate practice-based evidence grounded in theory (Olswang & Prelock, 2015). For example, in realist inquiry interventions are viewed in terms of context-mechanism and outcomes (CMO) configurations (Pawson & Tilley, 1997). Using this framework to delineate clear causal pathways could enhance intervention design.

Lay theory 3: Dosage is not key to children's outcomes

This study has revealed a striking finding about HPs' and teachers' beliefs around dosage i.e., that they do not appear to view dosage as being key to children's outcomes (Figure 5). This theme was derived from the data showing that the participants did not refer to dosage when they discussed the basis of their treatment decisions, nor when they considered the reasons why interventions may/may not work. This contrasts with the increasing research-based evidence base that demonstrates the importance of dosage on children's outcomes and indicates that this should be a consideration in clinical/classroom decision-making. It is likely that, if the participants were asked directly about whether dosage is important to children's outcomes, they would agree that it is. Research into EBP by SLTs and other HPs has previously shown that it is not unusual to observe cognitive dissonance in this regard i.e., a difference between what people say they believe and how they actually behave (McCabe 2018). Hence, the findings of this study concur with previous evidence around the challenges of implementing EBP within the constraints of limited time and training opportunities in real-life contexts (McCurtin & Carter, 2015). This study reinforces the need for practitioners to have time to reflect on intervention dosage and this should be a major component in the training of HPs in order to maximize efficiency and reduce waste in school-based services (Ebbels *et al.*, 2019).

Reflection on practice

This study also presents a novel finding around the difference between HPs' and teacher's confidence in the effectiveness of their practice. The teachers were less confident that what they currently do works and demonstrated less reflection on theory than the HPs. Their thinking appears to be dominated by the demands of the curriculum and the classroom. Since teachers have key responsibility for supporting children who are at risk of low WM in the classroom, they require training on WM and evidence-based interventions. Teachers' practice is influenced by working alongside HPs who provide services to mainstream schools, particularly when they jointly deliver classroom-based interventions. The current model of collaborative practice implemented by the RISE teams therefore appears to have great potential. However, if this is to be maximized, the interventions used require a clear theoretical underpinning, research-based evidence and careful consideration of dosage (Ebbels *et al.*, 2019)

The influence of context on practitioners' decision-making and impact on service delivery for school-aged children

The impact of the interacting systems of HP services and schools on decision-making and service delivery has been demonstrated in this study. Term-time schedules and resource constraints impact significantly on intervention delivery, particularly dosage i.e., the frequency of intervention sessions provided, and the nature/extent of training that the teachers co-delivering these programs may receive (thereby influencing effectiveness (Ebbels *et al.*, 2019). These factors, coupled with uncertain theoretical knowledge and a lack of EB, contribute to the generation of lay theories upon which intervention choices are based. To support the design and implementation of interventions in practice, individuals and teams of HPs and schools could be trained in the use of implementation science tools to support reason-based practice.

Study limitations

This was a small study conducted in one particular context in the UK where HPs work in transdisciplinary teams providing classroom-based interventions in mainstream primary schools, most frequently in areas of SD. Additional insights into clinical and classroom practices may have been obtained with a more diverse sample and across different countries. However, this study did not aim to produce generalizable findings but to open a novel window of inquiry into the investigation of practice at the theoretical level, considering the importance of WM. For the same reasons, reaching saturation was not a goal of the data collection although a considerable degree of consistency of responses was found across the focus groups.

It is possible that the use of a mixed-methods approach with the inclusion of a survey before conducing the focus groups would have enhanced the findings. This could have provided, for example, some further data around levels of confidence in WM theory. However, this would have biased the participants' responses regarding WM theory as they may have prompted them to read up on the topic before the focus group sessions. A survey could now be conducted to confirm the findings reported here and the authors intend to explore the potential of future research in this area.

The findings presented here should be interpreted in light of the fact that the first author (A.R.) had prior experience of working within one of the school-based teams. There are costs and benefits to research being conducted by an insider (someone who shares a role or experience with the participants) (Corbin Dwyer & Buckle, 2009). Whilst this may have influenced the data collection and analysis, disciplined bracketing was applied throughout the study. Discussion with the other members of the research team (J.T. and L.T. who do not hold insider status) minimized the risk of bias in the interpretation of the findings, particularly during the writing process (Tufford & Newman, 2010). The systematic approach to analysis by applying the socio-ecological model also supported the rigorous examination of the data.

Conclusions and implications

In the context of the transdisciplinary teams involved in this study, an inherent belief in the power of a 'whole child' approach to intervention, the influence of lay theories, and the influence of context means the classroom interventions they implement may impact positively on WM and its associated skills inadvertently, or they may not. Consequently, the lack of theoretically underpinned, evidence-based interventions results in service delivery which may work at times and may not work at others.

This study highlights the need for HPs and teachers to better understand WM and its associations with other skills so that children at risk of low WM can be identified and supported. It is crucial (at the least) that practice is theoretically underpinned (Roulstone, 2015). Teachers and HPs should be given opportunities not just to learn theory. but to apply it to practice, so that they can clearly articulate why and how interventions should work. By clearly specifying the causal mechanism(s) embedded within an intervention and understanding the contextual factors that impact on its delivery, clinical effectiveness could be capitalized and outcomes for children maximized (Lof, 2011). Researchers could also support this by designing clinically relevant studies conducted within local contexts. Practitioners, who are acquainted with the way in which contextual factors impinge on their practice, should be given opportunities to co-produce evidence that meets real-life needs.

Acknowledgements

This study was conducted as part of a doctoral research study funded by the Research and Development Division of the Public Health Agency, Northern Ireland. The funder was not involved in the design of the study and had no input to the interpretation of the results.

References

Alloway, T.P., Gathercole, S.E., Kirkwood, H.J., & Elliott J.E., (2009). The cognitive and behavioural characteristics of children with low working memory. *Child Development*, 80, 606-621. http://dx.doi.org/10.1111/j.1467-8624.2009.01282.x.

Alloway, T.P., Doherty-Sneddon, G., & Forbes, L., (2012). Teachers' perceptions of classroom behaviour and working memory. *Educational Research and Reviews,* 7(6), 138-142. http://dx.doi.org/10.5897/ERR10.223

Archibald, L.M. (2017). SLP-educator classroom collaboration: A review to inform reason-based practice. *Autism & Developmental Language Impairments*, 2, 1-17. https://doi.org/10.1177/2396941516680369

Archibald, L.M.D. (2018). The reciprocal influences of working memory and linguistic knowledge on language performance: considerations for the assessment of children with developmental language disorder. *Language, Speech and Hearing Services in Schools*, *49*(3), 424-433. https://doi.org/10.1044/2018_LSHSS-17-0094

Baddeley, A.D. & Hitch, G.J. (1974). Working Memory. In G.H. Bower (Ed.), *The psychology of learning and motivation,* Vol 8. London: Academic Press.

Baddeley, A.D., Gathercole, S.E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review,* 105, 158-173. https://doi.org/10.1037/0033- 295X.105.1.158.

Baddeley, A.D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences,* 4(11), 417-423. https://doi.org/10.1016/S1364-6613(00)01538-2.

Bennett, S., Tooth, L., McKenna, K., Rodger, S., Strong, J., Zivanni, J., Mickan, S., & Gibson, L. (2003). Perceptions of evidence-based practice: A survey of Australian occupational therapists. *Australian Occupational Therapy Journal*, 50, 13-22. https://doi.org/10.1046/j.1440-1630.2003.00341.x

Bhaskar, R. (1997). *A Realist Theory of Science.* London and New York: Verso.

Bishop, D. V. M., Snowling, M. J., Thompson, P. A., Greenhalgh, T., & The CATALISE Consortium (2016). CATALISE: a multinational and multidisciplinary Delphi consensus study. Identifying language impairments in children. *PLOS One*, 11 (7). http://dx.doi.org/10.1371/journal.pone.0158753

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. http://dx.doi.org/10.1191/1478088706qp063oa

Braun, V., Clarke, V., Hayfield, N. and Terry, G. (2018). Thematic Analysis. In: Liamputtong, P., (ed) Handbook of Research Methods in Health Social Sciences. Singapore: Springer.

Bunting, M.F., & Cowan, N. (2005). Working memory and flexibility in awareness and attention. *Psychological Research*, 69, 412-419. https://doi.org/10.1007/s00426-004-0204-7.

Chowdry, H., & McBride, T. (2017). *Disadvantage, behavior and cognitive outcomes: Longitudinal analysis from age 5 to 16.* London: Early Intervention Foundation.

Corbin Dwyer, S., & Buckle, J.L. (2009). The space between: on being an insider-outsider in qualitative research. *International Journal of Qualitative Methods*, 8(1), 54-63. https://doi.org/10.1177/160940691878817 6

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Prog Brain Res.*, 169, 323–338. https://doi.org/10.1016/S0079-6123(07)00020-9.

Dollaghan, C. A. (2007). *The handbook for evidence-based practice in communication disorders*. Baltimore, MD: Paul H. Brookes Publishing.

Ebbels, S.H., McCartney, E., Slonims, V., Dockrell, J., & Norbury, C.F. (2019). Evidence based pathways to intervention for children with Language Disorders. *International Journal of Language and Communication Disorders,* 54(1), 3-19. https://doi.org/10.1111/1460-6984.12387

Ellis Weismer, S., Davidson, M. M., Gangopadhyay, I., Sindberg, H., Roebuck, H. & Kaushanskaya, M. (2017). The role of nonverbal working memory in morphosyntactic processing by children with specific language impairment and autism spectrum disorders. *Journal of Neurodevelopmental Disorders*, 9, 28. https://doi.org/10.1186/s11689-017-9209-6

Engel de Abreu, P.M.J., Gathercole, S.E., & Martin, R. (2011). Disentangling the relationship between working memory and language: the roles of short-term storage and cognitive control. *Learning and Individual Differences*, 21(5), 569-574. http://dx.doi.org/10.1016/j.lindif.2011.06.002

Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual differences in working memory for comprehension and following directions. *Journal of Educational Research*, *84*, 253-262. https://doi.org/10.1080/00220671.1991.10886025.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, 11, 19–23. https://doi.org/10.1111/1467-8721.00160.

Frizelle, P., Harte, J., O’Sullivan, K., Fletcher, P. & Gibbon, F. (2007). The relationship between information carrying words, memory and language skills in school age children with language impairment. *PLoS ONE*, 12(7), e0180496. https://doi.org/10.1371/journal.pone.0180496

Furnham, A. (1988). *Lay Theories: Everyday Understanding of Problems in the Social Sciences*. Oxford: Pergamon Press.

Gascoigne M. (2006). *Supporting children with speech, language and communication needs within integrated children's services*. *RCSLT Position Paper.* London: RCSLT.

Gathercole, S. E., & Baddeley A.D. (1993). Phonological working memory: a critical building block for reading development and vocabulary acquisition. *European Journal of Psychology and Education, 8,* 259. https://doi.org/10.1007/BF03174081.

Gathercole, S. E., Alloway, T. P., Willis, C. S., & Adams, A. M. (2006). Working memory in children with reading disabilities. *Journal of Experimental Child Psychology,* 93, 265- 281. https://doi.org/10.1016/j.jecp.2005.08.003.

Gathercole, S.E. (2008). Working memory and education. *The Psychologist*, 21 (5), 382–385.

Gathercole, S. E., Alloway, T. P., Kirkwood, H. J., Elliott, J. G., Holmes, J., and Hilton, K. A. (2008). Attentional and executive function behaviors in children with poor working memory. *Learning and Individual Differences*. 18, 214–223. doi: 10.1016/j.lindif.2007.10.003

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology, 40*, 177–190. https://doi.org/10.1037/0012-1649.40.2.177

Gathercole, S.E., Woolgar, F., Kievit, R.A., Astle, D., Manly, T., & Holmes, J. (2016). How Common are WM Deficits in Children with Difficulties in Reading and Mathematics? *Journal of Applied Research in Memory and Cognition*, 5, 384– 394. https://doi.org/10.1016/j.jarmac.2016.07.013.

Harron, A., & Dickson F. (2013). Perspectives on trans-disciplinary working for children in mainstream education. Oral presentation: Rehabilitation and Therapy Research Society conference.

Henry, L. (2012). *The development of working memory in children.* London: SAGE.

Henry, L.A., Messer, D. J., & Nash, G. (2014). Testing for near and far transfer effects with a short, face-to-face adaptive working memory training intervention in typical children. *Infant and Child Development*, 23 (1), 84-103.

Henry, L., & Botting, N. (2017). Working memory and developmental language impairments. *Child Language Teaching and Therapy, 33*(1),19-32. https://doi.org/10.1177/0265659016655378.

Holmes, J., & Adams, J. (2006). Working Memory and Children's Mathematical Skills: Implications for mathematical development and mathematics curricula. *Educational Psychology, 26*(3), 339-366, DOI: 10.1080/01443410500341056.

ICAN/RCSLT. (2018). Bercow: Ten Years on an Independent Review of Provision for Children and Young People with Speech, Language and Communication Needs in England. London: ICAN/RCSLT.

Jaroslawska, A.J., Gathercole, S.E., Allen, R.J., & Holmes, J. (2016). Following instructions from working memory: Why does action at encoding and recall help? *Memory and Cognition,* 44, 1183–1191. https://doi.org/10.3758/s13421-016-0636-5.

Joffe, V., & Pring, T. (2008). Children with phonological problems: A survey of clinical practice. International Journal of Language & Communication Disorders, 43, 154–164. doi:10.1080/13682820701660259

Law, J., Campbell, C., Roulstone, S., Adams, C., & Boyle, J. (2008). Mapping practice onto theory: the speech and language practitioner's construction of receptive language impairment. *International Journal of Language and Communication Disorders*, 43, 245 – 263. doi/abs/10.1080/13682820701489717

Law, J. (2019). Population woods and clinical trees. A commentary on 'Evidence-based pathways to intervention for children with language disorders'. *International Journal of Language and Communication Disorders,* 54(1), 26-27. https://doi.org/10.1111/1460-6984.12424

Lof, G.L. (2011). Science-based practice and the speech-language pathologist. *International Journal of Speech-Language Pathology*, *13*(3),189–196. https://doi.org/10.3109/17549507.2011.528801

Martinussen, R., & Tannock, R. (2006). Working Memory Impairments in Children with Attention-Deficit Hyperactivity Disorder with and without Comorbid Language Learning Disorders. *Journal of Clinical and Experimental Neuropsychology,* 28(7), 1073- 1094. https://doi.org/10.1080/13803390500205700

McCabe, P.J. (2018). Elizabeth Usher Memorial Lecture: How do we change our profession? Using the lens of behavioral economics to improve evidence-based practice in speech-language pathology. *International Journal of Speech-Language Pathology*, 20(3), 300-309. https://doi.org/10.1080/17549507.2018.1460526

McLeod, S., & Baker, E. (2014). Speech-language pathologists' practices regarding assessment, analysis, target selection, intervention, and service delivery for children with speech sound disorders. Clinical Linguistics & Phonetics, 28, 508–531. doi:10.3109/02699206.2014.926994

McCurtin, A. & Carter, B. (2015). We don't have recipes; we just have loads of ingredients': explanations of evidence and clinical decision making by speech and language therapists. *Journal of Evaluation in Clinical Practice,* 21(6) 1142-1150. https://doi.org/10.1111/1460-6984.12425

McCurtin, A. & Clifford, A.M. (2015). What are the primary influences on treatment decisions? How does this reflect on evidence-based practice? Indications from the discipline of speech and language therapy. *Journal of Evaluation in Clinical Practice,* 21(6), 1178-1189. https://doi:10.1111/jep.12385

Moore, G., Evans, R., Hawkins, J., LITTLECOTT, H., Melendez-Torres, G.J., Bonell, C., & Murphy, S. (2019). From complex social interventions to interventions in complex social systems: Future directions and unresolved questions for intervention development and evaluation. *Evaluation,* 25(1), 23-45. https://doi.org/10.1177/1356389018803219

Murphy, C. (2019). The limits of evidence and the implications of context: considerations when implementing pathways to intervention for children with language disorders. *International Journal of Language and Communication Disorders,* 54(1), 20-23. https://doi.org/10.1111/1460-6984.12387

Nail-Chiwetalu, B., & Ratner, N.B. (2007). An assessment of the information-seeking abilities and needs of practicing speech- language pathologists. Journal of the Medical Library Association, 95, 182. https://doi.org/10.3163/1536-5050.95.2.182

Noble, K.G., McCandliss, B.D., & Farah, M.J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science,* 10(4), 464-480. https://doi.org/10.1111/j.1467-7687.2007.00600.x

Olswang, L.B. & Prelock, P.A. (2015). Bridging the Gap Between Research and Practice: Implementation Science, *Journal of Speech, Language and Hearing Research*, *58*(6), 1-9.

Pawson. R., & Tilley, N. (1997). *Realistic Evaluation.* London: SAGE.

Pintrich, P.R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research, 31,* 459-470.

Rodak, J., & Alloway, T.P. (2018). *Developmental Coordination disorder and working memory*. In T.P. Alloway (Ed.), *Working Memory and Clinical Developmental Disorders. Theories, Debates and Interventions*. London and New York: Routledge.

Roulstone, S. (2015). Exploring the relationship between client perspectives, clinical expertise and research evidence International *Journal of Speech-Language Pathology*, 17(3), 211-221. https://doi.org/10.3109/17549507.2015.1016112

Rowe, A., Titterington, J., Holmes, J., Henry, L., & Taggart, L. (2019). A systematic review of the effectiveness of non-computerised interventions targeting working memory in 4-11 year olds. *Developmental Review,* 52,1-23. https://doi.org/10.1016/j.dr.2019.02.001

Sackett, D.L., Rosenberg, W.M., Gray, J.M., Haynes, R.B., & Richardson, W.S. (1996). Evidence based medicine: what it is and what it isn’t. *British Medical Journal*, 312, 71–72. https://doi: 10.1136/bmj.312.7023.71

Singer, B.D., & Bashir, A.S. (2018). Wait…What??? Guiding Intervention Principles for Students with Verbal Working Memory Limitations. *Language, Speech and Hearing Services in Schools*, 49(3), 449-462. https://doi.org/10.1044/2018_LSHSS-17-0101

Stanovich, P. J., & Stanovich, K.E. (2003). *Using research and reason in education: How teachers can use scientifically based research to make curricular and instructional decisions.* Portsmounth, NH: RMN Research Corporation.

Swanson, H. L. (1994). Short-term memory and working memory: Do both contribute to our understanding of academic achievement in children and adults with learning disabilities? *Journal of Learning Disabilities*, *27*(1), 34–50. https://doi.org/10.1177/002221949402700107

Swanson, H.L., Jerman, O., & Zheng, X. (2008). Growth in working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology*, *100*, 343–379. http://dx.doi.org/10.1037/0022-0663.100.2.343.

Tufford, L., & Newman, P. (2010). Bracketing in qualitative research. *Qualitative Social Work*, 11(1), 80-96. https://doi.org/10.1177/1473325010368316.

Van de Ven, A.H. & Johnson, P.E. (2006). Knowledge for theory and practice. *Academy of Management Review*, *31*(4), 802-821. https://doi.org/10.5465/amr.2006.22527385

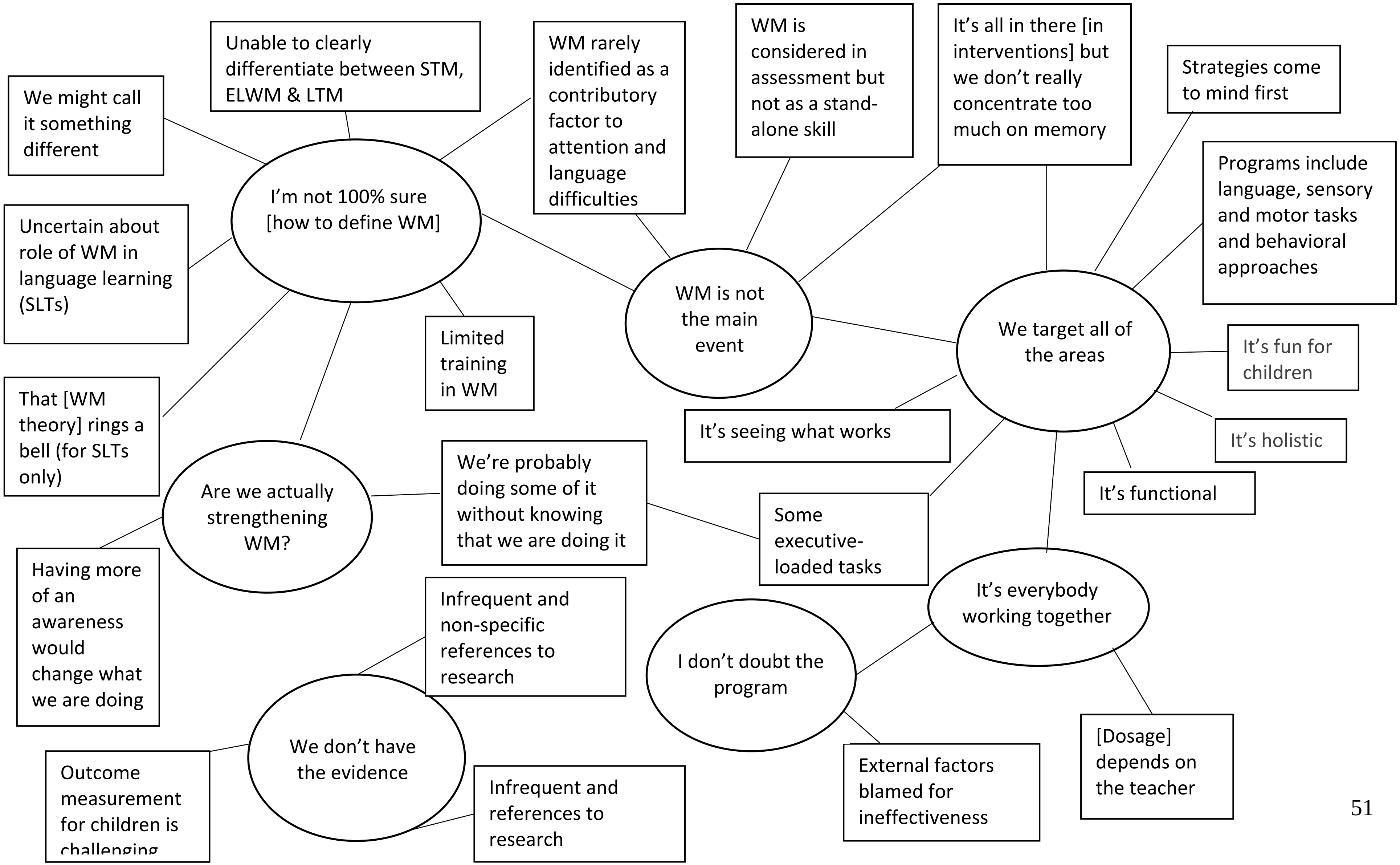
Zipoli, R.P., & Kennedy, M. (2005). Evidence-based practice among speech-language pathologists: Attitudes, utilization, and barriers. American Journal of Speech-Language Pathology, 14, 208–220. doi:10.1044/1058-0360(2005/021)

Appendix 1: Focus Group Schedule

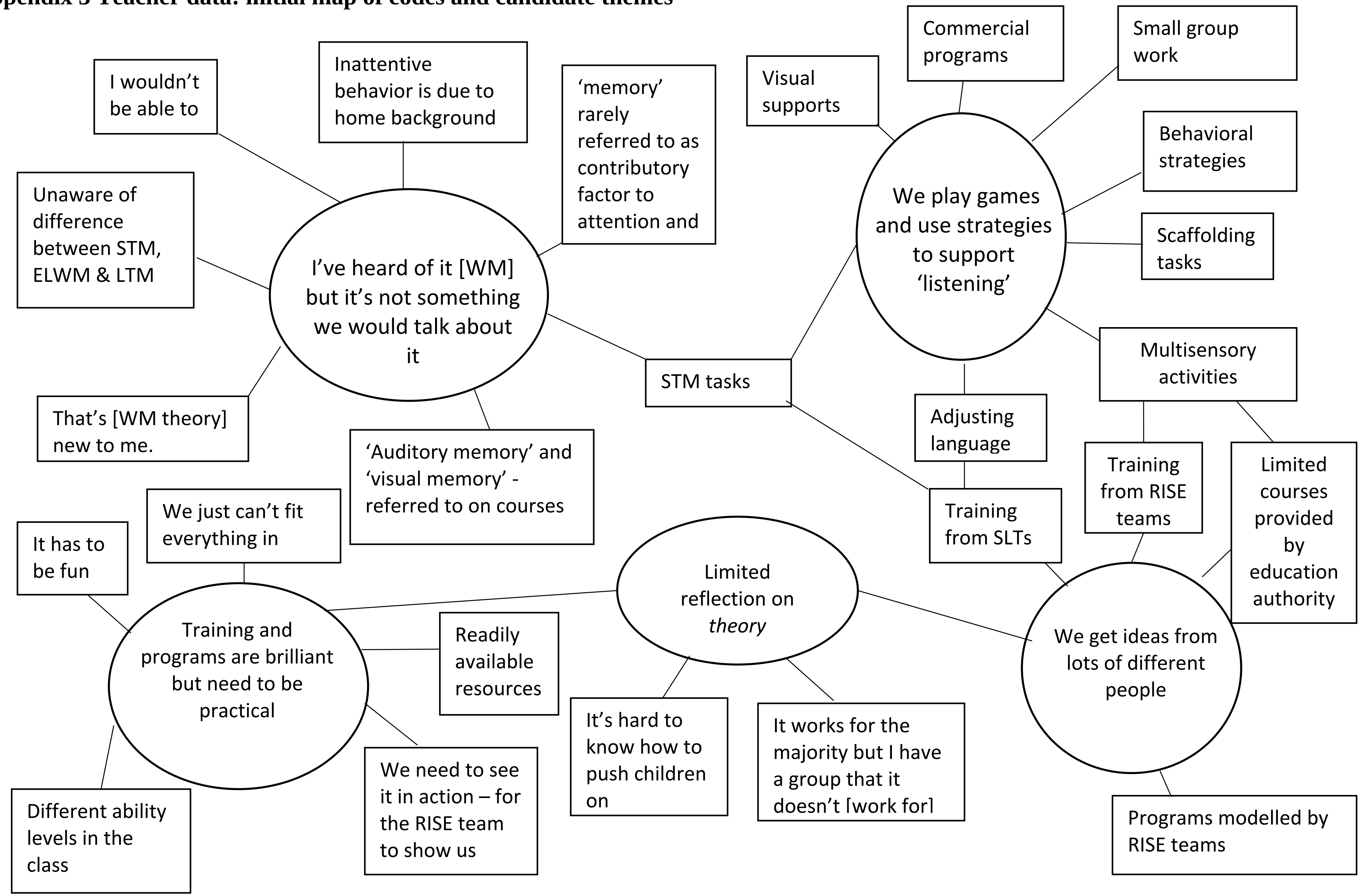
Introductions
• Obtain written consent for participation and consent for audio recording • Researcher introduces self and outlines the participants' role • Assurance of confidentiality and anonymity
Exploring knowledge and perceptions of working memory
Introduction to the topic: inform participants that the purpose of the focus group is to explore support for children who are inattentive and distractible in the classroom and have difficulty with: remembering and carrying out instructions; planning, organizing and keeping track of tasks Questions: - *What proportion of children would you say, in a year one classroom would experience these type of difficulties?* - *What do you think are the underlying reasons for these difficulties?* - *What do you think are the underlying commonalities which are causative to these difficulties?* - *What is your understanding of these causative difficulties?* Prompts for discussion: - *If participants directly name working memory as a causative factor – ask them how they would define it? What is their understanding of WM?* - *If nobody identifies working memory, explain that this can be a causative factor and ask the participants how they would define it? What is their understanding of WM?* - *If they seem unsure about working memory, explore whether they have had training on WM.*
Exploring current practice
Explain we are now going to think about the type of children described, who have difficulty coping in the classroom and may have underlying working memory problems. Questions: - *What key activities, strategies or interventions do you currently use to support the children that have been described in the classroom? How much and how frequently would you use these?* - *What informed your choice of these activities, strategies or interventions and the amount that you do?* - *What makes it easy/difficult to integrate activities into your practice?* - *How effective do you think they are?* - *Why do you feel your interventions work/don't work?*

Exploring knowledge of and responses to theory
If WM theory has spontaneously emerged in the discussion so far, refer back to participants' comments and use the questions below. If it has not been mentioned, explain that we are now going to think about what the research tells us about WM. Provide brief overview of: the working memory model (Baddeley and Hitch 1974, Baddeley 2000) Questions: - *Are there any differences in your understanding of WM and the research findings presented today?* - *If so, what was most striking to you?* - *Is this likely to change your thinking/classroom practice?*
Close
• Provide brief summary of information gathered. • Check if participants would like to make any additional comments. • Thank participants for their time and input. Ensure participants know what happens with their information, assure them again of anonymity and confidentiality and about the subsequent stages of the research and how the findings will be disseminated.

Appendix 2. Health professional data: initial map of codes and candidate themes



Appendix 3 Teacher data: initial map of codes and candidate themes



5.3 Summary of implications for intervention development and testing

Based on the findings of the qualitative study, the following implications for the development and testing of the novel intervention were identified:

1. Health professionals (HPs) and teachers involved in the development and testing of a novel classroom-based intervention targeting WM may benefit from training in: WM theory; the research evidence regarding the effectiveness of WM training; and the importance of dosage in intervention research and practice. This may be an important aspect of enabling HPs and teachers to deliver the to-be-developed intervention with fidelity to its protocol because, to date, they may have had limited training opportunities in the area of WM and its associations with attention in the classroom.
2. The amount of time and resources needed to enable HPs from the RISE teams and teachers to attend training and deliver interventions in the classroom context requires careful consideration during the intervention development. This reinforced the need to co-produce the intervention co-production with stakeholders in order to maximise the uptake and acceptability of the intervention (Wight *et al.* 2016).

Chapter 6 - Identifying the change mechanism

6.1 Introduction

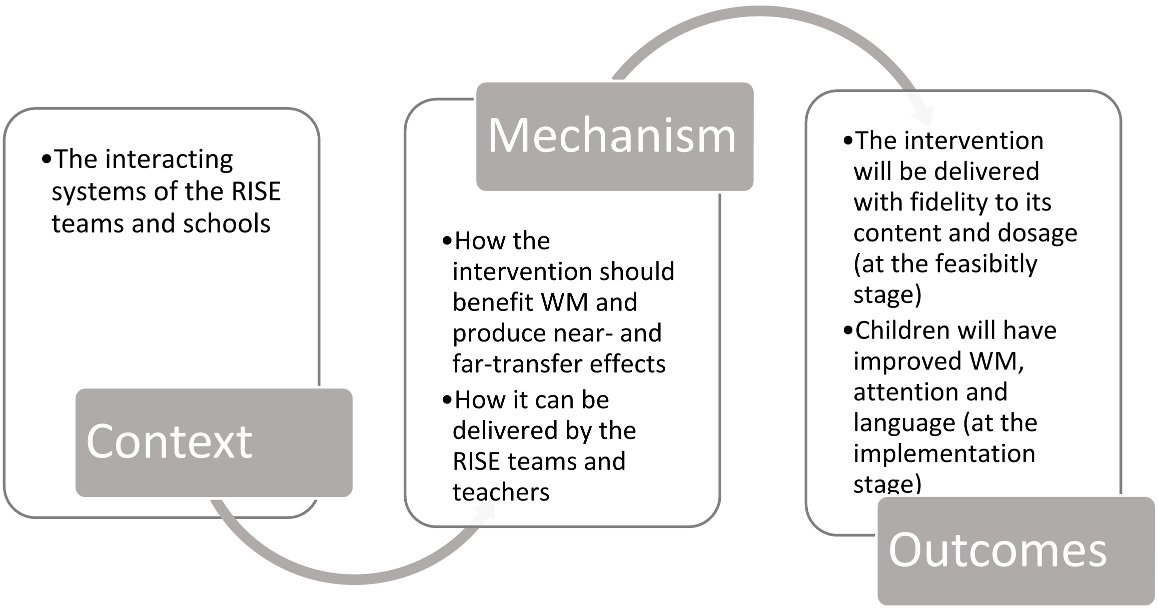
This chapter relates to step 3 of the Six Steps in Quality Intervention Development (6SQuID) model (Wight *et al.* 2016). It describes how the PhD researcher integrated the data gained from the systematic review and qualitative study, into a hybrid theoretically informed intervention. It commences with the rationale for why it was essential to elucidate both an individual and a systems theory of change in the current doctoral study and progresses to explain how this was done. The individual theory of change is then proposed. The next section details how the intervention components were selected and each one is described: two direct executive-loaded working memory tasks (listening recall and odd one out); phoneme awareness training and fantastical play. The final section summarises the process of developing an initial logic model that represents how the intervention should work in practice.

6.2 Rationale for developing a theory of change

The third step in the Six Steps in Quality Intervention Development model (6SQuID) model is to identify how to bring about change: the change mechanism (Wight *et al.* 2016). A theory of change should hypothesise or explain how and why an intervention will bring about the desired outcomes i.e., it should make the change *mechanism* embedded within an intervention explicit (Moore and Evans 2017). In other words, as discussed in chapter 3, it should open the so-called black box of an intervention (Hawe 2015). There are three key reasons why it was essential to propose a theory of change in this doctoral study.

Firstly, this is consistent with the realist paradigm that underpins the research aims and design. Identifying the mechanism embedded in an intervention is a central construct of Pawson and Tilley's (1997) Context-Mechanism-Outcomes (CMO) configuration that exemplifies the realist paradigm underpinning this study. The CMO framework demonstrates that the proposed casual mechanism embedded in an intervention can be altered or compromised by the context within which it is implemented, thus affecting its outcomes (Pawson and Tilley 1997). If an intervention's outcomes alone are evaluated (without consideration of whether the mechanism was delivered with integrity to its protocol), an otherwise potentially effective intervention may be dismissed as ineffective (Moore *et al.* 2019). It follows that, articulating a clear hypothesis of how and why an intervention should work supports the reliable evaluation of its implementation and/or efficacy (Moore and Evans 2017). Figure 6-1 depicts how the CMO framework supports the doctoral study.

Figure 6-1 Context-Mechanism-Outcomes Configuration for the to-be-developed intervention



The second reason for developing a theory of change takes cognisance of the criticisms levelled at previous WM research, where interventions failed to account for how and why they should improve children's WM and result in transfer to real-world skills (Melby-Lervåg and Hulme 2013, Redick *et al.* 2015) (see Chapter 2). In order for the to-be-developed intervention to make a meaningful contribution to WM research, it must be underpinned by a robust, evidence-informed theory that proposes how it should benefit WM skills in 4-5 year olds from areas of social disadvantage and produce far-transfer effects to their attention and language skills.

Thirdly, as discussed in Chapter 5, it is also vital that health professionals' and teachers' practice is underpinned by theory (Roulstone 2015). Therefore, in order that this doctoral study makes a valuable contribution to evidence-based practice and service provision for children from areas of social disadvantage with attention and language difficulties, it must provide a clear theoretical account for how it will support these skills (Lof 2011, McCabe 2018).

Theories of change often include more than one strand (Wight *et al.* 2016). The rationale laid out so far in this chapter explains the need for an individual theory of change that proposes how and why the to-be-developed intervention should impact on WM and enhance children's attention and language skills (Melby-Lervåg and Hulme 2013, Redick *et al.* 2015). In keeping with the realist paradigm that underpins this doctoral study, the causal mechanism proposed in the individual theory of change will operate according to the intervention *context* (Bhaskar 1997) and the intervention itself will take place within an open system (Bhaskar 2008, Byrne 1998). In the current study, the intervention context was identified as the complex interacting systems of the RISE teams and mainstream primary schools in Northern Ireland (NI) (see Chapters 1 and 3). Therefore, it was important to develop a systems theory of change to account for how the intervention could be implemented within this context (Shearn *et al.* 2017, Shiell *et al.* 2008). Furthermore, the explicit aim of developing a systems theory of change exemplifies the application of complexity theory (Byrne 1998) and the ecological perspective that complement realist research approach (McLeroy 1988). From a systems perspective, logic models (visual representations of how a programme works) can be a useful method of linking theoretical concepts to the actual activities and resources required to reach the desired outcomes within the defined context (WK Kellogg Foundation 2014) (see Chapter 3). Therefore, one of the key aims of this step in the intervention development was create a preliminary logic model of how the intervention should work.

6.3 Aims

There were three aims for this step of the intervention development, with each one building iteratively on the one before:

1) To identify a theory of change encompassing individual and systems elements to explain how and why the intervention targeting working memory (WM) to enhance attention and language skills in 4-5 year olds from areas of social disadvantage (SD) is expected to:

    a) Benefit the children's WM skills and produce transfer effects to attention and language skills (at the individual level).
    b) Be suitable for implementation within the context of the dynamic, interacting systems of the RISE teams and schools (at the systems level).

2) To select the intervention components, based on the individual change theory.

3) To develop a preliminary logic model representing how the hybrid, theoretically informed intervention should work in preparation for co-production work with stakeholders.

6.4 Aim 1a. To identify the individual theory of change

The individual change theory aims to account for how and why the intervention should benefit children's WM and produce near-transfer effects to untrained WM skills and far-transfer effects to attention and language skills (Melby-Lervåg and Hulme 2013, Redick *et al.* 2015).

6.4.1 Methods

A series of evidential and conceptual statements was extracted from: the extant literature on WM training and transfer effects based on empirical research (Chapter 2); current theorising around mechanisms of training and transfer effects (Chapter 2); and the novel evidence harvested in this doctoral study through the systematic review of interventions targeting WM in 4–11 year olds within their everyday contexts (Rowe *et al.* 2019a, Chapter 4). This series of statements were synthesised into one coherent hypothesis (Walker and Avant 2011, Pawson 2013, Shearn *et al.* 2017). To add to the rigour of this process, two forms of theory triangulation were used to ensure the robustness of the proposed theory (Denzin 1989). Firstly, it was viewed by the PhD researcher in terms of its consistency with the Working Memory Model (Baddeley and Hitch 1974, Baddeley 2000, 2007). Secondly, the two external advisors for this doctoral study (L.H. and J.H.) were consulted during this process.

6.4.2 Results

Table 6-1 presents the evidential and conceptual statements extracted from the existing empirical evidence on WM training, the systematic review findings and theories proposed in the WM literature. These statements relate to: the nature of the tasks that were found to benefit WM; why and how they may produce effects; the amount and intensity of training (dosage) that has shown to be effective; evidence about transfer effects; and the proposed ecological validity of WM training embedded within typical educational activities.

Table 6-1 Evidential and conceptual statements informing the individual theory of change

	Evidential/conceptual statements	**Evidence source**
Type of task trained	Both direct training on WM tasks and repeated practice on certain other tasks that may impact on WM indirectly (physical activity, fantastical play and inhibition) were beneficial. The common ingredient across effective interventions was the executive-loaded nature of the trained task i.e., training on a task that taps into attentional and processing resources under executive control not just the storage of information.	Systematic review evidence (Rowe *et al.* 2019a)
How/why tasks may be effective	Repeated practice on executive-loaded working memory (ELWM) tasks (rather than practising storage-only, short-term memory tasks) may improve the efficiency of processing or perhaps even facilitate the storage of information in WM.	Existing evidence base (Henry *et al.* 2014, Loosli *et al.* 2011)
Transfer effects	Training on certain complex span tasks may support the development of new cognitive routines that can then be applied to other tasks with shared features. In ELWM tasks, attention must be divided between the storage and processing demands of the task. This may overlap with the way attention is used in everyday (real-world) activities and support the development of new cognitive routines. Since treatment effects are more likely to transfer from trained activities to activities with overlapping features, direct training on ELWM tasks may benefit untrained WM tasks and real-world skills including attention and language (near- and far-transfer effects).	Theories proposed in WM literature (Gathercole *et al.* 2019)

	Embedding WM training within the types of classroom tasks that depend on it may be an ecologically valid intervention approach. This overlaps with how WM is used in real-life, where children must ignore distractions in the classroom, thereby tapping into the attentional resources of the central executive component of the WM model (Baddeley 2000, 2007).	Theories proposed in WM literature (Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014)
Amount and intensity of training (dosage)	Training effects can be observed following relatively short interventions (5-8 weeks)	Systematic review (Rowe *et al.* 2019a)
	The most robust evidence suggesting repeated practice 3 times per week for 6 weeks is effective.	Empirical evidence (Henry *et al.* 2014)

6.4.3 Conclusion – the proposed individual theory of change

Figure 6-2 shows the proposed individual theory of change derived from the synthesis of the evidence presented in Table 6-1. This theory is consistent with the Working Memory Model (Baddeley and Hitch 1974, Baddeley 2000, 2007) that accounts for a distinction between: storage-only (STM) tasks requiring the resources of the phonological loop or the visuospatial sketchpad; and executive-loaded working memory (ELWM) tasks that tap into higher-level cognitive processes within the central executive (see Chapter 2). However, it must be noted that the robustness of this theory is limited by the lack of empirical evidence for the cognitive routine theory proposed by Gathercole *et al.* (2019), which has not yet been tested. The challenges of testing theories of WM training and transfer effects must also be acknowledged. In order to ascertain whether transfer to untrained tasks has actually occurred, the features of the trained and untrained WM tasks, and the boundaries between them, must be specified clearly (Holmes *et al.* 2019, Gathercole *et al*. 2019).

Figure 6-2 The proposed individual theory of change

Content and setting:
If 4-5 year olds from areas of SD complete repeated practice on ELWM tasks in the classroom setting, they will have improved WM skills and created new cognitive routines, which will promote transfer effects to their attention and language skills because the nature of the trained tasks (requiring storage and processing) and their delivery in the classroom setting (requiring inhibition to resist distraction) overlaps with how WM is used in real-life.

Dosage:
Repeated practice on ELWM tasks 3 times per week for 6 weeks will improve children's WM.

If 4-5 year olds from areas of SD receive a multi-component intervention including executive-loaded tasks repeated 3 times per week for 6 weeks in the classroom setting, they will have improved WM skills and created new cognitive routines that will promote transfer effects to their attention and language skills because the intervention tasks and the need to resist distraction in the classroom setting overlap with how WM is used in real-life.

6.5 Aim 1b. To develop the systems theory of change

The systems theory of change aims to explain how the intervention could be implemented within the complex interacting systems of the RISE teams and schools (Shearn *et al.* 2017, Shiell *et al.* 2008).

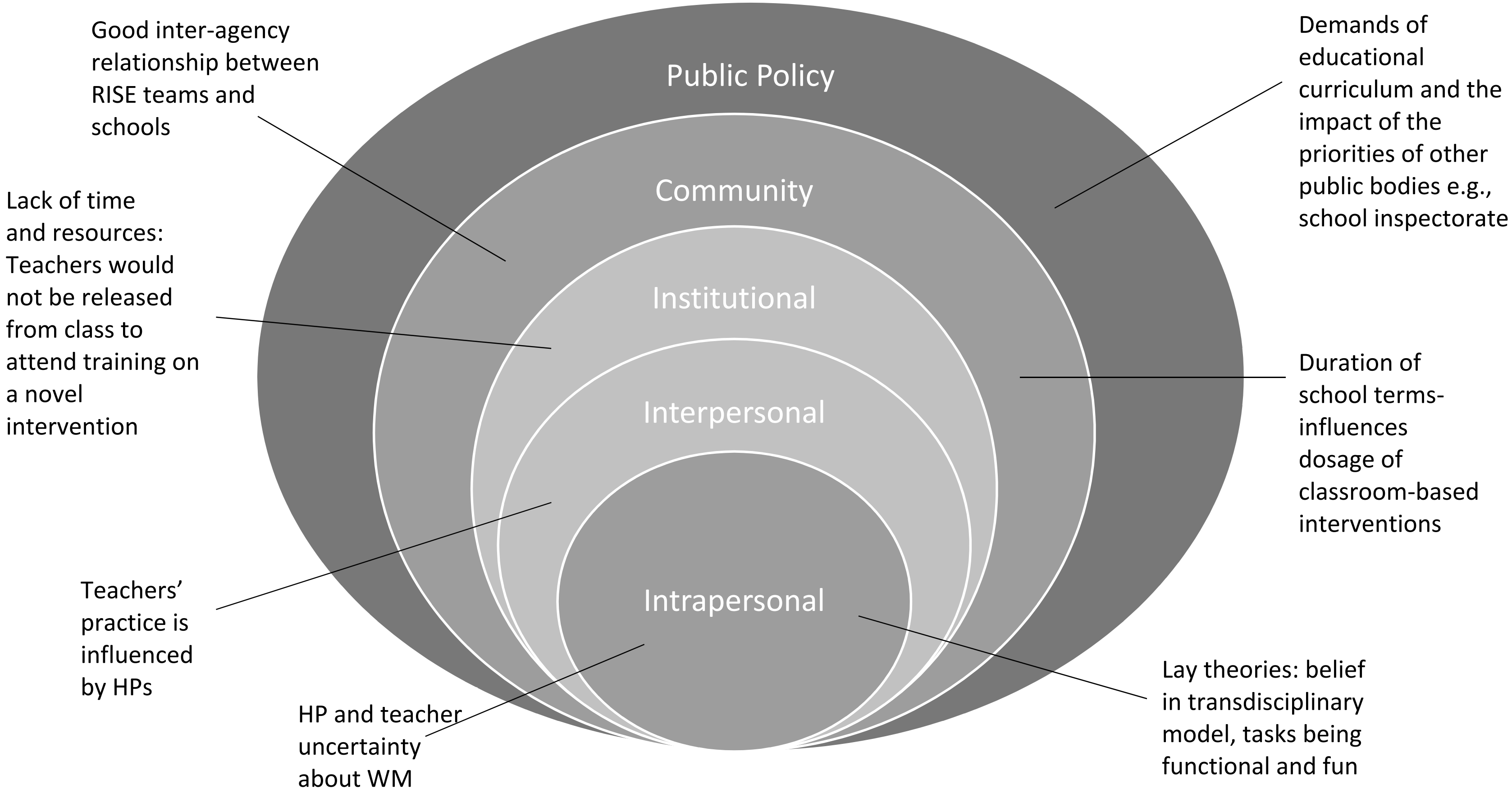
6.5.1 Methods

This was developed by creating a list of the potential barriers and facilitators to the development and testing of the novel intervention gathered through the qualitative study (Chapter 5). The data were categorised according to the five levels of the socio-ecological model (McLeroy *et al.* 1988) (see 3.5.2.5) and the implications for the intervention development were identified. Consultation with the Research Advisory Group that includes key stakeholders and service user representatives (see 3.4) for this doctoral study was also carried out to enhance the rigour of this process. Moreover, the (limited) literature regarding the implementation of classroom-based interventions was also consulted.

6.5.2. Results

Figure 6-3 presents the major barriers and facilitators to the intervention implementation within the context of the interacting systems of the RISE teams and schools, categorised according to the five levels of the socio-ecological model (McLeroy *et al.* 1988). Overall, the focus group findings indicated that both health professionals (HPs) and teachers might benefit from training on the underpinning theory and delivery of a classroom-based intervention prior to implementing it. This is reflected in the '*limited training on WM'* theme derived from the data (described in Chapter 5). However, the data also suggested that, due to resource constraints, it would be unlikely that teachers would be released from their teaching responsibilities to attend training. Discussion with the Research Advisory Group for the doctoral study, that includes a teacher and two managers from the RISE teams, reinforced this finding. In addition, they advised that, because of industrial action taking place at the time of the study, many teachers in Northern Ireland were not participating in activities outside of the typical school day.

Figure 6-3 Key system factors influencing decision making and service delivery at each level of the socio-ecological model (McLeroy *et al.* 1988)



The qualitative study also revealed that teachers' practice is influenced by having interventions modelled for them by the RISE teams and that *"seeing it in action"* enables them to replicate activities and strategies in the classroom. This led to the hypothesis that, rather than teachers attending direct training on the novel intervention, the HPs could model it for them i.e., that modelling is a way to cascade training. Both the teacher member and the RISE team managers corroborated this theory and confirmed that this is consistent with their current, routine collaborative practice. As outlined in chapter 1, the literature evidence is scarce in relation to the effectiveness of this practice and whether it enables interventions to be implemented with adequate fidelity to their protocols (Ebbels *et al.* 2019). However, the concept of HPs modelling activities and strategies in the classroom, with the aim of them subsequently being incorporated into everyday practice, has been proposed as a mutually beneficial aspect of collaborative practice in schools and a way of increasing intervention dosage (Archibald 2017a, Nippold 2011, 2012).

Table 6-2 provides additional details of the barriers and facilitators to the intervention implementation categorised according to the five levels of the socio-ecological model (McLeroy *et al.* 1988).

Table 6-2 The barriers and facilitators to the intervention development and testing and their implications

Level of socio-ecological model (McLeroy *et al.* 1988)	**Barriers to intervention development and/or testing**	**Facilitators to intervention development and/or testing**	**Implication for intervention development and testing**
Interpersonal	HPs and teachers are uncertain about WM including: a lack of recognition of WM as a potential contributory factor for children's inattentive behaviour in the classroom; and a lack of clarity on the structure and function of WM. They have received limited training on WM.	HPs engage with theory when presented with it.	Training on WM will be essential for HPs and teachers involved in the development and/or testing of a novel intervention targeting WM. This must include both WM theory and how to apply it to practice. HPs are likely to implement a novel intervention with good fidelity to its theoretical underpinning if provided with adequate training.
	Current practice is eclectic and based on lay theories.		This confirms evidence from consultation with the RISE teams during the conception of the doctoral study suggesting that the current intervention used to target attention and listening skills is not underpinned by WM theory. It may be an appropriate control intervention for a feasibility trial.
		Belief in the transdisciplinary model.	This lay theory is based on the concept that tasks are more effective when they are complex. This is consistent with the concept that ELWM tasks may be effective because they require children to use their attentional resources (see Chapter 2). Therefore, HPs should engage readily with the theory underpinning the novel intervention, which may in turn support their buy-in to an intervention that they did not create.

			Within the transdisciplinary model, a novel intervention targeting WM to enhance attention and language could be delivered by HPs in the RISE teams from any background (speech and language therapists, physiotherapists, occupational therapists and social, emotional and behaviour specialists).
		Belief that children learn when tasks are functional and fun.	This lay theory is consistent with the theory that motivation is important for learning (Pintrich 1999) (see Chapter 5). All tasks in the novel intervention should be designed to be fun for 4-5 year olds.
	Dosage is not key to children's outcomes.		The importance of dosage needs to be emphasised during training. Clear guidance regarding all aspects of dosage must be provided in any materials designed to support the intervention development and testing e.g., an intervention manual, session plans or materials
	Teachers are uncertain about their effectiveness.	HPs are confident about their effectiveness.	If HPs feel confident in the delivery of a novel intervention, they may be able to support teachers to deliver it i.e., training could be cascaded from HPs to teachers.
Intrapersonal	HPs' treatment choices are influenced by their perceptions of what teachers will find acceptable.	Teachers' practice is influenced by the interventions implemented by HPs in the classroom.	The importance of adhering to the theoretical underpinning of the intervention and its evidence-based dosage must be emphasised to HPs so that they model the novel intervention with good fidelity to the intervention protocol as this will affect teachers' delivery. Training and a detailed manual would support this.

Institutional		Lack of time and resources in schools.	Teachers would not be released from class to attend training on a novel intervention. Schools would not have a budget to buy additional resources required for the intervention. Any resources needed for the delivery of a novel intervention should be provided. Intervention implementation is dependent on school timetabling. The intervention delivery would be restricted to the classroom as it is unlikely that school timetables could accommodate the use of a larger hall several times per week.
Community	Relationship between RISE teams and schools.		The existing relationship between the RISE teams and schools may support the recruitment and retention of participants in a feasibility study.
Public Policy		Demands of the education curriculum.	A feasibility trial will be necessary to determine whether it is possible for teachers to deliver a novel intervention with adequate fidelity to its dosage in the whole class setting.

6.5.3 Conclusion – the proposed systems theory of change

It was considered unlikely that teachers would be released from their daily duties to attend training on WM and the delivery of the novel intervention. The qualitative study, coupled with stakeholder opinion, suggested that this issue could be managed best by trained HPs modelling the intervention sessions once per week for the teachers. Moreover, this approach is supported by suggestions in the literature around classroom-based interventions delivered for children at risk of language disorder (Archibald 2017a, Nippold 2011, 2012). Testing this approach would address the gap in the literature around the optimal models of service delivery in real-life contexts. Figure 6-4 shows the proposed systems theory of change derived from the synthesis of the evidence presented in Table 6-2.

Figure 6-4 The proposed systems theory of change

If HPs from the RISE teams are provided with training, they will be able to deliver a mutli-component WM intervention (including executive-loaded tasks) in the classroom setting once per week for 6 weeks with fidelity to the intervention protocol because they will understand the theory underpinning it.

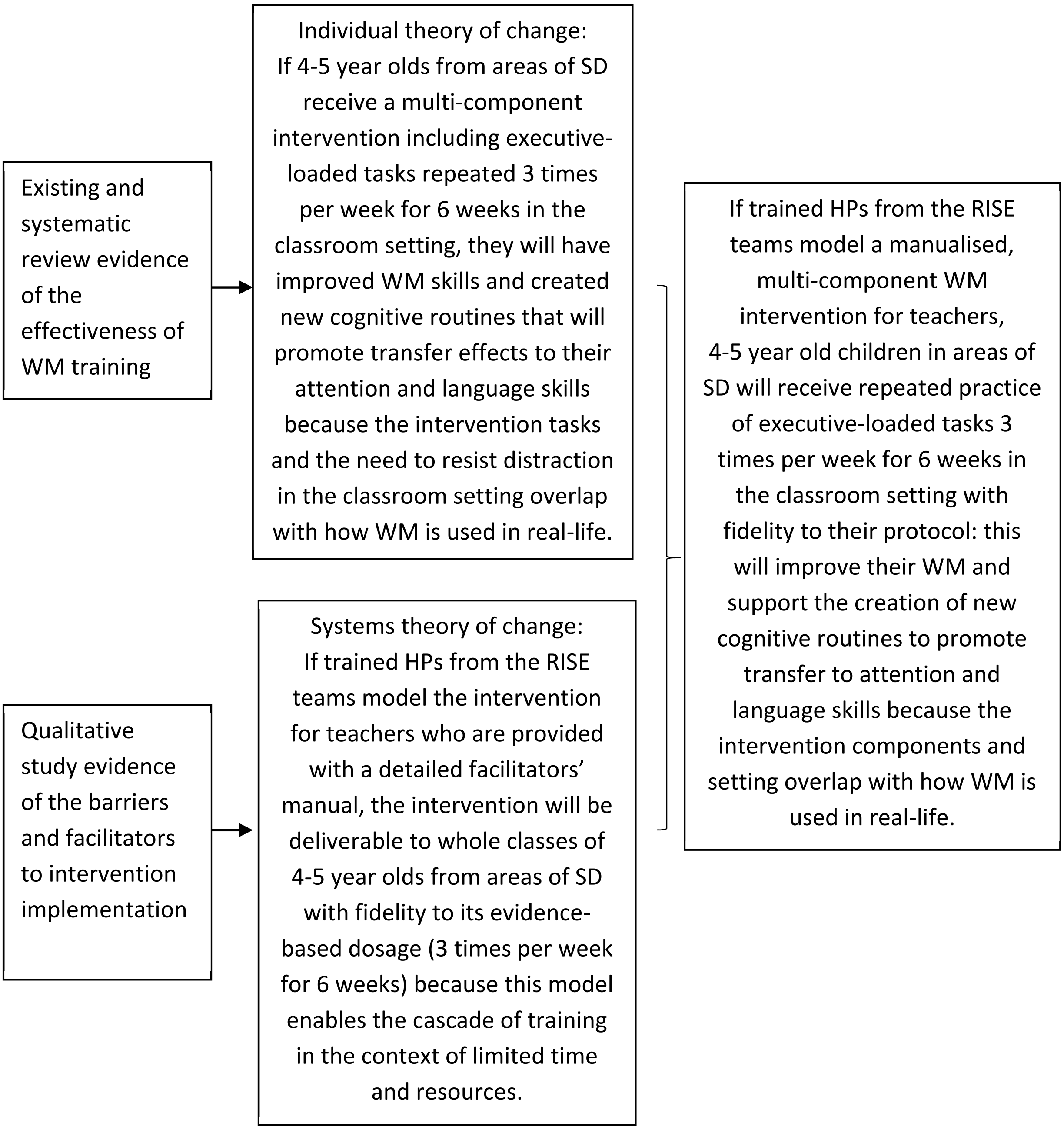
If teachers have a detailed facilitators' manual and observe HPs from the RISE teams delivering the classroom-based intervention once per week, they will be able to provide 2 practice sessions per week in adherence to the intervention protocol.

If trained HPs from the RISE teams model the intervention for teachers who are provided with a detailed facilitators' manual, the intervention will be deliverable to whole classes of 4-5 year olds from areas of SD with fidelity to its evidence-based dosage (3 times per week for 6 weeks) because this model enables the cascade of training in the context of limited time and resources.

6.6 The proposed intervention theory of change

Figure 6-5 shows how the proposed theory of change for the intervention was informed by the integration of mixed methods evidence.

Figure 6-5 The proposed theory of change underpinning the intervention development



6.7 Aim 2. To select the executive-loaded intervention components

Having identified that all of the intervention components were to be executive-loaded tasks (Figure 6-4), the next aim was to select which ELWM tasks should be included in the classroom-based intervention targeting working memory to enhance attention and language skills in 4-5yr old children from areas of social disadvantage.

The systematic review of working memory (WM) interventions applied with 4-11 year olds in everyday contexts found that both direct executive-loaded working memory (ELWM) training and targeting certain skills indirectly benefitted WM and had the potential to produce transfer effects (Rowe *et al.* 2019a). Based on this evidence, the novel intervention could include any (or all) of the following activities: direct ELWM training; cognitively-demanding physical activity, phoneme awareness training; fantastical play; and games targeting inhibitory control. From an ecological perspective, data from the qualitative study highlighted that teachers feel under pressure to deliver the education curriculum and time within the school day is limited (Chapter 5). Therefore, it was necessary to limit the number of tasks and to prioritise those that have the most potential to impact on the outcomes of interest (to produce effects on trained tasks, near-transfer to untrained WM tasks and far-transfer to attention and language skills).

6.7.1 Methods

The PhD researcher collated the data gathered through the systematic review using the completed Template for Intervention Description and Replication (TIDieR) checklists (Hoffmann *et al.* 2014) (see Appendix J). For each intervention deemed to have positive effects on WM, the following details were transferred onto a single excel spreadsheet: the rationale for the intervention; the materials and procedures required; who delivered it; how, where and when it was administered; and how much was provided (dosage). The decision to include or exclude activities/tasks from the intervention was based on the following criteria:

- their theoretical associations with the real-world skills of interest in this doctoral study (attention and language skills);
- whether they could be delivered in short sessions over a relatively short intervention period (6 weeks);
- whether the original study reported sufficient details of the task(s) to support their replication;
- and whether they could be administered easily and safely in the classroom setting.

This phase of the study demonstrates the integration of the extant theory on WM and its associations with attention and language skills with the unique findings from the systematic review and qualitative studies undertaken as part of this doctoral study.

6.7.2 Results

Table 6-3 presents a list of the tasks that were considered potential components for the classroom based intervention (identified from the systematic review evidence, Chapter 4), the decision to exclude or include them and the rationale for this decision. This shows that four components were selected for the intervention: direct ELWM training involving two tasks (listening recall and odd one out); phoneme awareness training; and fantastical play. Fantastical play was selected as a means of making the intervention fun for 4-5 year olds, whilst also potentially enhancing its effectiveness, but not as a directly trained task (see Table 6-3). The next section (6.7.3) defines these components and presents the theory and evidence that further underpin their selection for the intervention.

Table 6-3 Potential intervention components and rationale for their inclusion/exclusion

Intervention Type	Potential intervention tasks	Included/ excluded	Rationale for inclusion/exclusion in the novel intervention
Direct executive-loaded WM training	Listening recall Odd one out (Henry *et al.* 2014)	Included	Of these three directly trained ELWM tasks, listening recall and odd one out were favoured due to the strength of the evidence reviewed. The Henry *et al.* (2014) study had the most robust study design, including an active control group that received an intervention of comparable dosage to the experimental condition. This is desirable in research into behavioural interventions (Shipstead *et al.* 2012). This study was assessed as having a low risk of bias (see systematic review paper, Chapter 4) and reported all aspects of the intervention dosage, making their replication in the novel intervention straightforward.
	Verbal and visuospatial dual tasks (Passolunghi and Costa 2016)	Excluded	
	Backward digit recall (Witt 2011)	Excluded	
	Word list recall tasks with updating (Cornoldi *et al.* 2015)	Excluded	This intervention was conducted with children aged 8-10 years and included a meta-cognitive element that may be challenging for 4-5 year olds since evidence suggests that strategy-use only begins to emerge at around 5 years (Gill *et al.* 2006).
Training other skills to impact on WM indirectly	Cognitively-demanding physical activity	Excluded	The exact nature and theoretical underpinning of the interventions were specified poorly in some of the papers included in the systematic review. Where the tasks were specified, implementing them on a regular basis in the limited physical space of the classroom (where the school timetabling would most likely prohibit the use of a hall) would be challenging and potentially unsafe. For example, some of the interventions targeted ball skills (e.g., Alesi *et al.* 2016) which could only be carried out in the classroom with so much modification that the confidence in their effectiveness would be limited. In addition, the total duration of these interventions was too long (minimum 10 weeks) for the context of the RISE teams and schools (see Chapter 4).

Training other skills to impact on WM indirectly	Phoneme awareness training (Melby-Lervåg and Hulme 2010, van Kleeck *et al.* 1998, 2006)	Included	This is based on sound theoretical thinking around the associations between the effectiveness of phonological processing and language acquisition and the hypothesis that improving phoneme awareness skills might also improve the phonological mechanisms underlying WM, through increasing the efficiency of processing and supporting the creation of accurate, structured phonological representations (see additional details in Section 6.7.3.2). Since van Kleeck *et al.* (1998) investigated phoneme awareness training with small groups of children, it was reasoned that it could be implemented easily in the novel intervention. Furthermore, the tasks could be carried out with a pre-specified dosage.
	Fantastical play (Thibodeau *et al.* 2016)	Included	This is theoretically underpinned by the associations between play and cognitive skills (Vygotsky 1978). It has associations with functional language skills since the children use and develop scripts related to the fantastical theme when taking on a role (Thibodeau *et al.* 2016). Due to time constraints, it may not be possible to administer it with fidelity to the paper included in the systematic review and it would be difficult to specify dosage (Thibodeau *et al.* 2016). Therefore, it would not be possible to claim training effects based on its inclusion. However, some elements could be incorporated easily into the intervention and may enhance the children's engagement with and enjoyment of the programme.
	Games targeting inhibitory control (Volckaert and Noël 2015)	Excluded	The ultimate aim of a future effectiveness trial would be to contribute to the evidence base for far-transfer effects to attention skills from WM training. The inclusion of inhibitory control training in the intervention would make this challenging since the trained task and outcome measures of attention skills would be very similar.

6.7.3 Selected components: definitions, theory and evidence

6.7.3.1 Direct executive-loaded working memory training

Definition: Repeated practice of verbal or visuospatial tasks requiring the storage and processing of information, thereby tapping into attentional resources under executive control (Henry *et al.* 2014). The two direct ELWM tasks identified for inclusion in the intervention were listening recall and odd one out.

The theory: The use of tasks that directly target ELWM is based on the theory that ELWM underpins the processing of attention-demanding information. In ELWM tasks, attention must be divided between their storage and processing demands. This may overlap with the way attention is used in everyday activities. Therefore, ELWM tasks may be more effective than simple span (short-term memory) tasks in producing transfer to real world skills (Loosli *et al.* 2012, Henry *et al.* 2014). Repeated practice on ELWM tasks may improve the efficiency of processing or perhaps even facilitate the chunking of information during storage.

The evidence: There is evidence that direct ELWM tasks produce improvements on the trained skills and near-transfer to untrained WM tasks (Henry *et al.* 2014, Passolunghi and Costa 2016, Witt 2011).

a. Listening recall

This task targets verbal ELWM. It requires the child to listen to a short sentence, judge whether it is true or false and recall the last word of the sentence e.g., the child hears *'Cats are green'* and responds *'false'* and '*green'*. This is a complex span task, meaning that the difficulty of the task increases by asking the child to hold more items in their mind (rather than the complexity of the task increasing). The aim is to increase the number of sentences the child listens to and, therefore, the number of to-be-remembered words that they have to recall.

Listening recall is a complex span task with an interpolated processing item between the to-be-remembered word and the time of recall. The child judges the veracity of each sentence immediately after it is spoken but does not recall the final word of each sentence until after the total number of sentences has been heard. The child has to hold the last word of the sentence in their mind and protect it from interference/distraction while they judge whether the sentence is true/false (see Chapter 2). As the number of sentences increases, the target words are to be recalled in order. This is an example in which the child listens to two sentences i.e., there are two to-be-remembered words:

Adult: *Mermaids have legs.*

Child: *false*

Adult: *Fish can swim.*

Child: *true*

Adult: *Now tell me the last words of those two sentences.*

Child: *legs, swim*

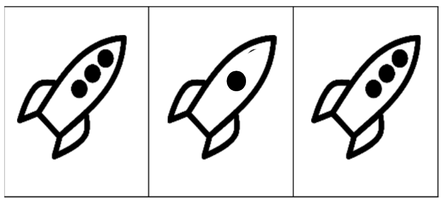
Evidence shows that even children with DLD can judge the veracity of simple sentences in the listening recall task (Ellis Weismer *et al.* 1999). This means this task should be appropriate for 4-5 year olds from areas of social disadvantage presenting with impoverished language skills (Law *et al.* 2011, Locke *et al.* 2002, Law *et al.* 2009). This is important because, if the processing demands of the task are too high (as they may be for children with limited vocabulary) the WM system could be overloaded and the children may 'zone out' or become distractible (Archibald 2017b, Gathercole 2008) (see Chapter 2).

b. Odd one out

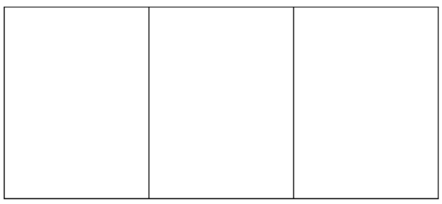
This task targets visuospatial ELWM. It requires the child to look at three pictures where one is slightly different from the others, then recall the position of the odd one out. Figure 6-6 provides an example of this task in which the children have to recall the location of one odd one out picture.

Figure 6-6 Example of odd one out task with one to-be-remembered location

The facilitator has a pile of cards. Each card shows three pictures, two are identical and one is slightly different in size, orientation or inner detail (the odd one out):



The facilitator shows the child one card, takes it away and asks the child to recall where the odd one out was. The child points to the location of the odd one out on a blank grid:



Odd one out is also a complex span task with an interpolated processing item i.e., the child has to judge the visual differences between the pictures in between seeing them for the first time and recalling the location of the odd one out (Holmes *et al.* 2019). As with the listening recall task, the aim is to increase the number of to-be-remembered odd items. To increase the difficulty level, the facilitator shows the child one card, then another card. Then the child points to the location of the two odd one out pictures on the blank grid, in the same order as they were presented.

6.7.3.2 Phoneme awareness training

Definition: Phoneme awareness is one aspect of a set of skills known as phonological awareness which has been defined as *"the ability to reflect on and manipulate the structure of an utterance (e.g., into words, syllables, or sounds) as distinct from its meaning"* (Stackhouse 1997 p.157). Hulme *et al.* (2012) refer to phoneme awareness as the ability to isolate and manipulate phonemes (sounds) in spoken words. It involves tasks in which children manipulate or make judgements on the sound structure of spoken words (Hulme *et al.* 2005) e.g., deciding if two words begin with the same sound.

The theory: Phoneme awareness training may impact on WM indirectly. Although the exact nature of the relationship between verbal WM skills and phonological awareness skills is not yet clear, there is evidence that they share a common phonological processing mechanism (e.g., Leather and Henry 1994, Oakhill and Kyle 2000). There is also evidence that our ability to recall words depends on their phonological representations in long-term memory (Bishop and Snowling 2004, Pennington and Bishop 2009). Improving phoneme awareness skills might also improve the phonological mechanisms underlying WM, through increasing the efficiency of processing and supporting the creation of accurate, structured phonological representations. In addition, phonological awareness tasks require attentional resources (e.g., Oakhill and Kyle 2000, Navarro *et al.* 2011). They require both the storage and processing of information e.g., holding a particular sound in temporary storage while you look for pictures that start with that sound. This is consistent with the theory that executive-loaded tasks enhance WM.

The evidence: Two types of evidence support the use of phoneme awareness tasks to improve WM. Firstly, phoneme awareness can be improved with intervention (e.g., Gillon 2000, 2002). Secondly, training phoneme awareness produces effects on WM skills (Melby-Lervåg and Hulme 2010, van Kleeck *et al.* 1998, 2006). In particular, the papers reviewed in Chapter 4 showed positive effects on verbal short-term memory (VSTM) measured using word span (see Tables A and B1 in Appendix I). This means that training phoneme awareness skills may have the potential to enhance language skills, since VSTM is associated strongly with word learning (e.g., Baddeley *et al.* 1998) (see Chapter 2).

6.7.3.3 Fantastical play

Definition: Fantastical play occurs when children engage in pretend play that is *fantasy-oriented*. This contrasts with pretend-play in which children simply pretend to be another person or animal without a fantastical element. For example, fantastical play might involve flying a car in outer space whereas pretend-play would involve the simple pretence of driving a car (Thibodeau *et al.* 2016).

The theory: Vygotsky (1978) proposed that pretend-play provides a natural environmental experience in which cognitive skills can be developed. Furthermore, it has been suggested that engaging in *fantastical* play may support children's executive function skills that are used to switch between the fantasy and reality and to remember the rules and scripts of the pretence (Estes *et al.* 1989, Golumb and Kuersten 1996).

***The evidence**:* Thibodeau *et al.* (2016) found that 3-5 year olds who participated in a fantastical play intervention (e.g., pretending to make food for a giant who has come for dinner) showed improvements on WM skills after a 5-week, small group intervention. Specifically, positive effects were observed on VSTM tasks (see Tables A and B1 in Appendix I). Therefore, as with phoneme awareness training, it is possible that the inclusion of this task may promote the development of functional language skills, based on the associations between VSTM and word learning (Baddeley *et al.* 1998). Children who received a pretend-play intervention (e.g. simply pretending to make dinner) or education as usual did not show improvements on their WM skills.

6.8 Aim 3. To develop an initial intervention logic model

Logic models are a recognised way of understanding the competing demands that may compromise intervention implementation (Hawe 2015). At this stage of the doctoral study, logic modelling was used to ensure that there was a basic, preliminary understanding of the intervention (according to the proposed individual and systems theories of change) in order to identify the activities and resources required to get the intervention ready for testing.

6.8.1 Methods

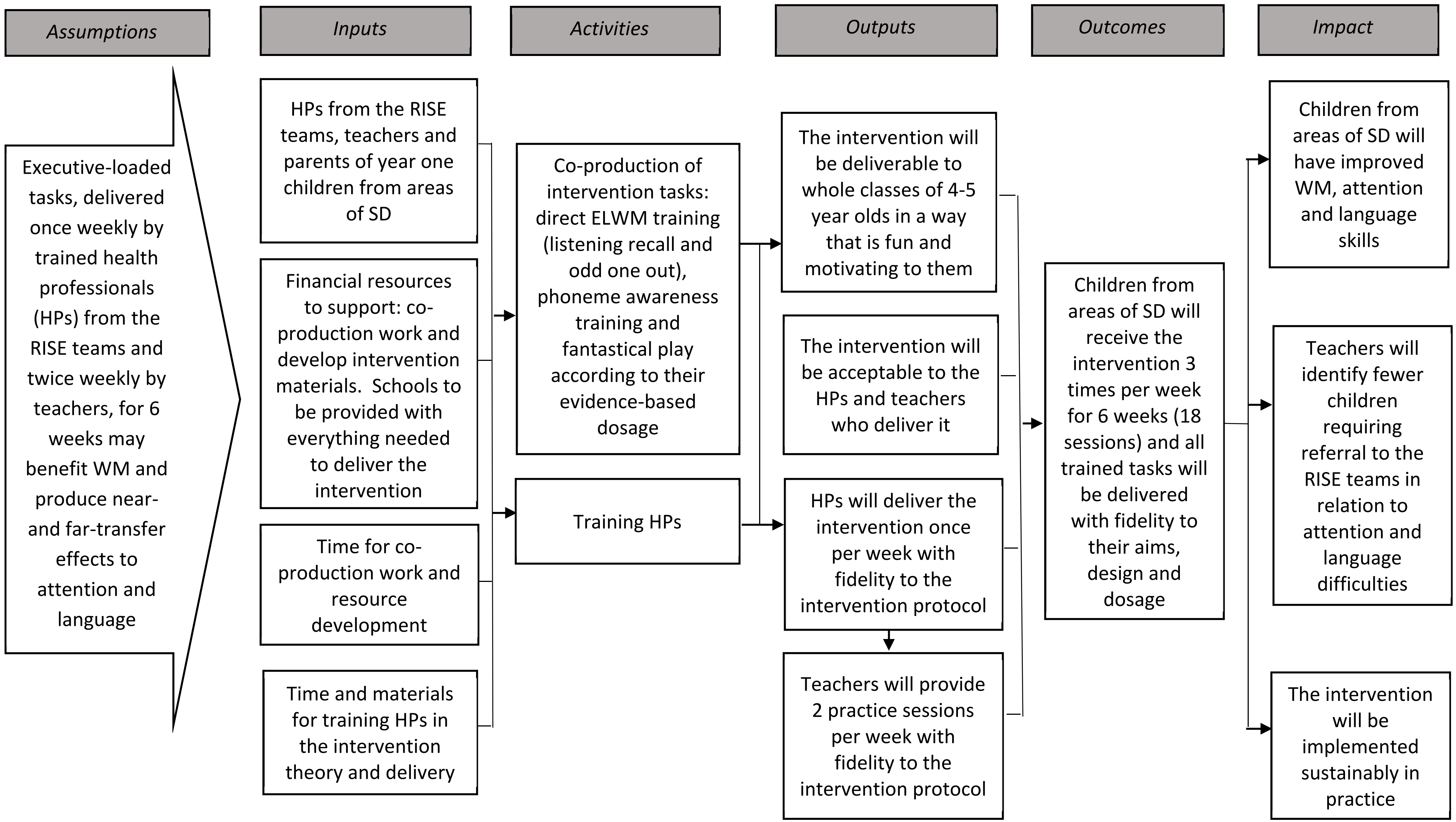
The PhD researcher mapped the theory of change and the selected intervention components described so far in this chapter onto the theory logic model template (presented in Chapter

3). This process demonstrates the integration of mixed methods evidence by embedding it within the logic model (Creswell and Creswell 2018).

6.8.2 Results

Table 6-4 presents the initial logic model, which highlighted that the major resource required to develop and test the intervention was HPs and teachers. This underscored the need to engage practitioners in co-production work (the next step of this study) in order to gain a full understanding of how to actually deliver the intervention in the real-life setting of the classroom. Furthermore, it emphasised the importance of gaining buy-in from these key stakeholders' during the intervention development process, rather than simply involving them in its ultimate implementation in practice (Hawkins *et al.* 2017).

Table 6-4 Initial intervention logic model for the to-be-developed intervention (WK Kellogg Foundation 2014)



6.9 Limitations

It is important to note the challenges and limitations encountered in identifying the change mechanism for the novel intervention and acknowledge that the result is a hybrid theory to be refined at subsequent steps of the intervention development and testing. Regarding the proposed individual theory of change, the strength of the evidence found in the systematic review was tempered by the lack of a clear theoretical underpinning, methodological issues and poorly specified dosage in many of the included studies. Notably, the activities have not been trialled with groups of children or with children as young as 4-5 years. This underscored the need to engage practitioners (HPs and teachers with experience in delivering classroom-based interventions to whole classes of children) in co-production work to design the intervention tasks and maximise their feasibility and acceptability (Funnell and Rogers 2011, Glasziou *et al.* 2010, Moore *et al.* 2019, van Meijel *et al.* 2004, Wight *et al.* 2016).

In relation to developing the proposed systems theory of change, the process highlighted uncertainties about whether a novel intervention with an evidence-based dosage (three times per week for six weeks) could be implemented. This stressed the importance of conducting a feasibility trial, so that any teething problems to do with implementation and fidelity (rather than genuine ineffectiveness) could be ironed out prior to a full-scale trial of the intervention effectiveness (Grant *et al.* 2013, Moore *et al.* 2019).

This initial intervention logic model was developed by the PhD researcher and, due to the lack of input from stakeholders, important activities and resources needed to implement the intervention successfully may have been omitted. However, this was viewed as an initial logic model that would develop iteratively, particularly through further engagement with key stakeholders during the co-production work (Funnell and Rogers 2011, Peyton and Scicchitano 2017).

6.10 Conclusions

The judicious review and integration of the mixed methods data gathered through the systematic review and qualitative studies (step 2 of the 6SQuID model, Wight *et al.* 2016), enabled the identification of a proposed intervention change mechanism incorporating individual and systems elements: *If trained HPs from the RISE teams model a manualised, multi-component WM intervention for teachers, 4-5 year old children in areas of SD will receive repeated practice of executive-loaded tasks 3 times per week for 6 weeks in the classroom setting with fidelity to their protocol: this will improve their WM and support the creation of new cognitive routines to promote transfer to attention and language skills because the intervention components and setting overlap with how WM is used in real-life.*

Based on this theory and the evidence from the systematic review (Rowe *et al.* 2019a), three executive-loaded components were selected for inclusion in the intervention: two directly trained ELWM tasks (listening recall and odd one out) and phoneme awareness training. Fantastical play was selected as a further executive-loaded intervention component that is not trained directly but aims to make the intervention fun and motivating for children. The initial intervention logic model suggested that it should be deliverable within the context of the interacting, complex systems of the RISE teams and schools. It also illuminated gaps in what was known about how to deliver the tasks in a fun and motivating way for 4-5 year old children from areas of social disadvantage and underscored the importance of involving stakeholders in co-production work to address these uncertainties.

Chapter 7 - Intervention co-production

7.1 Introduction

This chapter relates to steps four and five of the Six Steps to Quality Intervention Development (6SQuID) Model (Wight *et al.* 2016) and explains: how the theoretically underpinned hybrid version of the intervention was developed further through co-production with key stakeholders (step 4); and subsequently refined through expert and practitioner review (step 5).

The chapter starts by setting out the rationale for using co-production at this step in the intervention development and goes on to specify the aims and methods employed. A detailed overview of the resulting innovative intervention (Recall to Enhance Attention, Language and Learning (RECALL) is then provided, including: an overview of the structure of the RECALL sessions; examples of the trained tasks; how they progress in difficulty over the course of the intervention; the materials used; and how much practice is specified (dosage). Volume 2 of this thesis provides the materials used in RECALL and should be referred to alongside this chapter. The co-production group refined the intervention logic model in light of a greater understanding of how it would work and the revised version is presented. The final section of the chapter summarises step 5 of the 6SQuID model and explains how the RECALL intervention was refined through expert and practitioner review.

7.2 6SQuID Step 4. Identify how to deliver the change mechanism

Chapter 6 identified the theory of change underpinning the novel intervention targeting working memory to enhance attention and language skills in 4-5 year olds from areas of social disadvantage (SD): If trained HPs from the RISE teams model a manualised, multi-component WM intervention for teachers, 4-5 year old children in areas of SD will receive repeated practice of executive-loaded tasks 3 times per week for 6 weeks in the classroom setting with fidelity to their protocol, which will improve their WM and support the creation of new cognitive routines to promote transfer to attention and language skills because the intervention components and setting overlap with how WM is used in real-life.. It also described how the executive-loaded components for the intervention were selected by the PhD researcher through revisiting the evidence obtained through the systematic review (Rowe *et al.* 2019a, Chapter 4).

The next step in the 6SQuID model involved identifying how to deliver the change mechanism (Wight *et al.* 2016). The selected intervention components (direct training on ELWM and phoneme awareness tasks along with fantastical play to make the intervention fun and motivating for 4-5 year olds) have all been trialled in previous studies. However, this doctoral study aimed to develop an innovative intervention with several original aspects. Firstly, the development of a multi-component intervention, combining three types of tasks with an explicit emphasis on their executive-loaded nature. Secondly, the direct ELWM tasks (listening recall and odd one out) have not been conducted with groups of children in the classroom setting. This raised particular issues around how to deliver the intervention tasks in a way that is consistent with the evidence base showing that, to be effective, WM training should be continually challenging (adaptive) (e.g., Holmes *et al.* 2009, Klingberg *et al.* 2005, Melby-Lervåg and Hulme 2013) (see Chapter 2). Moreover, they have not been carried out with children as young as 4-5 year olds. Consequently, there were questions about how the three tasks could be integrated into the intervention and presented in a fun and motivating way for 4-5 year olds. Furthermore, the initial intervention logic model revealed major gaps in what was known about the resources needed.

To address these uncertainties, it made sense to harness the expertise of stakeholders with experience in working with 4-5 year olds. Co-production, rather than simply developing the intervention and then asking stakeholders their opinion on it, was deemed the most appropriate method to do this for a number of reasons. Firstly, co-production is now recommended as inherent to routine clinical practice by national and regional policy in Northern Ireland (NI) (DoHNI 2016, ICAN/RCSLT 2018). Secondly, from the realist paradigm underpinning this doctoral study, co-production is seen as fundamental in the creation of multi-component interventions delivered within complex systems (Stokols 2006). Lastly, the findings from the qualitative study (Chapter 5) and the preliminary intervention logic model (Chapter 6) illuminated the crucial role that HPs and teachers would play in the testing and implementation of the classroom-based intervention. Hence, co-production was viewed as a means of enhancing the uptake and acceptability of the intervention (Wight *et al.* 2016).

A second aspect of the co-production work was to refine the intervention logic model by tapping into the participants' lived experience of how everyday practice is impacted by the interacting system of the RISE teams and schools and the wider health and education supra-systems within which they operate (Moore *et al.* 2019). This exemplifies an iterative use of programme logic modelling that can maximise its benefits for intervention development and implementation (Funnell and Rogers 2011, Peyton and Scicchitano 2017).

This also addressed the limitations identified in Chapter 6 around the fact that the PhD researcher had developed the initial logic model without stakeholder input.

7.3 Aims and objectives

The overall aim of the co-production work was to address the uncertainties regarding the delivery of the three selected intervention components (direct ELWM training, phoneme awareness training and fantastical play) by harnessing: HPs' unique knowledge of child development; teachers' unique knowledge of the classroom setting and the education curriculum; and parents' lived experience of what is fun and motivating for 4-5 year olds (Funnell and Rogers 2011, Glasziou *et al.* 2010, Moore *et al.* 2019, van Meijel *et al.* 2004, Wight *et al.* 2016).

There were two specific aims for the co-production work:

1. To co-produce an intervention deliverable by the RISE teams and teachers in schools within areas of social disadvantage.

   The objectives were:

   a) To determine the structure of the intervention sessions.

   b) To delineate the content and delivery methods for each intervention task and ensure they are presented in a way that is continually challenging (adaptive), fun and motivating for 4-5 year olds from areas of social disadvantage.

   c) To clarify the dosage for each component of the intervention.

   d) To ascertain the resources required to deliver the intervention in the classroom setting.

2. To refine the intervention logic model.

7.4 Study design

Co-production work was undertaken with one purposefully sampled group of HPs from the RISE teams, parents of 4-5 year old children with a language disorder and teachers of year one children from schools in areas of social disadvantage.

7.5 Methods

The PhD reseacher facilitated three full days of interactive workshops with the co-production group, which were held one-month apart over a three-month period. Ideas and prototype materials for the intervention were generated through small group work and discussion.

7.5.1 Participants

7.5.1.1 Eligibility criteria

Purposeful sampling was used to recruit participants with the relevant knowledge, skills and experience (Parahoo 2014).

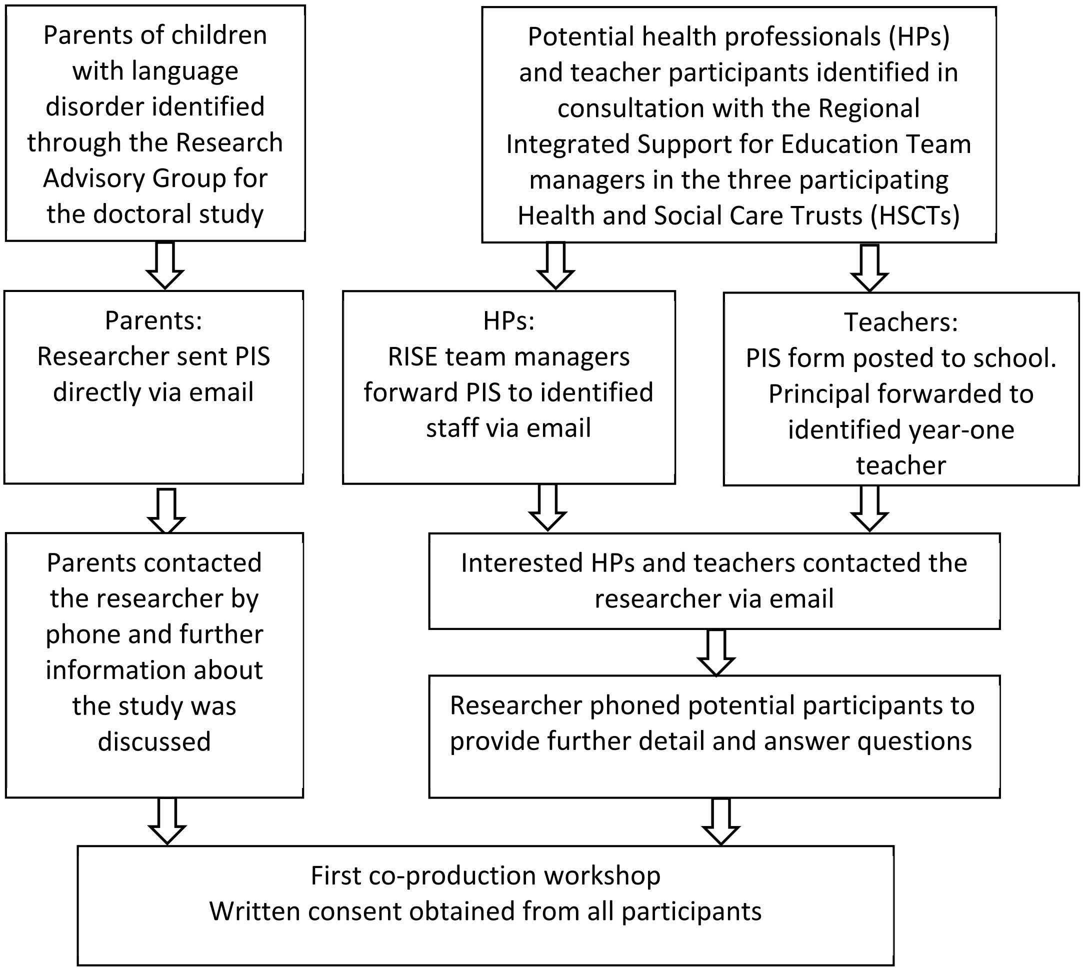
1) Health professionals (HPs): must have been Speech and Language Therapists (SLTs), Occupational Therapists (OTs), Physiotherapists (PTs) or Social, Emotional, Behaviour Specialists (SEBs) employed in a RISE team in one of the three participating Health and Social Care Trust (HSCT) areas. The aim was to ensure that all four disciplines in the transdisciplinary RISE teams in three of the Health and Social Care Trusts (HSCTs) in NI were represented in the co-production group in order to tap into a breadth of professional expertise and experience. They must have had at least two years' experience delivering classroom-based interventions in mainstream schools.

2) Teachers of year one children (4-5 year olds): must have had a minimum of two years' experience teaching year one in mainstream primary schools in areas of social disadvantage (SD) supported by the RISE teams. Teachers were not included or excluded on the basis of previous experience in programmes which target attention in the classroom (such as that offered by the RISE teams) as variations in experience may have added to the richness of the data gathered.
3) Parents: must have had a child with a language disorder attending a school in an area of SD who had received support from a RISE team. They must also have been members of the Research Advisory Group for this study. This was to ensure that the parents would have a good level of understanding of the aim of the research from the outset of the process, empowering them to feel comfortable and confident in taking part alongside the professionals involved (Ocloo and Matthews 2016).

7.5.1.2 Recruitment and consent

Figure 7-1 shows the recruitment flow chart. The potential HP and teacher participants were identified through consultation with the RISE team managers in the three HSCTs, who acted as Local Collaborators for the study. They identified staff in their teams who met the eligibility criteria and distributed a detailed Participant Information Sheet (PIS) to them via email. To recruit teachers, the schools were contacted by post in the first instance. The PIS was sent to the school principal who forwarded it to the identified year-one teacher (Appendix F). The potential participants responded to the PhD researcher directly via email to indicate their willingness to take part in the study. All of the individuals who were contacted agreed to participate in the study. Written consent was obtained at the first co-production workshop. To recruit parents, the members of the research advisory group for this doctoral study were approached directly by the PhD researcher via email and responded by phone to express their interest in contributing to this step of the research.

Figure 7-1 Recruitment and consent process for co-production workshops



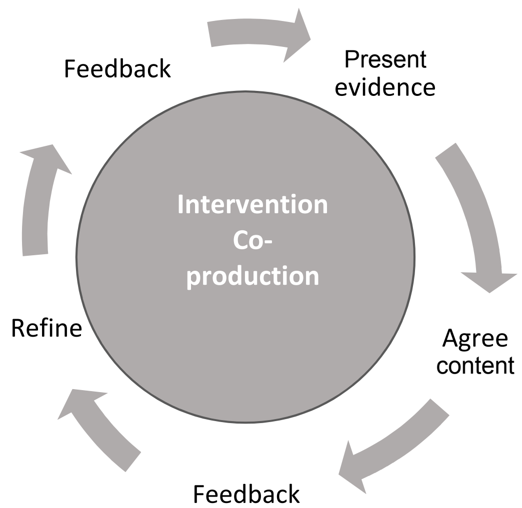
7.5.1.3 Sample

The participants included HPs from the RISE teams (*n*= 5) representing all four disciplines in the teams - SLTs (*n*= 1), OTs (*n*= 2), PTs (*n*= 1) and SEBs (*n*= 1); teachers (*n*= 2) and parents (*n*= 2) of children in year one (4-5 year olds). The HPs' clinical experience ranged from 7 to 29 years (mean = 20 years) with an average of seven years' experience working in mainstream schools. The teachers' experience ranged from 6 to 30 years (mean = 18 years).

7.5.2 Data collection

The purpose of the data collection was to obtain participants' views on the selected intervention components, based on their lived experiences of working with/parenting 4-5 year old children. Figure 7-2 shows the cyclical nature of the co-production process, with the theory underpinning the intervention and the research-based evidence (from the systematic review) being presented to the group, followed by the generation of ideas and activities that were agreed, discussed and refined.

Figure 7-2 Cyclical process of co-production workshops



7.5.2.1 Workshop schedule

Three full day workshops were conducted. The workshops were designed according to the principles for successful co-production identified by Greenhalgh *et al.* (2016): there were clear aims for each workshop; and the PhD researcher aimed to create a relaxed environment within which the participants' creativity and experience could be maximised.

The workshops were made as practical as possible and involved a combination of presentations, small group work, and discussions amongst the whole group together. The data were collected via flip-chart materials, worksheets, post-it notes and field notes maintained by the PhD researcher. The data were typed up by the researcher immediately after each workshop and anonymised to ensure the participants' names did not appear on any transcripts.

Day one commenced with training for the participants covering WM theory. This was given by the PhD researcher and included the evidence gathered from the systematic review (Rowe *et al.* 2019a). The provision of training was based on the evidence obtained from the qualitative study showing that HPs and teachers are uncertain about the structure and function of WM and the need for those involved in the co-production work to understand fully why certain tasks may need to be presented in a particular way. It was also reasoned, based on the findings from the earlier focus groups (Chapter 5), that the direct ELWM tasks might be unfamiliar to the participants.

Days two and three commenced with a recap of the data gathered during the previous workshop(s). Day two focused on delineating the intervention tasks. Day three continued with this process and included work on the intervention logic model. Table 7-1 provides a summary of the workshops schedule for each day. This was an iterative process with each day building on the previous.

Table 7-1 Overview of co-production workshops

	Workshop aims	Workshop schedule
Day 1	1) Participants will: - feel comfortable taking part in group discussions - have an awareness of the background, aims and objectives of the doctoral study - understand their role in co-production - understand the theoretical underpinning to the intervention - understand the crucial difference between short-term memory (STM) and executive-loaded WM (ELWM) tasks - be familiar with the proposed intervention activities, delivery and dosage 2) To obtain participants' feedback on the delivery of the activities and any barriers and facilitators to their delivery with 4-5 year olds	Introductions Presentation provided by the PhD researcher on: Background, research aim and design Participants' role WM theory Overview of the proposed intervention components (Systematic review evidence) Group discussion on the proposed intervention components. Discussions were recorded on flip chart paper relating to: What we like about the tasks What we don't like about the tasks How the tasks could be used/adapted for 4-5 year olds What resources might be required
Day 2	1) Participants will understand the importance of dosage and task progression in the design of tasks 2) To determine the structure of the intervention sessions 3) To identify a fantastical theme for each week of the intervention 4) To identify the content and delivery methods for each of the three intervention components	Recap from day one Presentation on importance of dosage and task progression Identifying a fantastical theme for each week of the intervention Small group work - developing the activities
Day 3	1) To go through the proposed intervention step-by-step and clarify any outstanding issues 2) To agree the content of the intervention manual so that it is user-friendly 3) To identify further facilitators and barriers to the intervention implementation and refine the intervention logic model	Recap from days one and two Group discussion Refine the logic model (based on the new understanding of the intervention developed in days 1 and 2)

7.5.3 Data analysis and interpretation

Following each workshop, a summary of the data collected to date was compiled and prototype intervention materials were developed by the PhD researcher. At the start of subsequent workshops, these were presented to the participants and they were asked if it represented their views and their thinking on what the intervention should look like in practice. This process of member checking can enhance the trustworthiness (dependability and credibility) of qualitative research findings (Creswell 2007). It also served as a form of bracketing the opinion of the researcher who, having previously worked in one of the RISE teams, could be described as having insider status that could introduce bias to the interpretation of the data (Corbin Dwyer and Buckle 2009).

To ensure further the trustworthiness of the findings, a second member of the research team attended the workshops (J.T.) and reviewed the data interpretation and prototype materials. Furthermore, the proposed content and material of each task were checked frequently for their consistency with: the proposed theory of change underpinning the intervention development; the TIDieR checklists (Hoffman *et al.* 2014) containing the details of how the intervention components were implemented in previous studies (Chapter 4); and the findings of the qualitative study (Chapter 5). The integration and triangulation of mixed methods data in the doctoral study is exemplified in this step of the intervention development. Following the co-production workshops the necessary resources were sourced or created and the comprehensive facilitator manual was written by the PhD researcher (Volume 2).

7.6. Ethical approval and considerations

Ethical approval for this study was granted by the Institute of Nursing and Health Research's Ethics Filter Committee at Ulster University (see Appendix A). Approval was also obtained from the relevant HSCT research offices. Participants were given detailed PIS forms and provided written, informed consent prior to data collection. Responses were anonymised immediately at transcription. All data were stored securely according to Ulster University's data management policy and the General Data Protection Regulation (EU) 2016/679.

There has been limited evaluation of the value of co-production (Clarke *et al.* 2017). This raises some ethical issues about the potential burden placed on participants, taking time out of their schedules to participate in something without proven value. However, it could be argued that this risk exists for all research studies so in itself this issue does not negate the use of co-production in the current study. Furthermore, the participants were likely to benefit from taking part in the workshops, particularly through the training provided on WM that may enhance their current practice.

In co-production work it is possible that participants may have unrealistic expectations about what may be deliverable in reality (Rycroft-Malone *et al.* 2016). In this study, there was a risk that people may perceive that all of their ideas would be accepted and incorporated into the intervention. In reality, this could not happen if people made suggestions that contradicted theory or evidence. To manage this risk, the participants' role was discussed openly at the start of the first workshop and the importance of underpinning the intervention with theory and evidence was emphasised regularly throughout the co-production process.

7.7 Results: the co-produced classroom-based intervention

This section describes the classroom-based intervention. As each aspect of the intervention is described, the contribution of the co-production group and the PhD researcher's individual input to its development is differentiated.

7.7.1 Overview of classroom-based intervention

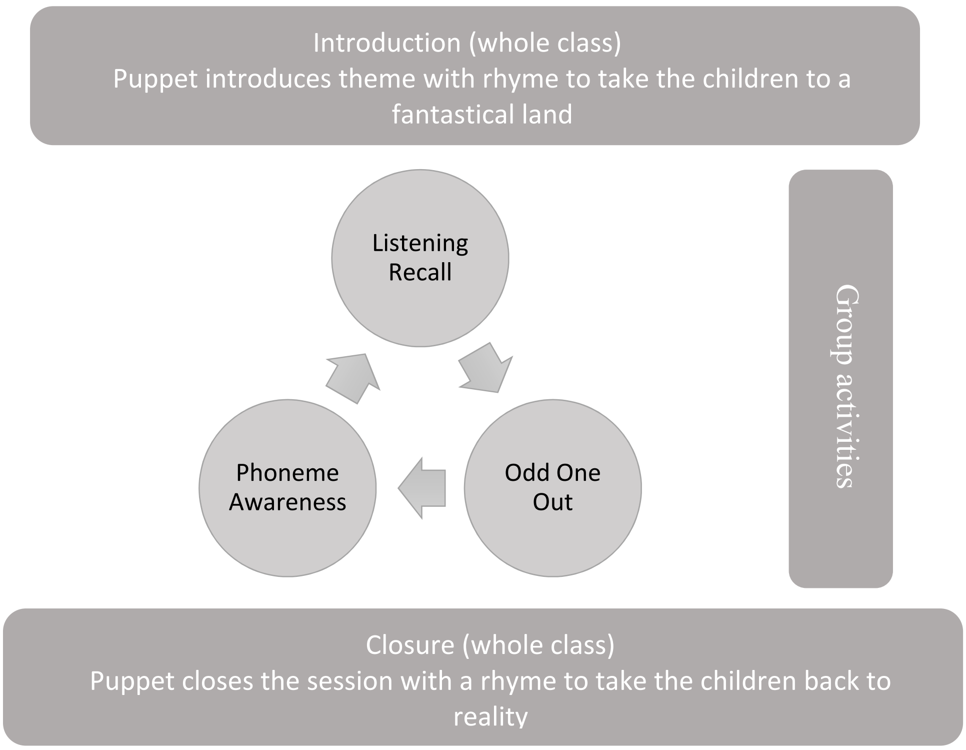
Recall to Enhance Children's Attention, Language and Learning (RECALL) consists of six, forty-minute sessions delivered once weekly by trained members of the RISE teams and repeated a further two times per week by the class teacher (supported by the classroom assistant) to whole classes of 4-5 year old children. Each RECALL session provided repeated practice on: direct executive-loaded WM tasks (listening recall and odd one out) and phoneme awareness training.

During the co-production workshops, the PhD researcher suggested to the group that fantastical play (Thibodeau *et al.* 2016) could be incorporated into the intervention by having a fantastical theme for each week, with the materials for the trained tasks relating to the theme. The participants identified six fantastical themes (one for each week) that they considered were age appropriate for 4-5 year olds: space, under the sea, superheroes, animal kingdom, castles and dragons, and miniature world. In particular, the parents in the group contributed to the generation of these themes. The participants decided that the theme could be introduced to the children at the start of each session using a puppet. They named the puppet 'Memory Mack' and came up with the idea that he could have a back pack full of props related to the theme and 'take the children' (in their imaginations) to a fantastical land. It was suggested that Memory Mack could use a rhyme, along with the props, to encourage the children to guess where they were going. To encourage the children to feel immersed in a fantastical land, the teachers suggested that a full-size picture related to the theme could be displayed on the interactive whiteboard in the classroom using a PowerPoint slide (see Volume 2).

7.7.2 Structure of RECALL sessions

Each RECALL session follows the same structure: the sessions commence with the facilitator using the Memory Mack puppet to introduce the fantastical theme for that week by saying a rhyme; then the children are divided into three groups that rotate around the direct ELWM and phoneme awareness training activities. During the session a picture to represent the fantastical theme is displayed on the whiteboard using a PowerPoint slide that is provided on a USB memory stick. At the end of the session, Memory Mack's rhyme takes the children back to the whole class. Figure 7-3 presents the session structure. Images of the fantastical theme pictures, the Memory Mack puppet and the props contained in the back pack can be seen in Volume 2 of this thesis.

Figure 7-3 Structure of RECALL sessions



The structure of the RECALL sessions was based largely on the experience of the teachers in the co-production group because their views were considered to be key to the feasibility of the delivering the sessions in the classroom. They reported that, since many activities in year one are presented in groups, it would be possible to divide the class into groups to complete the three directly trained tasks (listening recall, odd one out and phoneme awareness training). There was consensus among all of the group members that young children respond well when learning activities become part of a regular routine.

7.7.3 The intervention manual

The delivery of RECALL is supported by a comprehensive, 95-page facilitator manual that is included in its entirety in Volume 2 of this doctoral thesis. The co-production group made suggestions about the content and design of the manual and advised that it should be as visual as possible. It was agreed that the manual should include detailed session plans for each week of the intervention. The participants recommended that the session plans should include scripted sections that the facilitator could read aloud, particularly for the direct ELWM tasks (listening recall and odd one out) as they would be unfamiliar to most HPs and teachers. A further recommendation was that all of the resources required should be provided and labelled clearly for each session.

In addition to the suggestions made by the co-production group, the manual covers: the background and aims of the doctoral study; the theoretical underpinning of the intervention; and the evidence-base supporting the included tasks. It also includes a section on the importance of adhering to the prescribed dosage when delivering the tasks. The detailed session plans, including scripted sections are colour-coded and annotated with symbols with the aim of making the manual user-friendly and functional.

7.7.4 Content, task progression and dosage of directly trained tasks

The theory, evidence and typical presentation of the three tasks directly trained in RECALL (listening recall, odd one out and phoneme awareness training) were outlined in Chapter 6. In some cases, the way these tasks are delivered in RECALL differs from their usual format. This section details how each task is delivered in RECALL and why they are carried out in this way.

7.7.4.1 Listening recall

Listening recall targets verbal ELWM skills. The child listens to a short sentence, judges whether it is true or false, then recalls the last word of the sentence as noted in the earlier example provided in Chapter 6. The aim is to increase the number of to-be-remembered words that the child has to recall. Typically, this task has been administered to children on a one-to-one basis, meaning the facilitator can make the task adaptive by gradually increasing the level of difficulty so that the child is continually working at the ceiling of their ability (Henry *et al.* 2014). As discussed in Chapter 2, the continually adaptive nature of WM training may be a crucial factor in its effectiveness (Klingberg 2010).

Task progression in RECALL: During the development of RECALL it was clear that delivering the listening recall task in an adaptive manner to groups of children, with varying levels of ability, would be challenging. Since the co-production group had no experience of delivering the listening recall task, they were unable to contribute to the process of deciding how to manage this issue. Therefore, the progression of difficulty for the listening recall task was determined by the PhD researcher through: consultation with the expert advisors supporting this doctoral study (L.H and J.H); and the extant literature regarding the development of WM skills in young children. Since this task is considered to be challenging for 4-5 year olds (Gathercole *et al.* 2004b), it was anticipated that the rate of progression would be slow, with the expectation being that the children may be able to recall two to-be-remembered words by the end of the six-week intervention period. To manage the variation between the children's ability levels and try to ensure that the training is adaptive, it was decided that for most of the sessions the practice items would alternate in their level of difficulty (between the one and two word levels). The task difficulty increases across the six weeks in the following way:

Week 1: one to-be-remembered word. The children listen to one sentence, judge whether it is true or false, then recall the last word in the sentence.

Weeks 2-5: alternating between one and two to-be-remembered words.

Week 6: two to-be-remembered words.

Materials: Following the co-production work, the PhD researcher generated lists of sentences for each session (18 lists in total), that tie in with the fantastical theme for that week. For example, in the 'under the sea' week the sentences relate to dolphins, fish or lobsters. Care was taken to control the storage and processing load of each sentence. The final words of the sentences (the to-be-remembered words) are all monosyllabic and the total number of syllables in each sentence was counted to control the storage requirements of the task. Attention was also paid to the semantic content of the sentences in order to avoid ambiguity and ensure that the children would be able to judge their veracity with relative ease. The order of the true/false responses was varied so that the children had to pay attention and could not guess the answer. Across the six weeks of the intervention, there is minimal repetition of the concepts included in the sentences and of the last (to-be-remembered) words. All of the listening recall sentences used in RECALL can be found in the session plans included in the facilitator manual found (see Volume 2).

Dose (number of trials): To the PhD researcher's knowledge, listening recall has not been trialled with children as young as the target population for RECALL (4-5 year olds). Therefore, the number of practice items per session was based on the best available empirical evidence. Each session includes 11 practice items of listening recall and 11 odd one out tasks are specified in the intervention manual and session plans (as per Henry *et al.* 2014). To support the HPs and teachers delivering the intervention in administering the specified dose, detailed scripts were provided in the session plans and example and trial items were laid out clearly (see the RECALL manual, Volume 2).

7.7.4.2 Odd one out

Odd one out targets visuospatial ELWM skills, as outlined in Chapter 6.

Task progression in RECALL: The same challenges experienced with the listening recall task, in relation to determining the task progression and making it continually challenging (adaptive), applied to the odd one out task. Hence, this was addressed in the same way i.e., by consulting the expert advisors on this study (L.H. and J.H.) and referring to the WM literature (Gathercole *et al.* 2004b). The same approach was taken to alternating the task difficulty within each session. As the week's progress, the number of items the children have to recall increases as follows:

Week 1: one to-be-remembered location.

Week 2: alternating between one and two to-be-remembered locations.

Week 3: two to-be-remembered locations.

Week 4: alternating between two and three to-be-remembered locations.

Week 5: three to-be-remembered locations.

Week 6: alternating between three and four to-be-remembered locations.

Materials: Typically, children indicate their responses in this task by pointing to the location of the odd one picture on a blank grid (as per Chapter 6). During the development of RECALL, it was apparent that in the group setting this would not work. It would be impossible for the adults facilitating this task to look around at a group of children and accurately observe all of their responses.

Therefore, in RECALL, to monitor each individual child's progress, each child has a self-inking stamper and an A-4 size individual booklet showing one blank grid for each odd one out practice item. The facilitator shows the children the odd one out picture, takes it away and then the children mark its location on the blank grid in their booklet using their stamper. If the practice item has one to-be-remembered location, the page in the children's booklet shows one blank grid. If the practice item has two to-be remembered items, the page shows two blank grids and so on. The booklets have a separate page for each practice item. This aims to simplify the role of the facilitator by establishing a routine with the children in which they complete a practice item, turn the page, do the next one and so forth. The aim was that, if the facilitators' observed a child having particular difficulty with the tasks during the intervention delivery, they would be able to check the child's responses in their booklet.

Each week, the odd one out pictures tie in with the fantastical theme. All of the pictures are bespoke black and white images, created by the researcher. The pictures were either created from scratch (using shapes and drawing tools in Microsoft word) or they were downloaded from a website providing high-quality images that can be copied, modified or distributed for commercial or non-commercial use (Pixabay.com). Figures 7-5, 7-6 and 7-7 show examples of the odd one out picture cards (smaller than actual size) created for RECALL. Additional examples can be found in Volume 2 of this doctoral thesis, along with sample pages from the children's booklets.

Figure 7-5 Example of odd one out picture differing by size

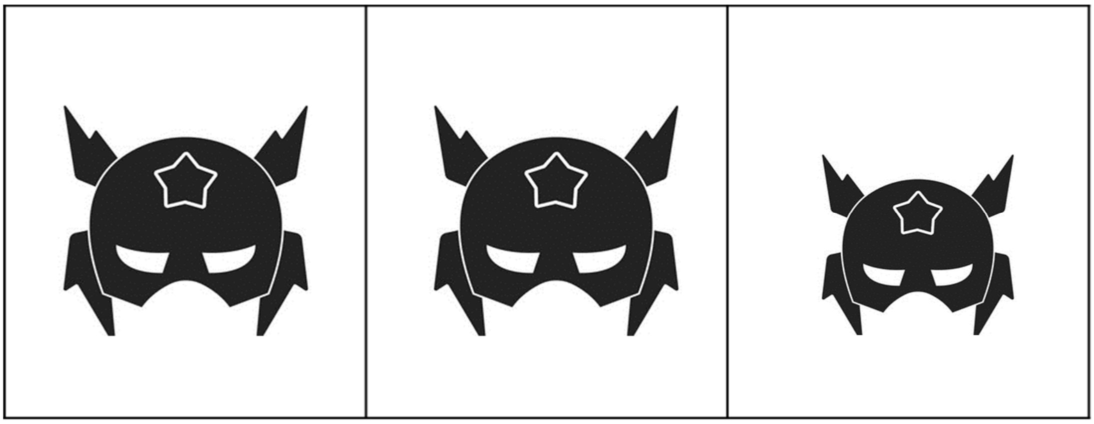


Figure 7-6 Example of odd one out picture differing by orientation

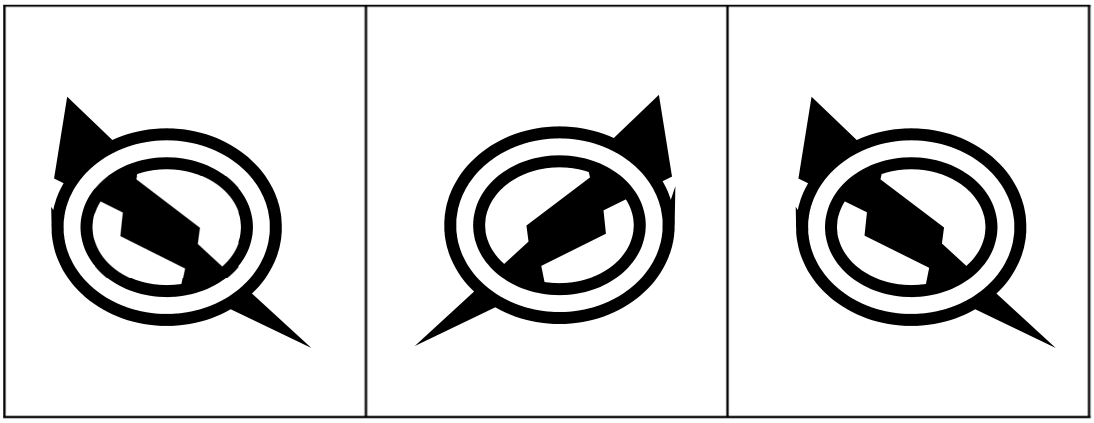
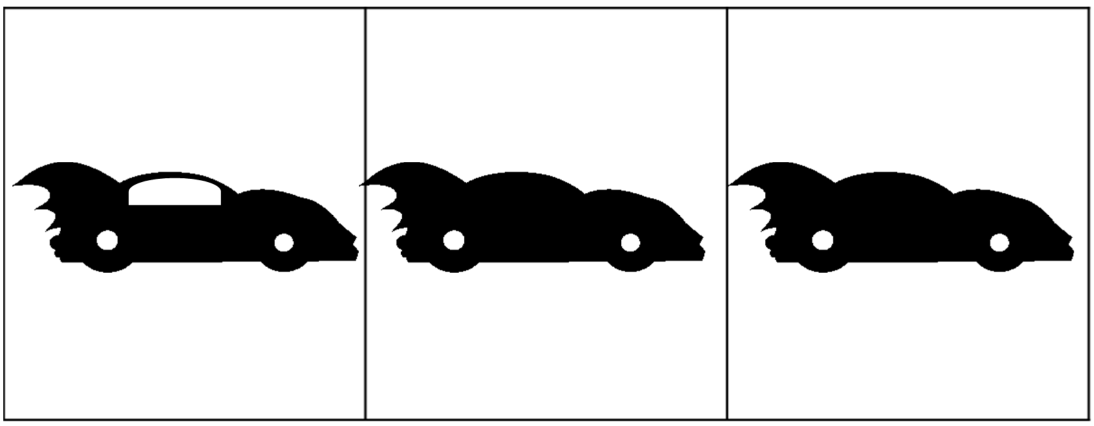


Figure 7-7 Example of odd one out picture differing by inner detail



Dose (number of trials): The dosage for the odd one out task is the same as for listening recall (11 tasks per session) (as per Henry *et al.* 2014). To support the HPs and teachers delivering the intervention in administering the specified dose, the intervention materials include detailed scripts in the session plans. The odd one out pictures for each session are labelled clearly and placed in a plastic wallet in order of presentation. The blank grids in the children's booklets are numbered so that the facilitators know that every practice item has been completed and so that the accuracy of the children's responses can be monitored (see images of pages in the children's booklets, Volume 2).

7.7.4.3 Phoneme awareness training

The phoneme awareness tasks included in RECALL were selected on the basis of the evidence obtained through the systematic review (Rowe *et al.* 2019a). In particular, the evidence from the study conducted by van Kleeck *et al.* (1998, 2006) influenced the choice of tasks due to the group nature of their intervention and the fact that it was conducted with children of the same age as the target population for RECALL (4-5 year olds). This empirical evidence was married with the wider literature regarding the developmental progression of phoneme awareness skills in 4-5 year olds (Gillon 2000, 2002).

There are four types of phoneme awareness tasks in RECALL. They all focus on developing awareness of the initial sounds in words (rather than the middle or final sounds) because this skill emerges prior to the identification of final sounds and it is developmentally appropriate for 4-5 year olds (Gillon 2000, 2002):

1. Alliterative matching: finding things that start with a target sound e.g., "Book starts with /b/. Can you find the other things that start with /b/?"
2. Segmenting initial sounds: "what sound does ____ start with?"

3. Alliterative matching and blending the target to generate new words: “Find the one that starts with ___? Let’s think of other things that start with _”
4. Blending sounds (onset + rime) to identify words: “Look at these pictures. Can you find the b + all?”

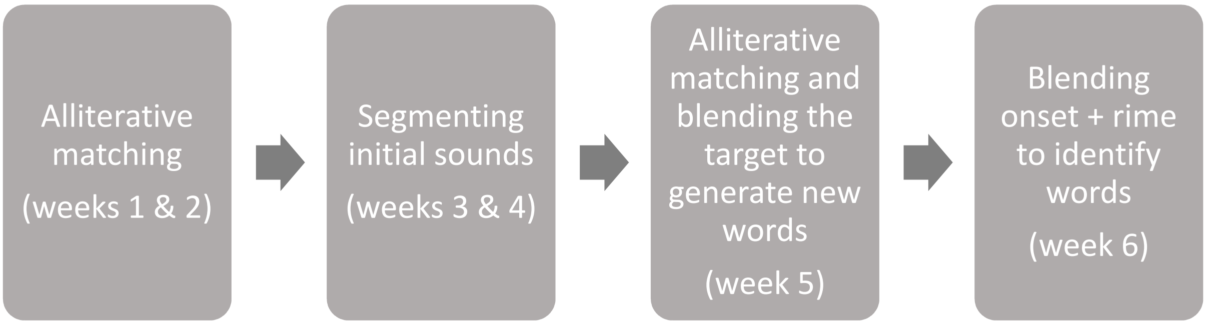
This framework for the phoneme awareness training was presented to the co-production group and they were asked to create some activities to target these skills in a fun way through activities related to the fantastical themes. The group needed considerable support from the research team to generate ideas but some creative ideas emerged. For example, for the superhero week, the alliterative matching task is based on the idea of a superhero who is sent on a mission by Memory Mack to fly over a city and find the items below him that start with a target sound. For the Animal Kingdom week, the children have a picture of an explorer going through a jungle who has to say the sound at the start of items that he finds on his way. All of the phoneme awareness tasks are detailed in the intervention manual, found in Volume 2 of this thesis, which also includes examples of the picture stimuli for these tasks created by the PhD researcher.

Task progression: The co-production group found it difficult to grade the level of the task difficulty for the phoneme awareness training. Therefore, this was determined by the PhD researcher (with the support of J.T.) based on the literature evidence. The tasks become progressively more difficult in three ways:

1. Type of task: the tasks progress in difficulty from matching initial sounds through to blending initial sounds, based on the typical development of phonological awareness skills (e.g., Cunningham 1990) and tasks used in previous interventions (van Kleeck *et*

al. 1998, 2006). Figure 7-8 shows the overall progression of difficulty of the phoneme awareness tasks in RECALL.

Figure 7-8 Progression of task difficulty for phoneme awareness training in RECALL



2. Phoneme selection: within each of the four tasks, the difficulty level of the practice items is differentiated through the careful selection of the target phonemes. These progress from early to middle to late developing phonemes, based on the typical development of speech sounds (Shriberg 1993) (see Table 7-2).

Table 7-2 Early, middle and late developing phonemes (Shriberg 1993)

Early 8	/m/ /n/ /j/ /b/ /w/ /d/ /p/ /h/
Middle 8	/t/ /ŋ/ /k/ /g/ /f/ /v/ /ʧ/ /ʤ/
Late 8	/ʃ/ /ʒ/ /l/ /r/ /s/ /z/ /ð/ /θ/ and clusters

3. The contrastive features between target phonemes: as the children practise each task the phonemes become progressively more similar, making it more challenging for the children to distinguish between them.

Full details of the target phonemes used across all of the RECALL sessions can be found in Table 5-1 in Volume 2 of this thesis.

The use of foils: Some of the phoneme awareness tasks also include foils (or distractor items) i.e., words that do not start with the target sounds. These are used to ensure that the task always challenges the children's phoneme awareness skills and reduces the risk of guessing. For example, in session 1a the children have to find the words that start with 'm' and draw a circle around them, then find the words that start with 'h'. If all of the words on their page start with 'm' and 'h', by the time they have completed the 'm' words only the 'h' words remain. They could then simply circle all the remaining words and it would be impossible to tell if they can really match the initial sound.

Materials*:* The colourful picture stimuli for the phoneme awareness tasks tie in with the fantastical theme for each week and were created by the PhD researcher in the same way as the odd one out pictures (using images freely available from Pixabay.com and Microsoft word). The target words used throughout the phoneme awareness tasks should be familiar to the children. However, in some cases the vocabulary used may require some explanation by the facilitator. Advice for the facilitators on how to manage this is provided in the intervention manual. For example, in session 1c, the facilitator is advised that they may need to explain that the astronaut is connected to the rocket by a chain (because he floats in space). The session plans in the RECALL manual provide the facilitators with all of the information needed to deliver the phoneme awareness tasks, including details of the target sounds, the examples provided in the children's booklets and, where applicable, the words used as foils for each session.

7.8 Refining the intervention logic model

The final aim of the co-production process was to refine the intervention logic model in light of the clearer understanding of the intervention design. This was carried out during the final co-production workshop through a brainstorming activity. Flip chart pieces of paper were placed on the wall and all of the group members helped to generate a list of factors that may facilitate or impede the testing or ultimate implementation of RECALL in the classroom-setting (within the context of the overlapping systems of the RISE teams and schools). A wide range of factors were identified. Following the workshops, the PhD researcher mapped these factors onto an interim logic model that could be amended following feasibility testing. Table 7-3 presents the model and shows how this has developed since the initial model presented in Chapter 6.

Table 7-3 Interim intervention logic model for RECALL (WK Kellogg Foundation 2014)

Assumptions	*Inputs*	*Activities*	*Outputs*	*Outcomes*	*Impact*
Executive-loaded tasks, delivered once weekly by trained health professionals (HPs) from the RISE teams and twice weekly by teachers, for 6 weeks may benefit WM and produce near- and far-transfer effects to attention and language skills	Financial resources for development of materials including booklets for children and manual. Schools to be provided with everything needed to deliver RECALL	Creation of bespoke resources for RECALL tasks to tie in with 6 fantastical themes: sentences for listening recall; pictures for odd one out (OOO); 4 phoneme awareness (PA) tasks based on typical development of phoneme awareness and speech sounds; purchase of puppets & props for fantastical play	RECALL will be deliverable to whole classes of 4-5 year olds in a way that is fun and motivating	Children from areas of SD will receive the intervention 3 times per week for 6 weeks (18 sessions) and all trained tasks will be delivered with fidelity to their aims, design and dosage	Children from areas of SD will have improved WM, attention and language skills
	Time for development and review of RECALL materials	Expert review to ensure tasks have appropriate storage and processing demands for 4-5 year olds	RECALL will be acceptable to the HPs and teachers who deliver it	The feasibility of RECALL will be evaluated accurately and the appropriate level of task difficulty for the OOO and PA tasks will be clarified	Teachers will identify fewer children requiring referral to the RISE teams in relation to attention and language difficulties
	Time (2 days) and materials for training HPs, to include practice modelling the RECALL tasks	Creation of booklets (1 per child each week) to record responses for OOO and PA	The effectiveness of RECALL will be maximised	Policy will support the use of RECALL. The RISE teams will include it as one of their classroom-based	The intervention will be implemented sustainably in practice
	RISE teams and schools	Training HPs	Completed booklets will evidence implementation & children's progress will be monitored		
	Support/buy-in from school principals, RISE managers and stakeholders in education e.g., inspectorate	Creation & practitioner review of RECALL manual with scripted session plans	HPs will deliver the intervention once per week with fidelity		
		Strategic meetings to disseminate RECALL	Teachers will provide 2 sessions per week with fidelity		
			Records of meetings		

7.9. Benefits and limitations of co-production

One of the main objectives of using co-production as a method of intervention development was to ascertain how the identified intervention components could be presented in a way that was fun and motiving for 4-5 year olds and would work in the everyday classroom context (see 7.3). The participants provided some creative ideas for the fantastical play element of the intervention and there were tangible benefits of co-production in this regard. Their knowledge of the system within which the intervention will be implemented also benefitted the refinement of the intervention logic model. This is consistent with the proposed benefits of co-production suggested in the literature (Funnell and Rogers 2011, Glasziou *et al.* 2010, Moore *et al.* 2019, van Meijel *et al.* 2004, Wight *et al.* 2016).

Whilst these contributions are notable, in some respects the use of co-production disadvantaged the intervention development. When it came to delineating the content of the three intervention components, the group needed a considerable amount of guidance from the PhD researcher(s) during the workshops. The participants generated some broad ideas but found it challenging to delineate the task details, including dosage and the progression of difficulty levels, despite the training provided at the start of the workshops that emphasised the importance of these aspects of the intervention. In relation to dosage, this adds weight to the findings from the qualitative study (Chapter 5) regarding practitioners' current practice being underpinned by a lay theory that dosage is not key to children's outcomes. It reinforced the need to stress the importance of dosage during training for the HPs delivering the intervention and for this to be clearly specified in the intervention manual. In relation to the progression of the task difficulty level, this finding may reflect a lack of detailed developmental knowledge about the specific tasks being targeted in the intervention. Again, this highlights the importance of training and manualisation in supporting effective understanding and delivery of the programme.

Whilst the benefits of co-production are referred to frequently in the literature, the challenges and potential disadvantages must be acknowledged (Verschuere *et al.* 2012). In the current study, the co-production process was costly and time-consuming. The lack of detail obtained from the co-production work regarding the content and delivery of the direct ELWM and phoneme awareness tasks resulted in the PhD researcher having to invest considerable time out-with the co-production groups to develop these independently. This highlights issues around the researchers' expectations of the knowledge and skills that might be tapped into within co-production workshops relative to what type of intervention is being developed. The more specialist the intervention being developed, perhaps the broader the expectations of the co-production work should be. Of course, this would vary depending on the population sampled within the co-production group. However, this type of consideration could result in a better, more efficient, use of researcher resources by devoting more or less time to the co-production phase as appropriate.

One argument for devoting more researcher time to the co-production process, is that genuine collaboration between researchers and other stakeholders takes time to develop (Rycroft-Malone *et al.* 2016). Mutuality (reciprocal relations with mutual responsibilities and expectations) has been suggested as a key principle of Personal and Public Involvement (PPI) (Ocloo and Matthews 2016). However, achieving this within a collaborative forum is difficult, especially when multiple stakeholders come together and when lay people may perceive a power imbalance between them and the other partners around the table (Rycroft-Malone *et al.* 2016). The HPs and teachers (from whom greater input to the task progression was anticipated) may have been inhibited by a sense of power lying with the researchers and perhaps three days were insufficient to break down this barrier. Co-production is a fashionable concept in both research and health service settings but unless it empowers service users and produces better outcomes it can be tokenistic (Ocloo and Matthews 2016). Investigating the participants' perceptions of the co-production process was beyond the scope of this doctoral study. However, the research has highlighted the need for future, robust evaluation of the value of co-production (Clarke *et al.* 2017, Voorberg *et al.* 2015).

7.10 6SQuID Step 5. Test and refine on small scale

The fifth step in the 6SQuID process is to test and refine the intervention on a small scale (Wight *et al.* 2016). The authors of 6SQuID note that this step is often rushed but can be vital in ensuring the optimal design of an intervention. In light of the limitations to the co-production work previously discussed (7.9), this step was deemed to be essential in the current study.

7.10.1 Aim

To evaluate formatively the quality and functionality of the intervention design, manual and materials including:

1. Whether the storage and processing demands of the trained tasks appeared to be at an appropriate level for 4-5 year olds.
2. Whether the manual and the session plans provided adequate detail for users who were unfamiliar with the tasks.

7.10.2 Methods

To achieve the first aim, the expertise of two leading experts in the field of WM research (L.H. and J.H.) was sought through research networks developed by the researcher over the course of this doctoral study. They provided feedback on the manual, materials and resources through a face-to-face meeting, Skype meetings and email. To achieve the second aim, practitioner opinion was obtained through face-to-face meetings with the two teacher representatives from the Research Advisory Group involved in this study. They provided feedback on the structure of the sessions, the manual and session plans. The feedback was recorded in the form of field notes recorded by the PhD researcher, hand-written feedback on hard copies of the draft manual, session plans and materials or tracked changes/comments on electronic versions of the documents.

7.10.3 Results

Table 7-4 provides a summary of the alterations made to the intervention manual, session plans and materials based on the feedback obtained from the recognised experts and practitioners.

Table 7-4 Alterations made to the RECALL intervention following expert and practitioner review

General adaptations to the intervention manual	Greater detail was added to the theory section of the manual to enhance its clarity Additional detail was added to the scripts included in the session plans
Listening recall task	Some of the sentences were replaced as they may have been ambiguous to 4-5 year olds i.e., the children may have found it difficult to judge their veracity Some of the to-be-remembered words were replaced to avoid repetition within and across sessions The length of the sentences was altered to control the storage demands
Odd one out task	An initial sample of the black and white pictures reviewed by the experts had limited processing demands i.e., the odd one out picture was too obvious. A new sample set of pictures was created and reviewed again prior to the development of the full set of materials.
Phoneme awareness training	Following the teachers' recommendations, some terms used in the manual were altered The consistency of the terminology used in the scripted sections of the session plan was improved. For example, when providing the instructions to the children the facilitator always refers to the sound at the 'start' of the word (rather than using beginning sound/first sound etc. Some of the pictures were altered so that the children could identify them more easily

7.11 Conclusions

The RECALL intervention was co-produced following a robust process of selecting active components that are evidence-based and consistent with the theory of change underpinning the intervention. The training components are: two direct ELWM tasks (listening recall and odd one out); and phoneme awareness training. Fantastical themes are used to present these tasks in a way that is fun and motivating for 4-5 year old children. The novel and original features of the intervention content are: its incorporation of these components into one coherent approach; it is designed to be delivered to groups of children in the classroom setting; and it is targeted at children aged 4-5 years (where previous studies have been conducted with children of 6 years or more) (Jaeggi and Buschkuehl 2014, Wass *et al.* 2012). The intervention logic model explains what could happen if: the intervention theory is correct; the tasks are delivered with fidelity to the protocol; the required resources are available; and the necessary activities take place at the right time (Hawe 2015). The intervention is to be implemented within a complex system that is dynamic and unpredictable (Moore *et al.* 2019). Therefore, there are many uncertainties about its implementation that need to be addressed. This highlights the need for a thorough investigation of the feasibility and acceptability of RECALL prior to a full-scale evaluation of its effectiveness (Campbell *et al.* 2007, Wight *et al.* 2016).

The fact that RECALL was co-produced by researchers, practitioners and parents is another novel feature of the intervention. This had both positive and negative effects on the process. It enhanced the fantastical play aspect of the intervention and informed the structure of the intervention sessions, the accompanying manual and the logic model. However, it was a costly and time-consuming process that delayed the completion of this part of the doctoral study. In comparison, the expert and practitioner review of the intervention significantly enhanced the quality and functionality of the intervention manual and materials and was an essential part of this study. There is a clear need for thorough investigation of the value of co-production in intervention development (Clarke *et al.* 2017).

Chapter 8 - Study protocol for feasibility trial

8.1 Introduction

Chapter 8 (in combination with chapter 9) relates to Step 6 of the Six Steps in Quality Intervention Development model (6SQuID) model (Wight *et al.* 2016) and aims to collect sufficient evidence to justify rigorous evaluation of an intervention. This chapter provides the study protocol for a cluster randomised feasibility trial that aimed to explore: the feasibility of conducting a full-scale trial of the effectiveness of the novel Recall to Enhance Children's Attention, Language and Learning (RECALL) intervention; and the acceptability of RECALL to HPs and teachers. This chapter contains the full pdf. version of the study protocol that was published in *Pilot and Feasibility Studies*. It includes its own abstract, introduction, methods, findings and discussion sections along with its own reference list. The trial was pre-registered with the International Standard Randomised Controlled Trial Registry (ISRCTN13633886, Registered 7 Sept 2018).

8.2 A classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): study protocol for a cluster randomised feasibility trial (Paper 3)

Citation details

Rowe, A., Titterington, J. and Taggart, L. (2019) A classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): study protocol for a cluster randomised feasibility trial. *Pilot and Feasibility Studies*, 5(82).

PhD researcher's contribution

This paper was co-authored by the supervisory team (L.T and J.T). The PhD researcher wrote the first draft of the study protocol, amended it based on feedback from the co-authors, prepared the manuscript for submission to the journal and managed the full submission process including revisions following the reviewers' responses.

Rowe et al. Pilot and Feasibility Studies (2019) 5:82
https://doi.org/10.1186/s40814-019-0468-8

Pilot and Feasibility Studies

STUDY PROTOCOL Open Access

A classroom-based intervention targeting working memory, attention and language skills in 4–5 year olds (RECALL): study protocol for a cluster randomised feasibility trial

Anita Rowe*, Jill Titterington and Laurence Taggart

Abstract

Background: There is international recognition of the need for creative, classroom-based interventions to support children at risk of low academic achievement and well-being, due to poor attention and language skills on school entry. Working memory (WM) is a cognitive skill that is strongly associated with attention and language skills. There has been speculation that WM training, embedded within typical educational activities, may improve children's WM skills and produce transfer effects to real-world skills such as attention and language. However, little is known about the effectiveness of this approach.

'Recall to Enhance Children's Attention, Language and Learning' (RECALL) is a novel, 6-week, classroom-based intervention targeting WM, attention and language skills in 4–5 year olds. RECALL was co-produced with health professionals, teachers and parents. This protocol describes the rationale, methods and analysis plan for a proposed cluster randomised feasibility trial of this RECALL programme.

Methods: This is a three-arm, cluster randomised feasibility trial comparing RECALL to an existing programme (active control), and no-intervention (education as usual). We will recruit six schools in socially disadvantaged areas in one region of the UK. Two schools will be randomly allocated to each arm of the trial. In each school, one class of children (ages 4-5 years) of approx. 30 children will be involved in this study. Ten children in each class will be sampled purposefully for outcome measurement including: standardised assessments of WM, language and attention skills; teacher ratings of attention; and parent ratings of functional communication skills. These will be administered at baseline and 1-week post-intervention in order to test the acceptability of the measures. A process evaluation using semi-structured interviews with participants will explore the acceptability of RECALL and the procedures employed in this trial.

Discussion: This feasibility study will explore the acceptability of RECALL to the health professionals and teachers who will deliver it and inform the optimal design of the programme. The inclusion of an active control group and the blinding of outcomes assessors enhance rigour in this study. The findings will determine whether this study can be scaled-up into a definitive cluster randomised trial to evaluate the effectiveness of RECALL.

Trial registration: ISRCTN13633886. Registered 7 Sept 2018.

Keywords: Working memory, Attention, Language, Intervention, School, Children, Feasibility, Study protocol

* Correspondence: harron-a@ulster.ac.uk
Institute of Nursing and Health Research, Ulster University, Shore Road, Newtownabbey, Antrim BT37 0QB, Northern Ireland

Background

Internationally, the need for classroom interventions that break cycles of academic underachievement, unemployment and poor mental and physical health is widely acknowledged [1]. In areas of low socio-economic status (LSES), high proportions of children present with impoverished language skills on school entry, and are subsequently at risk of poor school performance [2–4]. To address this, Speech and Language Therapy and other health services provide early intervention in schools through collaborative, classroom-based approaches. However, there is a lack of research-based evidence for the effectiveness of such interventions [5–7]. There is now a need for creative, therapeutic interventions to support this population [8, 9].

For children from LSES backgrounds, low language is often associated with cognitive difficulties [10, 11]. Working memory (WM) is a cognitive skill reflecting the ability to hold in mind and mentally manipulate information over short periods of time in the face of distraction [12–14]; it is strongly associated with attention skills [15–17] and language acquisition [18]. The implication of the symbiotic relationship between WM, attention and language [19] is that targeting WM as an underlying skill may produce improvements in these real-world skills [20].

Most research into the effectiveness of WM interventions has investigated computerised training packages (e.g. Cogmed 2005 [21]). The therapeutic value of this approach has been debated due to the consistently inconsistent evidence for transfer effects, i.e. the generalisation of positive effects on trained tasks to other untrained tasks [22]. In the WM literature, transfer effects have been differentiated into near-transfer and far-transfer. Near-transfer refers to improvements in untrained tasks that are similar to those trained, e.g. improvements in a visuospatial WM task following training on a verbal WM task [23, 24]. Far-transfer refers to enhanced performance in tasks quite different from those trained but which are deemed to be dependent on WM, e.g. improvement on real-world skills including language, literacy, numeracy and the ability to pay attention in class following WM training [23, 24]. The presence of near-transfer effects associated with an intervention is an essential criterion to corroborate any far-transfer effects identified [25].

On the basis that treatment effects are likely to transfer to activities with overlapping features to the trained task [26], there have been calls for WM training to be embedded within the typical activities in which benefits are needed [27, 28]. However, there has been limited research into the effectiveness of WM interventions applied with young children in everyday contexts. Furthermore, to date, the literature has focused on the cognitive benefits of WM training, and the individual differences that may moderate or mediate training and transfer effects [29, 30]. There has been little consideration of the contextual factors associated with the delivery of WM interventions in real-life settings such as schools. It has been suggested that controlling the quality, dose and fidelity of WM training in the classroom setting is challenging [29], but there has been a lack of empirical research into the barriers and facilitators of implementing WM interventions in schools.

To address this, we have developed the 'Recall to Enhance Children's Attention Language and Learning' (RECALL) programme. RECALL is a theoretically underpinned, evidence-based intervention that targets WM, attention and language skills in 4–5-year-old children through group and whole-class activities over a 6-week period. It is designed to be delivered by teachers and teams of health professionals that are commissioned to reduce barriers to learning in one region of the United Kingdom (UK), Northern Ireland [31]. The Regional Integrated Support for Education (RISE) teams include speech and language therapists (SLTs), occupational therapists (OTs), physiotherapists (PTs) and social, emotional and behavioural specialists (SEBs). They support children aged between 3 and 8 years (nursery to year 4) in mainstream schools. The majority of children referred to the team are year one pupils (4–5 year olds), attending schools in areas of low socio-economic status (LSES). There is evidence that for all of the referred children, teachers have identified concerns around their attention and language skills [32]. The RISE teams have developed a whole-class programme, known as the Attention and Listening Programme (ALP), that they currently provide to schools on request. This programme is similar to RECALL in its structure and format but it is not underpinned by WM theory and has not been robustly evaluated.

This protocol describes the rationale, methods and analysis plan for a proposed cluster randomised feasibility trial that will compare RECALL to the existing ALP intervention and education as usual. It aims to resolve uncertainties about the acceptability of RECALL to those who would be delivering it (health professionals and teachers), assess the feasibility of conducting a definitive cluster randomised trial (CRT) of its effectiveness and make a novel contribution to the WM literature regarding the barriers and facilitators to the implementation of WM training in real-life contexts.

Study aim and objectives

The key research question is whether it is possible to design a definitive CRT that will evaluate whether RECALL is more effective than an existing intervention (ALP), and education as usual, for enhancing WM, attention and language skills in 4–5 year olds from LSES areas.

We will conduct a cluster randomised feasibility trial that will enable us to:

1. Examine the acceptability of the novel RECALL programme and its accompanying manual to the health professionals and teachers who deliver it.
2. Measure the implementation of RECALL by health professionals and teachers including compliance and fidelity of delivery.
3. Understand the trial processes at the cluster and individual levels including recruitment, consent and sampling procedures, attendance levels and loss to follow-up.
4. Determine the acceptability of randomisation to schools.
5. Explore the appropriateness of the existing intervention (ALP) as an active control comparator to the experimental RECALL programme.
6. Explore how WM, attention and language skills are typically supported in the classroom (education as usual).
7. Determine the appropriateness and acceptability of the outcome measures for the children, teachers and health professionals.
8. Identify the facilitators and barriers (at the cluster and individual levels) to the implementation of RECALL and refine the intervention's logic model.[1]

Methods/design

This study is a three-arm, cluster randomised feasibility trial with a parallel group design. The novel RECALL classroom programme will be compared to an existing intervention (ALP, the active control) and education as usual (the no intervention control). The delivery of the interventions at the classroom level necessitates the use of a cluster design for this study [34, 35] with each school constituting a cluster. The experimental RECALL programme and the active control intervention will be delivered by health professionals from the multi-disciplinary RISE teams once per week. Thus, they will demonstrate the programmes for the teachers who will then provide two further practice sessions during the week.

Children's outcomes will be measured at two time points (baseline and 1-week post-intervention). The protocol has been developed according to the SPIRIT 2013 Statement [36] recommendations for protocol items for clinical trials and the CONSORT 2010 extension to cluster randomised pilot and feasibility trials [37]. Throughout the trial, a process evaluation will explore the factors that could impact on the internal and external validity of a future CRT and the intervention's logic model for RECALL will be refined [38, 39]. Figure 1 shows the flow chart of the study and Fig. 2 illustrates the timing of all trial processes.

Setting

This is a multi-site trial that will be conducted in primary schools in one region of the UK, Northern Ireland (NI), where children commence formal education at 4 years of age. The mainstream school population in NI includes a wide range of children including those with undiagnosed and diagnosed learning or developmental difficulties. Year one classes typically have one teacher, supported by a classroom assistant (CA). The multidisciplinary RISE teams are based within each of the five Health and Social Care Trusts (HSCT) in NI and this study will take place in two of the HSCT areas. The RISE teams work in partnership with schools and provide a range of services including: specialist assessment and intervention for referred children with recognised developmental difficulties; and targeted support for vulnerable children (considered to be at risk of developmental difficulties). Targeted interventions include whole-class and group programmes focusing on particular skills such as attention and listening. The aim of these interventions is to support all children in accessing the curriculum and reduce underachievement [40].

Sample size and participants

As this is a feasibility study, and the purpose is to explore the acceptability of the intervention rather than its effectiveness, a formal a priori power calculation has not been conducted [41]. The results will not be used to estimate the sample size, intra-cluster correlation or treatment effects for a definitive trial because, in the case of cluster randomised feasibility trials, these can be unrealistic and misleading [42, 43]. Therefore, the number of clusters and individual participants to be recruited has been selected in order to assess the acceptability and feasibility of RECALL and the outcome measures for children's WM, attention and language skills.

At the cluster level, six schools in areas of LSES will be recruited in total. One class of children in year one ($n = \sim 30$) will participate in each school (total: $n = \sim 180$ children). Two classes will receive the RECALL programme, two will receive the active control intervention (ALP) and two will receive education as usual. In the schools allocated to the to RISE and ALP groups, all of the children in the participating classes will receive the interventions. Health professionals from the RISE teams (SLTs, OTs, PTs and SEBs) will be recruited to deliver the RECALL and active control interventions.

Stratification of children

At the individual level, ten children, their parents/guardians and teachers will be recruited in each class to

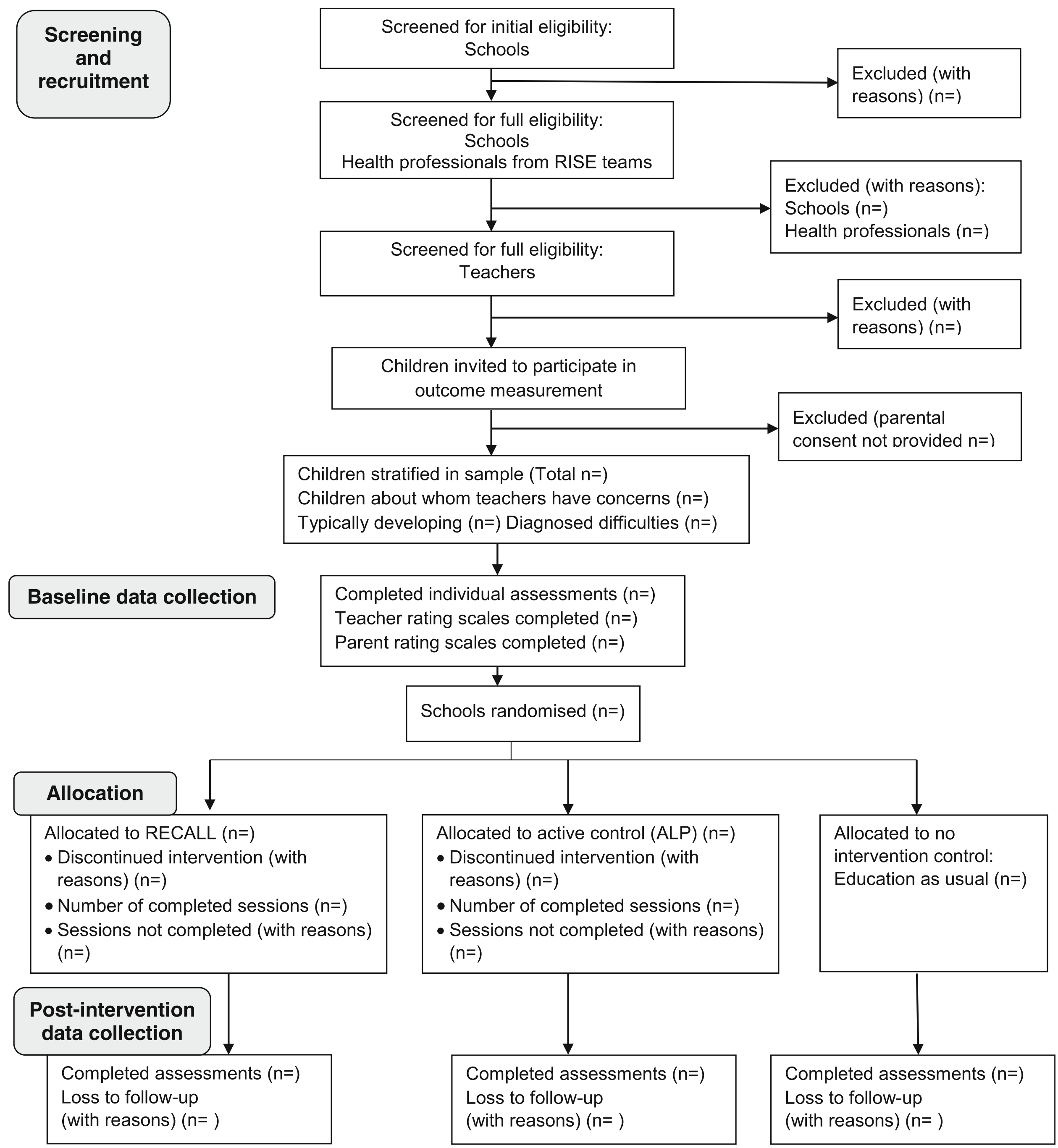


Fig. 1 RECALL cluster randomised feasibility trial: protocol flow chart

complete the outcome measures (total sample: n = 60 children). Due to the age of the children involved in this study (4–5 year olds), the number of standardised measures available, particularly of WM and attention, is limited. To determine the appropriateness and acceptability of the outcome measures that have been selected, they will be trialled with children representing the typical range of ability in a year one class. Hence, we will use stratified purposeful sampling [44]. Teachers in each class will identify children in three sub-groups/strata: (1) children about whom they have concerns around listening and communication skills but do not have a diagnosed developmental or learning difficulty (n = 5); (2) children with diagnosed developmental or learning difficulties (n = 2); and (3) typically developing children who do not have any identified listening and communication

		STUDY PERIOD				
	Recruitment	**Baseline data collection**	**Allocation**	**Post-allocation**		**End of Study**
TIMEPOINT	***$-t_1$***	***Weeks 1-2 t_1***	**0**	***Weeks 4- 10***	***Weeks 11- 12 t_2***	***t_x***
RECRUITMENT:						
Eligibility screen	X					
Informed consent	X					
Randomisation and allocation			X			
TRAINING FOR HEALTH PROFESSIONALS	X					
INTERVENTION:						
RECALL	X		X	↔		
Active control intervention	X		X	↔		
Education as usual control	X		X		X	
OUTCOMES:						
Feasibility and acceptability data	X	X		X	X	
Semi-structured interviews					X	
Children's data AWMA		X			X	
NEPSY		X			X	
NRDLS		X			X	
BRIEF-P		X			X	
FOCUS		X			X	
PROCESS EVALUATION	X	X	X	X	X	X
DEBRIEF & DISSEMINATION						X

Fig. 2 SPIRIT figure for RECALL cluster randomised feasibility trial

problems as recognised by the teachers (n = 3 per class). Children considered to be typically developing, within areas of social disadvantage, will be included due to the high incidence of speech, language and communication needs in this population [3].

Recruitment strategy

To recruit clusters, areas of LSES will be identified using data from the Northern Ireland Multiple Deprivation Measure (NIMDM) 2017 [45]. The NIMDM ranks the super output areas in NI from the most to the least deprived across seven types (or domains) of deprivation. An initial scope of this data indicated that there are approximately 72 primary schools in LSES areas in the two HSCTs where this study will take place. These schools will be ranked according to the Education, Skills and Training domain of the NIMDM and the aim is to recruit schools within the lowest decile for each HSCT area. Two local collaborators will be consulted in order to identify schools that meet the eligibility criteria (Table 1). Schools will be contacted in writing by the researchers, followed up by a phone call and a face-to-face meeting with the principal and year one teachers to discuss the study further. If more than one teacher in a school is interested in participating in the study, one class will be randomly selected.

To recruit children and their parents/guardians for outcome measurement (n = 10 in each school), the teachers will send a user-friendly research information leaflet, participant information sheet (PIS) and consent form home with each child. Parents will return the signed consent form to their child's teacher. From the list of children for whom consent is obtained, the teacher will choose ten pupils for outcome measurement according to the stratified sampling method. To enhance enrolment and retention in the study, parents who complete the communication skills rating scale at both the pre-and post-intervention time-points will be entered into a prize draw for a £100 supermarket shopping voucher.

To recruit the health professionals to deliver the intervention, the team mangers will identify the professionals who meet the eligibility criteria (Table 1) and disseminate the PIS and consent form. Staff will email the researcher to indicate their interest in the study and a meeting will be arranged to discuss this further and obtain written consent.

Eligibility criteria

Table 1 provides the inclusion and exclusion criteria for each participant group and the rationale for each prerequisite.

Consent

At the cluster level, written consent for trial entry will be obtained from the school principals [35]. Individual consent for participation will then be obtained from all other participants [34]. The teachers, parents/guardians and children will be asked to take part without being explicitly told about which intervention they will receive. This means consent is not fully informed but it reduces the risk of selection bias and enhances the internal validity of the study [47]. The acceptability of this and its impact on recruitment will be examined in the process evaluation. Consent from the health professionals and school staff will be obtained during the pre-study meetings with the first author. Regarding children's participation in the study, parental consent will be obtained. Child assent is deemed to be inappropriate in this study due to the age of the children. Although some 5-year-

Table 1 Cluster and individual participant eligibility criteria and rationale

Participant group	Inclusion criteria	Exclusion criteria	Rationale
Cluster eligibility (schools)	Situated in areas of LSES in the two participating HSCT areas. Have requested support from the RISE team in relation to children's attention and language skills.	Schools with no separate year one class, i.e. all year one children are taught within a composite class with older/younger children.	RECALL was not designed for composite classes.
Education staff (teachers and classroom assistants)	Work with year one classes in a school which meets the above criteria	Previously accessed the active control (ALP) intervention.	Teachers who have previously received the active control may use strategies or activities from it in their practice which may contaminate the study findings.
Health professionals	Situated in the two participating HSCT areas. Must be SLTs, OTs, PTs or SEBs with experience in delivering whole-class programmes.	Health professionals from the teams in the three HSCT trusts involved in the co-production of RECALL.	Teams that were involved in the co-production of RECALL may be biased and this could threaten the internal validity of the study [46].
Children	Currently in a year one class, aged 4–5 years, in a school that meets the above criteria. They may have diagnosed or undiagnosed learning or developmental difficulties.	Children whose first language is not English will be excluded from being selected for outcome measurement.	The outcome measures being trialled in this feasibility study are not standardised for children whose first language is not English.

old children may be able to provide assent [48], there are considerable challenges in knowing if this is accurate [49]. The amount of autonomy children typically exercise in a given situation is also an important consideration [50]. The RECALL programme will be delivered as part of the educational curriculum and in this context children typically have limited autonomy. Although children will not assent to take part, parents will be asked to inform their children that the study is taking place and will be given a child-friendly leaflet to help them tell their child about the research. If parents do not return the consent form, the child will still receive the RECALL or active control interventions but they will not be part of the research study and no outcome measurement will be carried out with them.

Randomisation and allocation

The six schools will be randomised to each arm of the trial: two will receive RECALL; two will receive the active control intervention (ALP); and two will receive education as usual. This will be conducted by the schools' names being placed in opaque, sealed envelopes which will be selected by an independent person from within the lead researchers' institute. This process has been deemed as introducing a low risk of bias in allocation concealment [51]. Randomisation will occur after baseline data collection with the children. As previously indicated, children will be selected for outcome measurement using stratification. The teacher will sort the names of all those whose parents provide written informed consent into the three strata previously specified. If more than the required number in each sub-group consent, the participants will be randomly selected using the same process of placing names in opaque envelopes.

Interventions

The experimental, theoretically underpinned RECALL programme and the active control interventions both incorporate group and whole-class activities designed to be fun for young children. The programmes are comparable in their structure, format and dosage (intervention frequency and duration). They both consist of six, 40-min sessions that are repeated three times per week for 6 weeks (18 sessions in total). The first session each week will be delivered by the health professionals who will model the activities for the teachers so that they can deliver the two further practice sessions.

Experimental intervention: RECALL

RECALL is a theoretically underpinned, multi-component, manualised intervention that explicitly targets WM skills in 4–5 year olds to enhance attention and language skills. It is underpinned by individual change theory (why the intervention components are expected to benefit WM and produce near- and far-transfer effects) and systems theory (considering the role of the school context in affecting change) [52–55]. It was co-produced through a series of workshops with one group of teachers, parents and health professionals in an inter-sectoral partnership [54].

Individual theory of change The tasks included in RECALL are based on evidence from a recent systematic review [56]. The review found certain tasks designed to either target WM directly (listening recall and odd-one-out) or indirectly (cognitively-demanding physical activity, inhibition, phoneme awareness and fantastical play) produced improvements on WM and some benefits for near-transfer activities [57–67]. The common ingredient across the effective interventions was predominantly the executive-loaded nature of the trained task, i.e. training on a task that taps into attentional and processing resources under executive control and not just the storage of information [56]. It has been suggested that repeated practice on executive-loaded working memory (ELWM) tasks (rather than practising storage-only, short-term memory tasks) may improve the efficiency of processing or perhaps even facilitate the storage of information in WM [58, 68]. Based on this evidence, all of the components in RECALL are executive-loaded tasks, where attention must be divided between the storage and processing demands of the task. This may overlap with the way attention is used in everyday (real-world) activities. Hence, since treatment effects are more likely to transfer from trained activities to activities with overlapping features [26], the direct training on ELWM tasks in RECALL may benefit untrained WM tasks and real-world skills including attention and language.

In addition to directly training ELWM skills, RECALL includes two other tasks that were identified in the systematic review as having potential. Interventions targeting phoneme awareness skills [64, 65] and fantastical play [66] were found to impact WM indirectly. These are included in RECALL due to their associations with functional language outcomes and attention. They are complementary to and consistent with the theory that ELWM tasks support WM because they are also executive-loaded tasks, i.e. they tap into processing and attentional resources under executive control. Phoneme awareness is the ability to isolate and manipulate sounds in spoken words [69]. Improving phoneme awareness might enhance the phonological mechanisms underlying WM, through increasing the efficiency of processing and supporting the creation of accurate, structured phonological representations. This may in turn support language development since our ability to recall words depends on their phonological representations in long-term memory [70, 71].

Fantastical play is a type of pretend play that is fantasy-oriented [66]. For example, pretend play could involve pretending to make tea, whereas fantastical play might involve pretending to make swamp tea for a giant. Engaging in fantastical play may support children's WM and other executive functions which are used to support switching between fantasy and reality and remembering the rules/scripts of the pretence [72, 73].

Systems theory of change (intervention delivery model) The theory underpinning how the ELWM tasks in RECALL can be delivered in the classroom was developed through the co-production workshops. The socio-ecological model [74] was used as a framework to inform the development of an intervention logic model (i.e. a pictorial representation of the relationships between the required resources, activities needed, mechanisms of change and desired outcomes [33]). This supported the identification of multi-level factors that may impact on the programme delivery in the classroom, e.g. the timing of intervention sessions in the classroom, the availability of resources and staff training needs. Consequently, the theory underpinning the delivery of RECALL is that the co-designed tasks will work in the classroom context when staff are supported with adequate training and a detailed manual. The health professionals model one RECALL session per week in the classroom. The teachers follow the activity plan in the RECALL manual so that they become familiar with the tasks and can deliver them independently a further two times in the week. Detailed session plans and accompanying materials such as picture stimuli and worksheets are provided in the RECALL manual.

RECALL components The ELWM tasks incorporated into RECALL include direct training on two ELWM tasks (listening recall and odd one out [58]), phoneme awareness training [64, 65] and fantastical play [66]. Table 2 provides a description of each task.

Task progression The manipulation of WM loads on a trial-by-trial basis may be important for improving WM where research has particularly shown the value of adaptive training, i.e. task difficulty that increases or decreases automatically based on an individual child's performance [77]. As RECALL is to be delivered in the

Table 2 RECALL components and task progression

RECALL component (ELWM task)	Task progression
Listening recall (direct WM training)	
- This task targets verbal ELWM. - The children listen to a short sentence, judge whether it is true or false and recall the last word of the sentence.	The number of to-be-remembered words increases from one word in week one to two words by week 6.
Odd one out (direct WM training)	
- This task targets visuospatial ELWM. - The children look at three pictures in a grid, decide where one the odd one out is (left, middle or right), then recall the location of the odd one out picture.	The number of to-be-remembered locations increases from one in week one, to three or four by week 6.
Phoneme awareness training	
There are four types of phoneme awareness task in RECALL, focusing on developing awareness of the initial sounds in words. 1. Alliterative matching: finding things that start with a target sound. E.g., "Book starts with 'b'. Can you find the other things that start with 'b'?" 2. Segmenting initial sounds: "what sound does _____ start with?" 3. Alliterative matching and blending the target to generate new words: "Find the one that starts with ___? Let us think of other things that start with _" 4. Blending sounds to identify words: "Look at these pictures. Can you find the b – all?"	The four tasks develop from the easiest (alliterative matching) to the most difficult (blending sounds) [75]. The difficulty level of the practice items in each task progresses from early to late developing phonemes based on typical speech sound development [76].
Fantastical play	
There is no direct training on fantastical play in RECALL. This is integrated into the programme through the use of a fantastical theme for each session, e.g. superheroes. However, the direct ELWM and phoneme awareness tasks incorporate the theme of each session throughout i.e., the words and pictures used relate to the theme.	

group context, individual adaptive profiles cannot be rolled out. Instead, the programme is designed to become progressively more difficult across its 6 weeks. Table 2 shows how the direct ELWM and phoneme awareness tasks in RECALL progress in difficulty across the course of the 6-week programme. Due to two novel features of the RECALL trial (the age of the children and the group nature of the intervention), establishing the span level at which to commence training and how to increase the level of difficulty from week to week was reasoned from previous studies with older children [58]. The appropriateness of this for 4–5 year olds will be explored in this feasibility trial.

Dosage The amount and intensity of training is often poorly reported in WM studies [56].[2] The dosage to be implemented in RECALL is based on the best available evidence from the systematic review which indicated that 11 trials (practice items) of each direct ELWM task (listening recall and odd one out) delivered three times per week for 6 weeks was effective [58]. For the phoneme awareness tasks, the dose (number of trials) administered in previous interventions is unclear. However, several studies identified that training sessions lasted 10–15 min [64, 65] and this is replicated in RECALL.

Structure of RECALL sessions Each of the six RECALL sessions follows the same format, incorporating whole-class and group activities (Fig. 3). The fantastical theme for the week is introduced using a puppet who tells the children they are going on an adventure. The children are encouraged to enter into the fantasy by moving like characters in the fantastical land, e.g. posing like a superhero. The children are then divided into three groups that rotate around the direct ELWM and phoneme awareness training activities. The sessions close with another whole-class activity so the puppet takes them back to the reality of the classroom.

Active control group: existing ALP

The active control group in this study will receive an existing intervention (ALP) developed and used by the RISE teams. This has been selected as the active control condition because the programme is delivered in the same way as RECALL, i.e. the health professionals model the activities for the teachers and provide them with session plans so that they can replicate them. The programme also has the same dosage as RECALL (six, 40-min sessions that are repeated three times per week delivered once by the health professionals and twice the teachers). This recognises the importance of equating the training intensity between groups in WM research [24, 79].

The crucial difference between this programme and the experimental RECALL intervention is that the ALP intervention is not underpinned by WM theory. It aims to improve children's attention and listening skills through repeated practice at listening tasks (e.g. the facilitator reads a story and the children must shake a musical instrument when they hear a particular word). It focuses on teaching children the importance of listening and on the use of visual, verbal and behavioural strategies to support listening, e.g. proximal praise. The tasks do not require the children to recall verbal or visuospatial information and they are not all executive-loaded. Whether

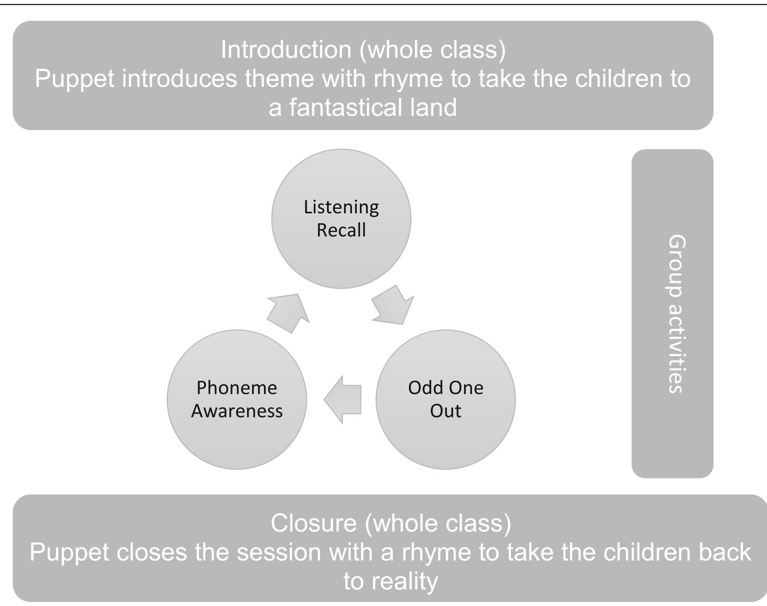


Fig. 3 Structure of RECALL session

this intervention is sufficiently different to act as a comparator in a full CRT will be explored in this trial.

No intervention control: education as usual

The two schools in this arm of the trial will not receive any whole-class interventions such as RECALL and the active control intervention during the 6-week trial period. Their teachers will be delivering the education curriculum as usual. How the teachers in these classes support the children's attention and language skills during the study period will be explored in semi-structured interviews at the end of the trial.

Compliance and fidelity

To enhance the implementation of RECALL, the health professionals, who will be modelling the programme each week for the teachers, will attend a 2-day training course prior to delivering it. They will be given the detailed programme manual which they will also supply to the teachers. To monitor compliance with the programme delivery and dosage, the health professionals and teachers will be asked to keep a simple log of their implementation (e.g. how often they delivered the programme and how long for). To monitor fidelity, three RECALL sessions in each school (one delivered by the health professional team and two by the teacher) will be observed by the first author. One of the health professional sessions and one of the teacher-delivered sessions will be observed simultaneously by a second member of the research team who will independently rate the delivery. Agreement between the raters will be checked by a third member of the team.

The researchers will use a structured observation tool designed within Carroll et al.'s (2007) [80] conceptual framework to explore four key elements of implementation (content, coverage, frequency, duration) and four moderating variables (intervention complexity, facilitation strategies, quality of delivery and participant responsiveness). Since this is a feasibility study, some adaptation to the intervention will be allowed (i.e. the researchers may address any problems raised by the health professionals or teachers). Any advice given will be recorded and examined in the process evaluation [81]. The interventions will be discontinued if a teacher withdraws from the study. If a health professional withdraws, another member of staff will be recruited and trained.

Blinding

The school participants (principal, teachers and classroom assistants) and parents/guardians in the two intervention groups will be blinded to their group allocation. It is especially important that teachers and parents are blinded to group allocation, as their ratings of children's attention skills will be used as outcome measures [25]. Maintaining the teachers' blinding for the duration of the trial may be challenging, especially if the participating schools are in close geographical proximity to each other. This will be explored as part of the process evaluation in this study. Blinding of the health professionals to the schools' allocation will not be possible as the teams will inevitably know which intervention they are delivering. The risk of this influencing the outcomes will be minimised further by the blinding of the research assistant (RA) who will be collecting the outcomes data. Whether the RA becomes aware of group allocation will also be investigated during the process evaluation.

Outcome measures

Table 3 details the data that will be gathered at the cluster and individual levels to meet the primary objectives of this study regarding the acceptability of RECALL in the school setting and the feasibility of the trial processes.

Data collection

The acceptability and feasibility data will be gathered throughout the study and during the process evaluation (see Fig. 1). In WM research, it is essential to demonstrate clear causal pathways [25]. A future large-scale trial of the effectiveness of RECALL would therefore have to include a range of measures of children's outcomes including measures of the trained activities (WM and phoneme awareness skills), untrained WM tasks (near-transfer) and attention and language skills (far-transfer effects). Testing the feasibility and acceptability of measuring all of these skills with 4–5 year olds, for whom the range of standardised assessments is limited, is one of the key objectives of this feasibility trial. This will occur at two points, baseline and post-intervention (see Fig. 2). Four types of measurement will be trialled with the sample of ten children in each cluster.

1. Standardised assessments administered directly with the children by a trained research assistant (RA). The RA, who will be blinded to group allocation, will withdraw children individually from their classroom for approximately one hour at each time point to complete the following standardised assessments:

a) Phoneme awareness: The Preschool and Primary Inventory of Phonological Awareness (PIPA) [82]. This test is standardised for children aged 3 years to 6 years 11 months. It includes six subtests examining a range of phonological awareness skills. The phoneme isolation subtest will be used to directly assess children's ability to identify the initial

Table 3 Acceptability and feasibility data at the cluster and individual levels

Data	Cluster level	Individual level
Acceptability of RECALL intervention and its manual to health professionals and teachers	Measures of compliance and fidelity.	Qualitative data: • Semi-structured interviews • Comments on intervention logs • Feedback from pre-study training provided for health professionals.
Compliance	Number of sessions delivered in each cluster	Qualitative data from semi-structured interviews including reasons for any sessions not being completed.
Fidelity	Structured observations by research team following Carroll et al. (2007) Research team records of any advice given.	–
Recruitment, consent and sampling procedures	Number and proportion of schools: • Meeting eligibility criteria • Approached • Principals who consent • Teachers who consent Number and proportion of children identified by teachers in each of the 3 sub-groups.	Number and proportion of parents who consent
Attendance levels and loss to follow-up.	Number of completed interventions	Number of standardised assessments, teacher rating scales and parent rating scales completed post-intervention
Acceptability of randomisation	School consent rates and reasons given for participation/non-participation.	Qualitative data: teachers' perspectives on random allocation.
Acceptability of active control intervention as a comparator to RECALL	–	Qualitative data: health professionals' perspectives on similarities/differences between the programmes. Observations of delivery by research team.
Exploration of education as usual	–	Qualitative data–semi-structured interviews with teachers in the education as usual control arm.
Acceptability of outcome measures for the children, teachers and RISE teams	–	Number of completed assessments for each child at each time point Number lost to follow-up and reasons why if possible Quality of audio-data will be reviewed Qualitative data: semi-structured interviews
Unexpected adverse effects	Any unanticipated effects will be recorded by the RISE team and teachers	
Blinding	Qualitative data: recording if blinding maintained at end of study.	

sound in a word, thereby providing a measure of a task directly trained in RECALL.

b) Working memory: The Automated Working Memory Assessment (AWMA) [83] is a computerised assessment that will be administered using a laptop. This test has good validity as a measure of WM compared to other assessments [84]. Good test-retest reliability has also been demonstrated [15] and this measure is used widely in WM research. Two subtests will measure trained executive-loaded WM skills (listening recall and odd one out). Four further subtests will measure WM tasks not directly trained in the intervention (near-transfer effects). These subtests (digit recall, block recall, counting recall and non-word recall) have been selected due to their use in previous studies [58, 85].

c) Attention: NEPSY-II–A Developmental Neuropsychological Assessment (NEPSY) [86]. Standardised, performance-based measures of attention for children under 6 years are limited [87]. The NEPSY-II is one of the few available assessments that includes attention subtests suitable for children of 4–5 years and (or its previous edition) has been administered in relevant studies [67].

2. Language: The New Reynell Developmental Language Scales (NRDLS) [88] is a standardised assessment for children aged between 3 years and 7 years 6 months. It has two scales: one that examines children's understanding of selected

vocabulary items and grammatical features (the Comprehension Scale); and another that tests children's production of the same features of language (the Production Scale). This test is widely used in clinical and research contexts [89] in the identification of language impairment. It uses objects (rather than picture stimuli) during the assessment and this should make it accessible to the target population in this study.

3. *A teacher rating scale of the child's attention in the classroom:* The Behaviour Rating Scale of Executive Function-Preschool Version (BRIEF-P) [90]. This tool is designed to specifically measure the behavioural characteristics associated with executive function skills including WM. It is a standardised, validated scale consisting of 63 items that can be used with children from 2 years to 5 years 11 months. It has good clinical utility and sensitivity and has been shown to complement performance-based measures of executive functions including WM [91, 92].
4. *A parent rating scale of the child's language and communication skills at home.* The Focus on Communication Outcomes Under Six (FOCUS) [93]. This has shown excellent test-retest reliability and internal consistency [94]. The forms will be posted to the parents one week before each data collection point and they will be asked to return the form to their child's teacher. The completed forms will be collected by the RA along with the teacher-completed BRIEF-P.
5. *Weekly monitoring of the child's performance on the trained tasks.* Capturing individual responses will be an important part of a large-scale CRT due to the need for WM training to be adaptive. Therefore, assessing the feasibility of measuring children's progress from week to week is an important part of the current feasibility study. For the classes receiving RECALL, the children's performance on the direct WM and phoneme awareness tasks will take place during the first session each week which is delivered by the RISE NI teams. It is anticipated that the presence of additional adults in the classroom will facilitate this process. Each child will have a RECALL booklet in which they will complete the tasks using stampers or by drawing circles around the target pictures to indicate their responses. This will not be possible for some tasks that require purely verbal responses. For these tasks, digital voice recorders will be used (with parental consent) to record what the children say. There are significant uncertainties around the feasibility of audio-recording such data amidst the background classroom noise. Due to the level of uncertainty around this method, we aim to carry this out with just five, randomly selected children, in one of the RECALL classes. The voice recorder will be placed in a small gadget-holder which the children will wear across their bodies. A tie-clip microphone, connected to the recorder, will be placed on the children's jumpers or lapels. The devices will be switched on and off by the teacher or classroom assistant.

Data analysis

The feasibility data will be analysed and reported descriptively using means, frequencies and percentages. The data will be summarised and presented graphically. A CONSORT flow diagram will be used to report the response, recruitment and retention rate of clusters and individual participants at each point of the study. Where available, reasons for attrition and loss to follow-up will be reported.

Regarding the data obtained from the outcome measures completed with the children, statistical significance of treatment effects will not be analysed as this study would be under-powered for this purpose. However, between group comparisons will be conducted to inform the statistical model for the future trial. This will include two elements: (1) a series of one-way analyses (ANOVAs) of the baseline data of children's standardised scores on the working memory (AWMA), attention (NEPSY subtests) and language measures (CELF-P) to investigate pre-intervention group differences; and (2) a series of analyses of covariance (ANCOVAs) to investigate post-intervention group differences). As the standardised assessments of WM, language and attention will be repeated within a short time-frame, results from the education as usual group will be used to examine test-retest effects. Qualitative analysis of the data gathered in the semi-structured interviews will be carried out using Braun and Clarke's (2006) thematic analysis [95].

Process evaluation

A process evaluation will be conducted throughout the study to support an understanding of how the trial processes relate to the context within which RECALL will be implemented [80]. The cluster and individual level data on the acceptability and feasibility of RECALL will be integrated with the qualitative findings and observations of cluster characteristics using the model proposed by Grant et al. [96]. Through this, the barriers and facilitators to implementation will be explored and the intervention logic model developed during the co-production phase will be refined.

Criteria for proceeding to a full CRT

The primary factor for consideration as to whether to proceed to a full trial will be the feasibility data pertaining to recruitment and retention rates and the completion of outcome measures. However, strict thresholds for progression have not been set as these factors can be influenced by contextual variations that may not impact on a future trial [42, 97]. Rather, the decision to proceed to a main trial will be made along by the research team in collaboration with the Trial Steering Committee. Solutions to any problems observed in the feasibility trial will be sought through four potential options suggested by Bugge et al. [98]: (1) adapt the intervention, (2) adjust the context within which the intervention would be delivered, (3) amend elements of the trial design or (4) implement a combination of all of these actions.

Monitoring

Trial steering committee

The conduct of this trial will be overseen by a Trial Steering Committee (TSC) that includes experienced researchers, key stakeholders from the health and education sectors in NI and service users. This group has been involved in the design of the trial and will meet at an interim point to review the progress towards the trial aims and to monitor the safety and well-being of all participants. Due to the nature and purpose of the primary data to be collected in this study (feasibility and acceptability measures), a Data Management Committee is not deemed necessary at this stage but will be established prior to the definitive CRT.

Modifications

Any modifications to the study protocol such as the eligibility criteria, recruitment procedures or outcome measures will only be carried out in agreement with the TSC. The changes made and reasons underlying them will be carefully recorded as these could be vital to the design of the future trial.

Stopping guidelines

Any adverse events occurring in the course of the trial will be carefully recorded and reported to the TSC, although this is not anticipated given the low risk nature of the study. The TSC will be contacted in this unlikely event and the trial may be discontinued. The study may also be discontinued if both schools in the RECALL arm of the trial withdraw. In the case of the trial being discontinued, all of the other active participants will be informed. The active control intervention may be continued as part of routine practice by the health professionals but no further data would be collected from the children for outcome measurement. The parents would be informed accordingly.

Ethical considerations

As noted, this is a low-risk study in that no additional potential harm is associated with the research compared to the everyday activity of the participants. The main ethical considerations relate to the welfare of children, parental consent and the children's capacity to assent, and the maintenance of confidentiality. The schools' policies regarding health and safety and child protection will be obtained in advance by the research team and adhered to throughout the trial. All members of the research team will hold valid Access NI Enhanced Disclosure Certificates[3] confirming they are permitted to work with children in compliance with NI legislation. Through the whole-class sessions, it is possible that children with neurodevelopmental difficulties may be identified by the health professionals. In this instance they will advise the teacher of an appropriate service to which the child could be referred and ask them to seek parental consent prior to making a referral. Children who already attend another service will continue to receive this support during the trial. The procedures for obtaining parental consent in this study have been designed according to guidance provided by the Health Research Authority (2017) [50] (see consent section). All information/data obtained during the study will remain confidential and will be held in accordance with the General Data Protection Regulation (EU) 2016/679. Aside from the initial consent forms, all further material will be identified by unique number only, with no identifying information. The procedures used to ensure anonymity and confidentiality may be subject to audit through Ulster University's annual audit programme.

Dissemination

The findings from this trial will be disseminated to all of the participants at a local level through informal networks in the first instance. At a national and international level, the results will be disseminated through conferences and publications in professional literature and peer-reviewed journals prior to the final design and conduct of a full CRT.

Discussion

To our knowledge, RECALL is the first theoretically underpinned, multi-component, whole-class intervention that specifically aims to enhance WM, attention and language skills in 4–5-year-old children through activities applied within their everyday context. This study responds to calls for ecologically valid approaches to WM intervention for young children [28, 99] and the testing of creative approaches for children with low-language ability who are at risk of academic underachievement and poor employment prospects [8, 9].

A realist perspective underpins all stages of this research, influencing the intervention development, trial design and process evaluation. This approach recognises the impact of context on the implementation of interventions in real-life settings [39, 52, 53], which has been lacking in WM research to date. Therefore, the findings from this feasibility study will be of interest to researchers and practitioners interested in implementing WM interventions in the classroom.

In particular, the observations of RECALL being delivered in the classroom will allow investigation of whether it is possible for WM interventions to be delivered in the classroom with fidelity to their design and dosage. Key in this examination will be whether the executive-loaded nature of the trained tasks is maintained in their implementation. The inclusion of qualitative data in the process evaluation is a strength of this feasibility trial. This will allow us to explore participants' views on the acceptability of RECALL and, crucially, the reasons for any differences between the intervention model and their fidelity to it. Thus we will be able to identify issues that may impact on the external and internal validity of a large-scale CRT.

The study design takes cognisance of the previous criticisms of the methodological quality of previous WM research [23–25], through the inclusion of an active control group (receiving a comparable intervention in terms of structure and dosage) and the blinding of outcomes assessors. The findings from this feasibility study will inform whether it can be scaled-up into a full CRT to evaluate the clinical and cost-effectiveness of RECALL.

Trial status

Recruitment will commence in December 2018.

Endnotes

[1]See Kellogg Foundation 2004 guidance for a comprehensive overview of logic modelling [33].

[2]The term dosage is used to refer to all components of the intervention intensity; dose refers to the number of trials per single intervention session [78].

[3]AccessNI Criminal Record checks are compulsory for all employees or volunteers in working with vulnerable adults or children in NI (https://www.nidirect.gov.uk/articles/types-accessni-checks)

Abbreviations

ALP: Attention and Listening programme; CA: Classroom assistant; CRT: Cluster randomised trial; HSCT: Health and Social Care Trust; LSES: Low socio-economic status; NI: Northern Ireland; OT: Occupational therapist; PT: Physiotherapist; RA: Research assistant; RECALL: Recall to Enhance Children's Attention Language and Learning; RISE: Regional Integrated Support for Education; SEB: Social Emotional and Behaviour Specialist; SLT: Speech and language therapist; STM: Short-term memory; TSC: Trial Steering Committee; WM: Working memory

Acknowledgements

The authors thank Dr. Joni Holmes (MRC Cognition & Brain Sciences Unit, University of Cambridge) and Professor Lucy Henry (City, University of London) for their contributions to the theoretical underpinning and design of RECALL; and Professor Mike Clarke (Director of MRC Methodology Hub, Queen's University Belfast) for his input to the methodological design of this feasibility trial.

Funding

This trial constitutes part of a doctoral research study funded by the Research and Development Division of the Public Health Agency, Northern Ireland. The funder has not been involved in the design of the protocol and will have no input to the interpretation or publication of the study results. The authors alone will be responsible for the conduct of the trial, the data analysis, interpretation and publication of the findings.

Availability of data and materials

As this is a feasibility trial, sharing of the dataset is not anticipated. However, any requests for data or material should be made to the corresponding author. Requests will be reviewed by the Trial Steering Committee.

Authors' contributions

AR, JT and LT conceived of the study and applied for the funding of the doctoral project of within which this study will take place. AR wrote the first draft of the protocol to which JT and LT then contributed. All of the authors have read and approved the final manuscript.

Ethics approval

Ethical approval for this study has been granted by the Ulster University Research Ethics Committee (REC/18/0036). The trial has been registered with the International Standard Randomised Controlled Trial Registry (ISRCTN13633886).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Received: 19 December 2018 Accepted: 13 June 2019
Published online: 24 June 2019

References

1. World Health Organization (WHO) Social Determinants of Mental Health. 2014. https://apps.who.int/iris/bitstream/10665/112828/1/9789241506809_eng.pdf. Accessed 9 Sept 2015.
2. Conti-Ramsden G, Durkin K, Mok PLH, Toseeb U, Botting N. Health, employment and relationships: correlates of personal wellbeing in young adults with and without a history of childhood language impairment. Soc Sci Med. 2016;160:20–8.
3. Elliott NL. An investigation into the communication skills of long-term unemployed young men. 2011. http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.553779 Accessed 30 Sept 2017.
4. Roulstone S, Law J, Rush R, Clegg J, Peters T. Investigating the role of language in children's early educational outcomes. Bristol: University of the West of England; 2011.
5. Archibald LM. SLP-educator classroom collaboration: a review to inform reason-based practice. Autism & Developmental Language Impairments. 2017;2:1–17.
6. Cirrin FM, Schooling TL, Nelson NW, Diehl SF, Flynn PF, Staskowski M, et al. Evidence-based systematic review: effects of different service delivery models on communication outcomes for elementary school–age children. Lang Speech Hear Serv Sch. 2010;41:233–64.
7. Ebbels SH, McCartney E, Slonims V, Dockrell J, Norbury CF. Evidence based pathways to intervention for children with Language Disorders. Int J Lang Commun Disord. 2019;54(1):3–19.
8. Nippold MA. Different service delivery models for different communication disorders. Lang Speech Hear Serv Sch. 2012;43(2):117–20.

9. Norbury CF, Vamvakas G, Gooch D, Baird G, Charman T, Simonoff E, et al. Language growth in children with heterogeneous language disorders: a population study. J Child Psychol Psychiatry. 2017;58(10):1092–105.
10. Botting N. The interplay between language and cognition. In: Clegg J, Ginsborg J, editors. Language and Social Disadvantage, vol. 2006. Chichester: Wiley; 2006. p. 28–43.
11. Kapa LL, Plante E. Executive function in SLI: recent advances and future directions. Curr Dev Disord Rep. 2015;2(3):245–52.
12. Allen RJ, Hitch GJ, Baddeley AD. Cross-modal binding and working memory. Vis Cogn. 2009;17(1–2):83–102.
13. Baddeley AD, Hitch GJ. Working Memory. In: Bower GH, editor. The psychology of learning and motivation, vol. 8. London: Academic Press; 1974.
14. Cowan N. (2008). What are the differences between long-term, short-term, and working memory? Prog Brain Res. 2008;169:323–38.
15. Alloway TP, Gathercole SE, Kirkwood H, Elliott J. The cognitive and behavioural characteristics of children with low working memory. Child Development. 2009;80(2):606–21.
16. Bunting MF, Cowan N. Working memory and flexibility in awareness and attention. Psychological Research. 2005;69:412–9.
17. Cowan N, Fristoe NM, Elliott EM, Brunner RP, Saults JS. Scope of attention, control of attention and intelligence in children and adults. Mem Cogn. 2006;34(8):1754–68.
18. Baddeley AD, Gathercole SE, Papagno C. The phonological loop as a language learning device. Psychol Rev. 1998;105:158–73.
19. Archibald LM. Working memory and language learning: a review. Child Lang Teach Ther. 2017;33(1):5–17.
20. Holmes J, Butterfield S, Cormack F, Loenhoud AV, Ruggero L, Kashikar L, et al. Improving working memory in children with low language abilities. Front Psychol. 2015;6:519.
21. Cogmed Working Memory Training. Pearson Assessment; 2005.
22. Soveri A, Antfolk J, Karlsson L, Salo B, Laine M. Working memory training revisited: a multi-level meta-analysis of n-back training studies. Psychon Bull Rev. 2017;24:1077–96.
23. Melby-Lervåg M, Hulme C. Is working memory training effective? A meta-analytic review. Dev Psychol. 2013;49(2):270–91.
24. Melby-Lervåg M, Redick TS, Hulme C. Working memory Training does not improve performance on measures of intelligence or other measures of "far transfer": evidence from a meta-analytic review. Perspect Psychol Sci. 2016; 11(4):512–34.
25. Redick TS, Shipstead Z, Wiemers EA, Melby-Lervåg M, Hulme C. What's working in working memory training? An educational perspective. Educ Psychol Rev. 2015;27:617–33.
26. Gathercole SE, Holmes J, Dunning DL, Norris D. Working memory training involves learning new skills. J Mem Lang. 2019;105:19–42.
27. Dunning D, Holmes J, Gathercole SE. Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial. Dev Sci. 2013:1–12.
28. Dunning D, Holmes J. Does working memory training promote the use of strategies on untrained working memory tasks? Mem Cogni. 2014;2: 854–62.
29. Jaeggi SM, Buschkuehl M. Working memory training and transfer: theoretical and practical considerations. In: Toni B, editor. New Frontiers of Multidisciplinary Research in STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health). Springer Proceedings in Mathematics & Health, vol 90. Cham: Springer; 2014;16(6):915–925
30. Schwaighofer M, Fischer F, Bühner M. Does working memory training transfer? A meta-analysis including training conditions as moderators. Educ Psychol. 2015;50(2):138–66.
31. Department of Education (DENI) Budget 2006–08 Children and Young People Funding Package. Belfast: Department of Education; 2006.
32. Harron A, Dickson F. Perspectives on trans-disciplinary working for children in mainstream education. Oral presentation: rehabilitation and Therapy Research Society conference; 2013.
33. Kellogg Foundation WK. Logic Model Development Guide. Battle Creek, MI: W.K Kellogg Foundation; 2004.
34. Medical Research Council (MRC) Cluster randomised trials. Methodological and ethical considerations. London: Medical Research Council; 2002.
35. Edwards SJL, Braunholtz DA, Lilford RJ, Stevens AJ. Ethical issues in the design and conduct of cluster randomised controlled trials. BMJ. 1999; 318(7195):1407–9.
36. Chan A-W, Tetzlaff JM, Altman DG, Laupacis A, Gøtzsche PC, Krleža-Jerić K, et al. SPIRIT 2013 statement: defining standard protocol items for clinical trials. Ann Intern Med. 2013;158:200–7.
37. Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. BMJ. 2016; 355:i5239.
38. Craig P, Dieppe P, McnItyre S, Mitchie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ. 2008;337:a1655.
39. Moore G, Evans R. What theory, for whom and in which context? Reflections on the application of theory in the development and evaluation of complex population health interventions. SSM Population Health. 2017;3:132–5.
40. Gascoigne M. Supporting children with speech, language and communication needs within integrated children's services. RCSLT Position Paper. London: RCSLT; 2006.
41. Arain M, Campbell MJ, Cooper CL, Lancaster GA. What is a pilot or feasibility study? A review of current practice and editorial policy. BMC Med Res Methodol. 2010;10:67.
42. Eldridge SM, Costelloe CE, Kahan BC, Lancaster GA, Kerry SM. How big should the pilot study for my cluster randomised trial be? Stat Methods Med Res. 2015;25(3):1039–56.
43. Thabane L, Ma J, Chu R, Cheng J, Ismaila A, Rios LP, et al. A tutorial on pilot studies: the what, why and how. BMC Med Res Methodol. 2010;10(1):1–10.
44. Sandelowski M. Combining qualitative and quantitative sampling, data collection and analysis techniques in mixed-methods studies. J Nurs Health Res. 2000;23:246–55.
45. Northern Ireland Multiple Deprivation Measure (NIMDM) (2017) https://www.nisra.gov.uk/statistics/deprivation/northern-ireland-multiple-deprivation-measure-2017-nimdm2017. Accessed 28 Mar 2018.
46. Mohr DC, Spring B, Freedland KE, Beckner V, Arean P, Hollon SD, et al. The selection and design of control conditions for randomized controlled trials of psychological interventions. Psychother Psychosom. 2009;78:275–84.
47. Eldridge SM, Ashby D, Feder GS. Informed patient consent to participation in cluster randomized trials: an empirical exploration of trials in primary care. Clin Trials. 2005;2:91–8.
48. Meaux JB, Bell PL. Balancing recruitment and protection: children as research subjects. Issues Compr Pediatr Nurs. 2001;24(4):241–51.
49. Fargas Malet M, McSherry D, Larkin E, Robinson C. Research with children: methodological issues and innovative techniques. J Early Child Res. 2010; 8(2):175–92.
50. Health Research Authority (HRA) Consent and Participant Information Sheet Preparation Guidance V4 February 2017. http://www.hra-decisiontools.org.uk/consent/index.html. Accessed 15 Dec 2017.
51. Higgins JPT, Altman DG. Assessing risk of bias in included studies. In: J.P.T, Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions. Chichester: Wiley; 2008.
52. Shearn K, Allmark P, Piercy H, Hirst J. Building realist program theory for large complex and messy interventions. Int J Qual Methods. 2017;16:1–11.
53. Shiell A, Hawe P, Gold L. *complex* interventions or complex systems? Implications for health economic evaluation. BMJ. 2008;336:1281–3.
54. Wright D, Wimbush E, Jepson R, Doi L. Six steps in quality intervention development (6SQuID). J Epidemiol Community Health. 2016;70:520–5.
55. Stokols D. Toward a science of transdisciplinary action research. Annu J Commun Psychol. 2006;38(6):63–77.
56. Rowe A, Titterington J, Holmes J, Henry L, Taggart L. A systematic review of the effectiveness of non-computerized interventions targeting working memory in 4–11 year olds. Dev Rev. 2019;52:1–23.
57. Cornoldi C, Carretti B, Drusi S, Tencati C. Improving problem solving in primary school students: the effect of a training program focusing on meta-cognition and working memory. Br J Educ Psychol. 2015;85:424–39.
58. Henry LA, Messer DJ, Nash G. Testing for near and far transfer effects with a short, face-to-face adaptive working memory training intervention in typical children. Infant Child Dev. 2014;23(1):84–103.
59. Passolunghi MC, Costa HM. Working memory and early numeracy training in preschool children. Child Neuropsychol. 2016;22(1):81–98.
60. Witt M. School based working memory training: preliminary finding of improvement in children's mathematical performance. Adv Cogn Psychol. 2011;7(1):7–15.
61. Alesi M, Bianco GL, Palma A, Pepi A. Improving children's coordinative skills and executive functions: the effects of a football exercise program. Percept Mot Skills. 2016;122(1):27–46.

62. Kamijo K, Pontifex MB, O'Leary KC, Scudder MR, Wu C, Castelli DM, et al. The effects of an afterschool physical activity program on working memory in preadolescent children. Dev Sci. 2011;14(5):1046–58.
63. Koutsandréou F, Wegner M, Niemann C, Budde H. Effects of motor versus cardiovascular exercise training on children's working memory. Med Sci Sports Exerc. 2016;48(6):1144–52.
64. Melby-Lervåg M, Hulme C. Serial and free recall in children can be improved by training: evidence for the importance of phonological and semantic representations in immediate memory. Psychol Sci. 2010;21(11): 1694–700.
65. Van Kleeck A, Gillam RB, Hoffman LM. Training in phonological awareness generalizes to phonological working memory: a preliminary investigation. J Speech Lang Pathol – Applied Behavior Analysis. 2006;1(3):228–43.
66. Thibodeau RB, Gilpin AT, Brown MM, Meyer BA. The effects of fantastical pretend-play on the development of executive functions: An intervention study. J Exp Child Psychol. 2016;145:120–38.
67. Volckaert AMS, Noël M. Training executive function in preschoolers reduce externalizing behaviors. Trends Neurosci Educ. 2015;4:37–47.
68. Loosli SV, Buschkuehl M, Perrig WJ, Jaeggi SM. Working memory training improves reading processes in typically developing children. Child Neuropsychol. 2011;18:62–78.
69. Hulme C, Bowyer-Crane C, Carroll JM, Duff FJ, Snowling MJ. The causal role of phoneme awareness and letter-sound knowledge in learning to read: combining intervention studies with mediation analyses. Psychol Sci. 2012; 23(6):572–7.
70. Bishop DVM, Snowling MJ. Developmental dyslexia and specific language impairment: same or different? Psychol Bull. 2004;130:858–86.
71. Pennington BF, Bishop DVM. Relations among speech, language, and reading disorders. Annu Rev Psychol. 2009;60:283–306.
72. Estes D, Wellman HM, Woolley J. Children's understanding of mental phenomena. In: Reese H, editor. Advances in child development and behavior. New York: Academic Press; 1989. p. 41–86.
73. Golumb C, Kuersten R. On the transition from pretense play to reality: what are the rules of the game? Br J Dev Psychol. 1996;14:203–17.
74. McLeroy KR, Bibeau D, Steckler A, Glanz K. An ecological perspective on health promotion programs. Health Educ Behav. 1988;15:351–77.
75. Cunningham AE. Explicit versus implicit instruction in phonemic awareness. J Exp Child Psychol. 1990;50:429–44.
76. Shriberg LD. Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. J Speech Hear Res. 1993;36:105–40.
77. Klingberg T. (2010) Training and plasticity of working memory. Trends Cogn Sci. 2010;14(7):317–24.
78. Warren SF, Fey ME, Yoder PJ. Differential treatment intensity research: a missing link to creating optimally effective communication interventions. Ment Retard Dev Disabil Res Rev. 2007;13:70–7.
79. Shipstead Z, Hicks KL, Engle RW. Working memory training remains a work in progress. J Appl Res Mem Cogn. 2012;1:217–9.
80. Carroll C, Patterson M, Wood S, Booth A, Rick J, Balain S. A conceptual framework for implementation fidelity. Implement Sci. 2007;2(40):1-9.
81. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions: Medical Research Council guidance. BMJ. 2012;350:h1258.
82. Dodd B, Crosbie S, Macintosh B, Teitzel T, Ozanne A. Primary and Preschool Battery of Phonological Awareness (PIPA). London:Psychological Corporation; 2000.
83. Alloway TP. Automated working memory assessment. London: Pearson Assessment; 2008.
84. Alloway TP, Gathercole SE, Kirkwood HJ, Elliot JE. Evaluating the validity of the automated working memory assessment. Educ Psychol. 2008;7:725–34.
85. Elliott JG, Gathercole SE, Alloway TP, Holmes J, Kirkwood H. An evaluation of a classroom-based intervention to help overcome working memory difficulties and improve long-term academic achievement. J Cogn Educ Psychol. 2010;9(3):227–50.
86. Korkman M, Kirk U, Kemp S. NEPSY-II: a developmental neuropsychological assessment. San Antonio, TX: The Psychological Corporation; 2007.
87. Mahone EM, Schneider HE. Assessment of attention in pre-schoolers. Neuropsych Rev. 2012;22(4):361–83.
88. Edwards S, Letts C, Sinka I. The New Reynell Developmental Language Scales. London: GL-Assessment; 2011.
89. Letts C, Edwards S, Sinka I, Schaefer B, Gibbons W. Socio-economic status and language acquisition: children 's performance on the new Reynell Developmental Language Scales. Int J Lang Commun Disord. 2013;48(2): 131–43.
90. Gioia GA, Espy KA, Isquith PK. The Behavior Rating Inventory of Executive Function-Preschool version (BRIEF-P). Odessa, FL: Psychological Assessment Resources; 2003.
91. Mahone EM, Hoffman J. Behavior Ratings of Executive Function among Preschoolers with ADHD. Clin Neuropsychol. 2007;21:569–86.
92. Sherman EMS, Brooks BL. Behavior Rating Inventory of Executive Function—Preschool Version (BRIEF-P): test review and clinical guidelines for use. Child Neuropsychol. 2010;16(5):503–19.
93. Thomas-Stonell NL, Oddson B, Robertson B, Rosenbaum P. Development of the FOCUS (Focus on the Outcomes of Communication Under Six), a communication outcome measure for preschool children. Dev Med Child Neurol. 2010;52:47–53.
94. Washington K, Oddson B, Robertson B, Rosenbaum P, Thomas-Stonell N. Reliability of the focus on the outcomes of communication under six (FOCUS). J Clinical Pract Speech-Lang Pathol. 2013;15(1):25–31.
95. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol. 2006;3(2):77–101.
96. Grant A, Treweek S, Dreischulte T, Foy R, Guthrie B. Process evaluations for cluster-randomised trials of complex interventions: a proposed framework for design and reporting. Trials. 2012;14:15.
97. Eldridge SM, Lancaster GA, Campbell MJ, Thabane L, Hopewell S, Coleman CL, Bond CM. Defining feasibility and pilot studies in preparation for randomised controlled trials: development of a conceptual framework. PLoS ONE. 2016;11(3):e0150205.
98. Bugge C, Williams B, Hagen S, Logan J, Glazener C, Pringle S, et al. A process for decision-making after pilot and feasibility trials (ADEPT): development following a feasibility study of a complex intervention for pelvic organ prolapse. Trials. 2013;14:353.
99. Wass SV, Scerif G, Johnston MH. Training attentional control and working memory- is younger better? Dev Rev. 2012;32:360–87.

Chapter 9 - Findings from feasibility trial

9.1 Introduction

This chapter reports the findings of the three-arm cluster randomised feasibility trial that aimed to explore: the feasibility of conducting a full-scale trial of the effectiveness of the novel Recall to Enhance Children's Attention, Language and Learning (RECALL) intervention; and the acceptability of RECALL to HPs and teachers. The findings have been written as a paper that has been submitted for publication to *Pilot and Feasibility Studies*. The next section includes the pdf. version of the paper in its entirety, as submitted to the journal. Ethics approval for this study was granted by the Ulster University Research Ethics Committee (REC/18/0036). (see Appendix B at the end of this thesis). Based on the trial findings, the intervention logic model was refined and the new logic model is presented at the end of this chapter.

9.2 Findings from a classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): a cluster randomised feasibility trial (Paper 4)

Author details and title

Rowe, A., Titterington, J., Holmes, J., Henry, L. and Taggart, L Findings from a classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): a cluster randomised feasibility trial (submitted to *Pilot and Feasibility Studies*).

PhD researcher's contribution to the paper

The PhD researcher was responsible for every aspect of conducting the feasibility trial including: writing the recruitment documents, applying for ethical approval, the recruitment of participants, training the Research Assistants who conducted the outcome measurement, co-ordinating and carrying out fidelity visits, conducting the semi-structured interviews and analysing the quantitative and qualitative data. The PhD researcher wrote the first draft of the manuscript and revised it based on the co-authors' feedback and is the first and corresponding author for the journal submission.

Findings from a classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): a cluster randomised feasibility trial.

Abstract

Background: International debate around the best models of speech and language therapy provision for children with language disorders has highlighted the need for research into classroom-based approaches and intervention dosage. Working memory (WM) is a cognitive skill linked to attention and language. 'Recall to Enhance Children's Attention, Language and Learning' (RECALL) is a novel, six-week, classroom-based intervention designed to target WM and enhance attention and language skills in 4-5 year olds.

Methods: A cluster randomised feasibility trial was conducted to address: i) the feasibility of a definitive trial to evaluate RECALL; ii) the acceptability of RECALL to the health professionals and teachers who would deliver it; iii) and the factors that may impact on the fidelity of its delivery in the classroom. Six classes of 4-5 year olds participated: two received RECALL; two received an existing intervention targeting attention skills (not underpinned by WM theory); and two received education as usual (no intervention). Ten children in each class (*n*= 60) were sampled to assess the appropriateness of the outcome measures that may be used in a definitive trial. A process evaluation included observations of the fidelity of the intervention delivery and semi-structured interviews with the health professionals (HPs) and teachers who delivered RECALL.

Results: Recruitment targets were achieved and all six schools completed the trial. For the experimental RECALL intervention, 95% of sessions were delivered but fidelity to the intervention protocol varied between 76% and 45% across the two schools. The interview data revealed mixed findings regarding the acceptability of the intervention tasks and the outcome measures for RECALL. A greater understanding of the theory underpinning RECALL could have enhanced the teachers' fidelity to its delivery.

Conclusions: The trial processes (e.g., recruitment and consent procedures) could be easily scaled-up in a future definitive trial, but the RECALL intervention requires modification to enhance its acceptability. Large class sizes, and child and facilitator factors impacted on the dose (number of practice items) accessed by individual children, particularly those most at risk. This study highlights the need for thorough training for teachers and health professionals engaged in the delivery of classroom interventions for children with language disorders.

Trial registration: ISRCTN13633886**.** Registered 7 Sept 2018**.**

Keywords: working memory, classroom interventions, dosage, working memory, attention, language, feasibility

Key messages regarding feasibility:

- This study addressed the acceptability of a novel intervention for children with language disorders, and the feasibility of delivering it to whole classes of 4-5 year old children.
- The fidelity of the intervention delivery, and its potential effectiveness, could be optimised if it were repackaged as a small group intervention.
- The methods used to record children's progress during the intervention period should be modified prior to a full trial.

Background

The use of classroom-based interventions

Worldwide, there has been debate around the best models of Speech and Language Therapy (SLT) provision for school-aged children who are at risk of language disorders, particularly those from areas of social disadvantage (SD) where high proportions of children present with impoverished language skills on school entry [1-2]. SLT services are increasingly providing collaborative, classroom-based interventions but there is a lack of research-based evidence for this approach [3]. This raises important questions about whether valuable and limited resources are being used in the most efficient way [3-5]. Due to the role SLTs have in early intervention and prevention for language disorders, there is a need for ecologically valid research (conducted in real-life contexts) to provide an evidence-based practice approach [6-7].

Context of the current study

The current study was conducted in the real-life context of health and education services in one region of the United Kingdom (UK), Northern Ireland (NI), where there are high rates of SD associated with educational underachievement [8-9]. Extending the role of health professionals within early intervention and integrated service provision across the health and education sectors is a key strategy [10] that aims to harness health professionals' (HPs) specialist knowledge of the developmental skills that form the foundation for learning (e.g., language and motor skills) to enhance educational practice. The Regional Integrated Support for Education (RISE) teams are based in five Health and Social Care Trusts (HSCTs) that provide integrated health and social care services across NI. The RISE teams include: speech and language therapists (SLTs), occupational therapists (OTs), physiotherapists (PTs) and social, emotional and behavioural specialists (SEBs). They provide: individualised (specialist) support for children referred by their teachers; and whole class (targeted and universal) interventions that aim to prevent potential future difficulties for at risk children (i.e., non-referred children) [3]. The teams work in a transdisciplinary model in which professionals jointly plan and deliver interventions. Within the classroom context this also involves teachers and classroom assistants. Overall, this approach aims to maximise clinical and cost effectiveness by enhancing the holistic nature of interventions and streamline the clinical pathway for children by professionals sharing their expertise [11].

In NI children commence formal education at four years of age, and the mainstream school population includes a wide range of children including those with undiagnosed and diagnosed intellectual and / or developmental difficulties. The majority of children referred to the RISE teams are 4-5 year olds (year 1 pupils in the UK) from schools in areas of SD. Attention and language difficulties are most frequently cited as the reason for referral [12]. Current support, developed and provided by the RISE teams, is a whole-class intervention targeting attention skills: the Attention and Listening Programme (ALP). This intervention has not been evaluated robustly and, unlike the new intervention developed in this study, it is not underpinned by working memory (WM) theory.

Rationale for developing an intervention that targets WM

Working memory (the ability to hold in mind and mentally manipulate information over short periods of time in the face of distraction) is a cognitive skill linked to both everyday attentional skills and language development [13-14]. Interventions aimed at improving WM may therefore enhance these closely related real-world skills [15]. However, the potential for WM interventions, and in particular computer-based training programmes, to improve untrained WM tasks and real-world skills (transfer effects) has been widely debated [16].

Overall, the evidence indicates that existing computer-based training programmes consistently produce gains on the trained tasks and closely related memory tasks [17-18]. It has been suggested that to improve the therapeutic value of WM training, it may be necessary to embed it within typical classroom activities that are ecologically valid [19]. To test this, a new intervention was developed in the current study: The Recall to Enhance Children's Attention Language and Learning' (RECALL) programme. This is a theoretically underpinned, evidence-based intervention that targets WM in 4–5-year-old children through group and whole-class activities over a 6-week period. It is designed to be delivered by HPs from the RISE teams and teachers, and was co-produced with a group of these practitioners through a series of interactive workshops [20-22].

Rationale for conducting a feasibility trial

Existing collaborative practice between the RISE teams and schools in NI provided the optimal setting to develop and evaluate the RECALL intervention. Prior to conducting a definitive trial of RECALL, it was crucial to conduct a feasibility trial to deepen the understanding of the intervention [23], and to test whether it could be run with children as young as 4 years in a group setting. Previous evidence for WM classroom-based WM training interventions have been run with older children (6-7 year olds) who were trained on a one-to-one basis [24]. Little is currently known about the optimal intervention dosage (amount and intensity) required in classroom-based interventions for children with language disorders, or the factors that might impact on this [25-26]. A goal of this study was to evaluate these issues in a feasibility trial of RECALL.

Study aims and objectives

The specific aims of the study were:

1) To determine the feasibility of conducting a definitive cluster randomised trial (CRT) evaluating whether RECALL is more effective than an existing intervention (ALP), and 'education as usual', in 4-5 year olds from areas of SD;
   a) To understand trial processes including: recruitment, consent and sampling; blinding; attendance, and loss to follow-up.
   b) To determine the appropriateness of the outcome measures for the children, teachers and HPs.
2) To explore the acceptability of RECALL to HPs and teachers who deliver classroom-based interventions in mainstream schools.
3) To measure the compliance and fidelity of the intervention delivery.

Methods/design

This section provides a summary of the study design, methods of the feasibility trial, and the interventions implemented (RECALL and RISE). The study was designed and is reported according to the CONSORT 2010 extension to cluster randomised pilot and feasibility trials [27]. The trial was registered with the International Standard Randomised Controlled Trial Registry (ISRCTN13633886). Comprehensive details can be accessed in the study protocol associated with this trial [28].

Study design

This was a three-arm, cluster randomised feasibility trial with a parallel group design that took place in two HSCT areas in NI. Two classes of 4-5 year olds were randomly allocated to each arm of the trial: i) RECALL (experimental condition); ii) the existing ALP intervention developed by the RISE teams (active control condition); and iii) education as usual (no intervention condition). The experimental RECALL and active control interventions were delivered by HPs from the RISE teams once per week, followed up by two practice sessions delivered by teachers. Children's outcomes were measured at baseline and 1-week post-intervention by Research Assistants (RAs).

Participants

The target population were: HPs from the RISE teams (SLTs, OTs, PTs and SEBs) who had experience of delivering classroom-based interventions and were not involved in the co-production of RECALL; mainstream primary schools situated in areas of SD based on data from the NI Multiple Deprivation Measure [29]; teachers who had not previously received the ALP intervention; and children in year 1 classes (4-5 year olds).

Sample size and procedure

The recruitment targets were: eight HPs from the RISE teams and six schools. The aim was to recruit one class of 4-5 year olds in each school (*n*= ~30) with a stratified sample of 10 children in each class (*n*= 60 in total) for outcome measurement. The aim was to recruit a sample representing the typical range of ability in mainstream schools: i) children about whom teachers have concerns around listening and communication skills but do not have a diagnosed developmental or intellectual difficulty (*n*= 5 per school, *n*= 30 in total); ii) children with diagnosed developmental or intellectual difficulties (*n*= 2 per class, *n*= 12 in total); and iii) typically developing children who do not have any identified listening and communication problems as recognised by the teachers (*n*= 3 per class, *n*= 18 in total).

Randomisation and blinding

Randomisation took place at the school level after baseline data collection. The school names were placed in opaque envelopes that were randomly selected and allocated by the third author (overseen by the second author). The HPs were not blinded to the schools' allocation as they inevitably knew which intervention they were delivering to which school. The school participants (principals, teachers and parents), and the RAs who conducted the outcome measurement with the children were blind to intervention groupings.

Interventions

The experimental RECALL and active control (ALP) interventions were both 6-week interventions consisting of 40-minute sessions repeated 3 times per week. The HPs delivered the first session each week and demonstrated the activities for the teachers who provided two further practice sessions during the week (18 sessions in total). Details of these interventions are reported here according to the Template for Intervention Description and Replication (TIDieR) Checklist [30].

a. Experimental intervention: RECALL This novel intervention targets WM explicitly and is based on a systematic review of evidence suggesting that repeated practice on certain (non-computerised) activities can improve WM and have the potential to produce effects on untrained WM skills (near-transfer) and real-world skills such as attention and language (far-transfer) [31]. The common ingredient across the effective interventions was the executive- loaded nature of the trained task i.e., training on a task that taps into attentional and processing resources under executive control and not just the storage of information.

RECALL includes 3 executive-loaded tasks with specified dosage and task progression (Table 1). Each session starts with a whole-class activity in which a fantastical theme is introduced for that week using a puppet e.g., space. This is based on evidence that fantastical play supports children's WM [32]. The class is then divided into 3 groups (of 9-10 children) that rotate around the three tasks, namely, listening recall, odd one out and phoneme awareness tasks (described in Table 1). The HPs attended a 2-day training course prior to delivering RECALL (provided by the first author). The training aimed to enable the HPs to deliver the first intervention session each week in the classroom, thereby modelling the activities for the teachers who were to provide two further practice sessions per week. This method of cascading training is carried out routinely in the context of the RISE teams and schools. The decision to only provide direct training for the HPs (and not for the teachers) was based on evidence from a qualitative study conducted prior to the intervention development which highlighted that, due to resource constraints, it was highly unlikely that teachers would be released from their everyday duties to attend training (in preparation). The HPs and teachers were provided with a detailed manual including the theory underpinning the intervention.

Executive-loaded task	Dosage	Task progression
Listening recall [24] - Targets verbal ELWM. - The children listen to a short sentence, judge whether it is true or false, then recall the last word of the sentence	11 trials (practice items) per session.	The number of to-be-remembered words increases from one word in week one to two words by week 6.
Odd one out [24] - Targets verbal ELWM - The children look at three pictures in a grid, decide where one is the odd one out is (left, middle or right), then recall the location of the odd one out picture	11 trials per session.	The number of to-be-remembered locations increases from one in week one, to three or four by week 6.
Phoneme awareness [33-34] - Targets the ability to isolate and manipulate sounds in spoken words e.g., identifying the first sound in a word	10-15 minutes per session.	Difficulty increases from alliterative matching to blending onset and rime. Each task progresses from early to late developing phonemes based on typical speech sound development.

Table 1. RECALL components, dosage and task progression

b. Active control intervention: ALP This pre-existing programme was informally developed by the RISE teams and aims to improve attention and listening skills through: repeated practice of listening tasks and teaching children the importance of listening through visual and verbal cues. It is not underpinned by WM theory and does not require the children to recall verbal or visuospatial information.

c. No intervention control: Education as usual These schools did not receive any classroom-based interventions such as RECALL or ALP during the 6-week trial period.

Outcome measures

The primary outcomes relate to the feasibility of the trial processes and the acceptability of RECALL. The main feasibility outcomes were the rates of recruitment, consent and retention in terms of the number and proportion of participants at each stage in the study. The acceptability of RECALL was explored through semi-structured interviews with the HPs and teachers who delivered it (see Appendix 2). These were audio-recorded, transcribed verbatim and analysed using Braun and Clarke's (2006) [35] approach to thematic analysis.

The secondary outcomes were children's skills (*n*= 60) at baseline and one - week post-intervention. These determined the acceptability of the outcome measures. Following good practice in WM research [36], this included standardised assessment of: i) the trained tasks (listening recall, odd one out and phoneme awareness); ii) the untrained WM tasks (near-transfer); and iii) attention and language skills (far-transfer effects). Table 2 details the assessments used.

During the baseline assessment phase, the RAs felt that the children appeared to be performing close to ceiling level on two of the tasks, leading to concerns regarding the sensitivity of the measures to detect change as a result of treatment. This raised questions about the appropriateness of both the phoneme isolation subtest of the Preschool and Primary Inventory of Phonological Awareness (PIPA) [37] for phoneme awareness and the comprehension scale of the New Reynell Developmental Language Scales (NRDLS) [38] for language. Consequently, two alternative measures were trialled in one randomly selected school (*n*= 10 children): the phoneme segmentation subtest of the PIPA for phoneme awareness; and the Clinical Evaluation of Language Fundamentals-Preschool (CELF-P) [39] for language. These two subtests were not included in the measures administered in the other 5 participating schools.

The children's performance from week to week on the trained tasks was also monitored in order to explore the appropriateness of the difficulty level of the tasks

(Table 2). The children completed the odd one out and phoneme awareness tasks in individual booklets using crayons and stampers to indicate their responses. For verbal tasks (listening recall and some phoneme awareness tasks) the use of individual digital voice recorders was trialled with five randomly selected children in one of the RECALL classes.

Outcome measured	Skill	Standardised assessment
Trained task	Trained WM tasks	**Automated Working Memory Assessment (AWMA) [40]** • A computerised assessment administered using a laptop • 2 subtests administered in all 6 schools (*n*= 60 children): - Listening recall - Odd one out
Trained task	Phoneme awareness	**The Preschool and Primary Inventory of Phonological Awareness (PIPA) [37]** • A standardised assessment consisting of 6 subtests for children aged 3 years to 6 years 11 months • 2 subtests trialled: - Phoneme isolation subtest (administered in 5 schools, *n*= 50 children) - Phoneme segmentation subtest (administered in 1 school, *n*= 10 children)
Near-transfer	Untrained WM tasks	**Automated Working Memory Assessment** (detailed above) [40] • 4 further subtests administered in all 6 schools (*n*= 60 children): - digit recall - block recall - counting recall - non-word recall
Far-transfer	Attention	**NEPSY-II – A Developmental Neuropsychological Assessment (NEPSY) [41]** • Includes standardised performance-based measures of attention for children under 6 years • 2 subtests administered in all 6 schools (*n*= 60 children) - Auditory attention - Statue
	Language	**The New Reynell Developmental Language Scales (NRDLS) [38]** • A standardised assessment for children aged between 3 years and 7 years 6 months. • Comprehension scale administered in 5 schools (*n*= 50 children) **Clinical Evaluation of Language Fundamentals- Preschool (CELF-P) [39]** • A standardised assessment for 3 – 6 year olds that examines children's: understanding and use of syntax (grammar/sentence structure), semantics (word meanings) and grammatical morphology (markers of grammatical relationships • Core language subtests (*n*= 10) conducted in 1 school (*n*= 10)

	Behaviour in the classroom	**Behaviour Rating Scale of Executive-Function- Preschool Version (BRIEF-P) [42]** (*n*= 60) • A standardised, validated scale completed by teachers • Includes consisting of 63 items that can be used with children from 2 years to 5 years 11 months to measure behavioural characteristics associated with executive function skills including WM • Completed by teachers in all 6 schools (*n*= 60 children)
	Communication skills at home	**The Focus on Communication Outcomes Under Six – 34 (FOCUS-34) [43] (*n*= 60)** • A checklist of children's communication skills at home completed by parents to measure change over time • Completed by parents in all 6 schools (*n*= 60 children)

Table 2. Standardised assessments trialled at baseline and post-intervention

Process Evaluation

A process evaluation was conducted in parallel to the feasibility trial [44]. This was based primarily on the framework for the design and reporting of process evaluations of cluster randomised trials [45]. It also included elements of Steckler and Linnan's (2002) model [46] that are relevant to the delivery of classroom-based interventions. These included: i) the consideration of context (local factors that influence implementation); ii) fidelity (the extent to which the intervention is delivered as conceived); iii) the dose delivered (the amount of intervention offered to participants); and iv) the dose accessed by individuals (the extent of participants' engagement in the intervention).

Compliance and fidelity to the intervention protocol were measured through observations of three RECALL sessions in each school (one delivered by the HPs and two by the teacher), each carried out by the first author. One session in each school was observed simultaneously and rated independently by the second or third authors. Fidelity was scored using a structured checklist based on Carroll et al.’s 2007 framework (see appendix 1) [47]. These data were integrated with the findings from the semi-structured interviews with the HPs and teachers who delivered RECALL to determine the overall feasibility and acceptability of intervention.

Ethical approval

Ethical approval was granted by the Ulster University Research Ethics Committee (REC/18/0036) and approval was obtained from the relevant HSCT research offices.

Results

This section presents the participant characteristics and results in relation to the three key aims: the feasibility of conducting a definitive CRT; the acceptability of RECALL; and the compliance and fidelity of the intervention delivery.

Participant characteristics

Table 3 provides details of the number and characteristics of the schools (clusters) and the individual participants recruited to the study compared to the recruitment targets.

Participants	Recruitment targets	Number recruited	Characteristics
Health professionals	*n*= 8	*n*= 8	Professional backgound: SLT (*n*= 4) OT (*n*= 2) PT (n= 1) SEB (n= 1)
Schools (clusters)	*n*= 6	*n*= 6	Social disadvantage ranking (based on data from the NIMDM 2017 [29]): Within lowest decile for their HSCT area (*n*= 3) Within lowest quintile for their HSCT area (*n*= 3)
Children recruited for outcome measurement	*n*= 60	*n*= 60	Gender: girls (*n*= 26, 43%); boys (*n*= 34, 57%) Age at baseline: 56 months to 67 months (mean = 61 months)
	n= 30 (50% of sample)	*n*= 22 (37%)	1) children about whom teachers had concerns around listening and communication skills
	n= 12 (20%)	*n*= 12 (20%)	2) children with diagnosed developmental or learning difficulties
	n= 18 (30%)	*n*= 26 (43%)	3) typically developing children who did not have any identified listening and communication problems as recognised by the teachers

Table 3 Participant characteristics

Feasibility of conducting a definitive CRT

Recruitment, consent and sampling

Figure 1 shows the study flow chart including the response, recruitment and retention rates throughout the study. The recruitment targets were met in terms of: HPs (*n*= 8); schools (*n*= 6); and the total number of children (*n*= 60) (Table 3). Due to staff absence (maternity leave/sick leave) the RISE teams could only facilitate the study in particular geographical sectors within their HSCT areas. Consequently, from the list of schools identified in areas of SD (*n*= 43), a considerable number (*n*= 17) had to be excluded on the basis of their location. As a result, the criteria in respect of SD was widened to include schools ranked within the lowest quintile within the HSCT (rather than the lowest decile). The overall rate of parental consent (72%) was good. However, some parents of children about whom teachers had concerns did not consent and the desired proportion of children in this sub-group was not achieved (*n*= 22, 37% compared to the target of *n*= 30, 50%). It was also apparent during the sampling process that teachers did not always know whether children did/did not have a diagnosis.

Blinding

The outcome assessors (RAs) remained blind to the intervention groups but, due to the nature of the intervention and materials provided, the teachers in RECALL became aware of their allocation.

Attendance and loss to follow up

No schools or individual participants dropped out of the study. Two children did not complete post-intervention assessments as they were absent from school, indicating minimal loss to follow up (3%).

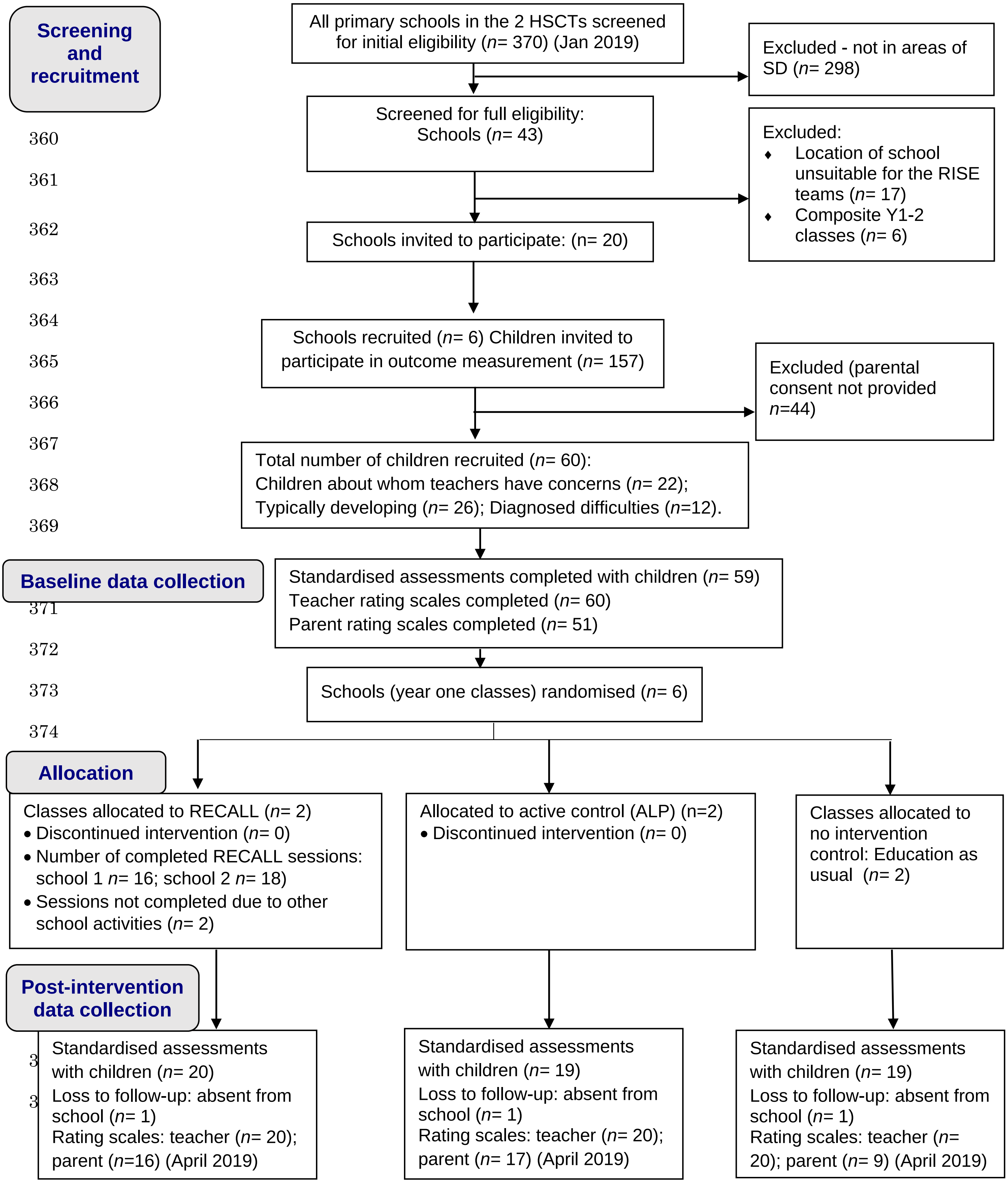


Figure 1. RECALL cluster randomised feasibility trial flow char (following CONSORT guidance, 2010) [27]

Appropriateness of outcome measures

The acceptability of the outcome measures used with the children was considered from two perspectives: i) the ease of administration and scoring; and ii) the appropriateness of the tests in terms of their psychometric properties for assessing WM, attention and language in the population of interest (4-5 year olds in areas of SD).

Ease of administration

Two methods were used to monitor the children's progress from week to week. For the odd one out task and some of the phoneme awareness tasks, the children each had an individual booklet and they marked their response using stampers. The data gathered through the observations of RECALL in the classroom and via the semi-structured interviews with the HPs and teachers indicated that this approach was not acceptable. The children needed help to turn the pages of the booklets so the HPs or teachers had to repeatedly pause the task to ensure all of the children were on the right page. The children were distracted by the stampers and tended to stamp ad hoc in their booklets. Hence, not only was the data collected unreliable, this method interfered with the task delivery.

For tasks that required a verbal response (listening recall and some of the phoneme awareness tasks) individual digital voice recorders were trialled with five children. The devices were small and unobtrusive and did not interfere with the delivery of the task. However, this method did not yield usable data. The microphones picked up too much background noise from the classroom, meaning the child's voice could not be distinguished. It was also difficult to hear the facilitator's voice when presenting the trial items so the accuracy of the child's response, could not be judged.

Regarding the pre-and post-intervention outcome measures, administering the full battery of assessments with each child was time-consuming and this may have impacted negatively on the children's motivation and performance. In particular, the NRDLS took a considerable amount of time to complete, whereas the CELF-P (trialled in one school) was much quicker to administer. With regards to the auditory attention and statue subtests of the Developmental Neuropsychological Assessment (NEPSY-II), all of the RAs found it difficult to observe and simultaneously record the children's performance. Therefore, they doubted the accuracy of their scoring. If this test were used in a full trial, thorough training and practice should be provided to those administering it and inter-rater reliability must be measured.

Regarding the proxy measures of children's functional skills, all of the teacher rating scales of attention in the classroom using the Behaviour Rating Inventory of Executive Function- Preschool Version (BRIEF-P) were completed. This suggests that the checklist was acceptable to teachers. Children's communication skills at home were measured using the Focus on Communication Under Six - 34 (FOCUS-34). This tool looks at change/improvement in the child's communication skills over time (rather than providing a direct measure of their ability). It should be completed by the same parent at each time point with support from a SLT [43]. Due to the classroom-based nature of this trial, the forms were sent home for parents to complete and return to the school. Therefore, the parents completed this measure without support. Completed checklists were returned at both time points for 35 children (58% of the sample) but examination of the raw data indicated that for 8 children the forms were not completed by the same parent at the two time points. This raises questions about the reliability of the data. Furthermore, two outlying scores were apparent indicating possible misunderstanding of scoring (a Likert scale) by the parents. In a future trial, greater support would need to be provided to parents (as outlined in the protocol for the FOCUS-34) to avoid these potential issues.

Psychometric properties

One of the key aims of this feasibility study was to determine whether the outcome measures are sensitive enough to detect change as a result of intervention. To examine the sensitivity of the outcome measures, we looked at the distribution of the children's scores at baseline for each assessment. If a lot of children scored at floor levels (low scores), a measure may be sensitive to change, though only if the floor effect is not so low that it masks future improvement. Conversely, if a lot of children score at ceiling levels (high scores) at baseline, the measure may not detect change at the post-intervention time point.

To identify potential floor or ceiling effects, the direction of the scores were explored in terms of skewness: negative skewness values indicate a clustering of scores at the high end that could indicate ceiling effects; and positive skewness values indicate a clustering of scores at the low end that may indicate floor effects [48]. First, the skewness of the children's scores for the full sample (*n*= 60) at baseline were explored. This sample included children considered to be typically developing (*n*= 26), as well as those with identified difficulties (*n*= 20) and those about whom teachers had concerns around listening and communication skills (*n*= 22). This means that any clustering of scores to the high end (negative skewness) could be attributed to high performance on the part of the typically developing children, which could mask the true sensitivity of a measure to detect improvements in children with poorer baseline skills. Consequently, further assessments of normality were conducted by splitting the sample into two groups: typically developing children (TD group) (*n*= 26); and children about whom there are concerns/ recognised difficulties with listening and communication skills (concerns group) (*n*= 34).

Table 4 presents the descriptive statistics for the baseline data (mean, standard deviation and skewness) for all of the outcome measures for the total and the split sample, along with a brief interpretation of these results. Degrees of skewness were interpreted as follows: less than −1 or greater than +1 = highly skewed; between −1 and −.5 or between +.5 and +1= moderately skewed; and between 0.5 and +.5 = approximately symmetric distribution [49]. Moderate skewness values were considered to be acceptable, but high skewness values (denoted by shaded cells in Table 4) were taken as an indication that a test may not be appropriate for a full trial. The table clearly shows the difference in the distribution of scores between the TD group and the concerns group. For the TD group, potential ceiling effects were found for the phoneme isolation subtest of the PIPA (skewness -1.99), and the BRIEF-P global executive and WM scales (skewness 1.67 and 1.32 respectively[1]). The overall direction of the scores for the children with concerns was the same for these measures (skewed towards better performance) but only to moderate levels indicating that these tools should be appropriate for use in a full trial of RECALL.

[1] On the BRIEF-P higher scores indicate higher executive dysfunction meaning that the child presents with greater difficulty coping in the classroom so positive skewness values indicate potential ceiling effects.

The pattern of results presented in Table 4 highlighted some issues that required further investigation. For the listening recall subtest of the AWMA, scores were clustered at the lower end for both groups (TD skewness 1.08, concerns group skewness 2.21) indicating potential floor effects that may mask children's improvement in a large scale trial. In addition, there was a need to clarify the optimal measures for phoneme awareness (the phoneme isolation or segmentation subtest) and language skills (the NRDLS or the CELF-P). Given the issues highlighted previously about the parents' scoring of the FOCUS-34 the results of this measure also needed further examination.

Baseline and post-intervention scores (mean and standard deviations) for the three intervention groups (RECALL, RISE and no-intervention control) for the full sample (n=60) were compared (Table 5) to provide an indication as to whether the outcome measures detected change. As the difference score between pre and post intervention assessment on the FOCUS-34 is the measure of interest for that assessment, only the change score was analysed. The data were not tested for statistical significance of treatment effects because this study aimed to assess the feasibility of a future full trial and consequently, the sample obtained was not statistically powered to support this type of analysis [27]. The findings are summarised below.

<u>Listening recall</u>: Table 5 shows that this test detected differences between the means for the three intervention groups at baseline and at the post-intervention time points. Therefore, despite children's scores being highly skewed towards the lower end, this test should be appropriate for a large-scale trial of RECALL.

Phoneme awareness: The phoneme isolation subtest was originally favoured for this study because it relates directly to the tasks trained in RECALL (identifying the first sound in a word). Due to concerns about potential ceiling effects at baseline, the phoneme segmentation subtest was trialled as an alternative in one school. Post-intervention results suggest that the phoneme isolation subtest is sensitive to change in the population of interest because differences across the intervention groups were apparent. Table 5 shows that the RECALL and RISE (active control) groups improved on the phoneme isolation task, but the no-intervention control group did not. Since the RAs reported that these tasks were quick and easy to administer, it may be acceptable to include both the phoneme isolation and segmentation subtests of the PIPA in a full trial.

Language: The direction of the distribution of scores for the NRDLS and the CELF-P (Table 4) indicated that the NRDLS scores were moderately skewed towards high scores (-.57) and the cumulative raw scores for the three subtests of the CELF-P were moderately skewed towards low scores (.56). Taken together with the RAs' report that the NRDLS was time-consuming to complete, this suggests that the CELF-P may be a more appropriate language measure for a definitive trial of RECALL.

FOCUS-34: For the purpose of the analysis of the parent rating scale two outliers (where it was apparent that the parents had misinterpreted the form) were removed. The FOCUS-34 measures change over time, with a difference of more than 11 points indicating significant clinical change [43]. Table 5 shows a clear difference between the mean change score (the post-intervention score minus the baseline measure) for the no-intervention control group ($\bar{x}$= 2.12, *SD* = 10.23) in comparison to the RECALL ($\bar{x}$= 13.46, *SD*= 21.70) and RISE groups ($\bar{x}$= 12.58, *SD*= 18.38). This suggests that the measure would be sensitive to change over time.

Outcome Measure			Full sample (*n*= 60)		Split sample				Interpretation of results
					Typically developing group (*n*= 26)		Concerns group (n= 34)		
Outcome	**Task**	**Test**	**Mean (SD)**	**Skewness[2]**	**Mean (SD)**	**Skewness**	**Mean (SD)**	**Skewness**	
Trained task	Listening recall	AWMA[3]	1.16 (1.68)	1.57	1.58 (1.98)	1.08	.81 (1.33)	2.21	Both groups: scores highly skewed towards the low end- potential floor effects
	Odd one out	AWMA	7.16 (3.54)	.28	7.88 (3.98)	-.13	6.56 (3.07)	.61	Both groups - distribution approximates normality
	Phoneme awareness	PIPA Phoneme isolation*	8.90 (4.04)	-1.08	10.08 (3.75)	-1.99	7.81 (4.05)	-.60	Full sample and TD group: highly skewed towards high scores - potential ceiling effects. Children with concerns- moderately skewed
		PIPA Phoneme segmentation†	.30 (.675)	2.28	.00	-	.38 (.74)	1.95	Both groups: highly skewed towards the low end - potential floor effects.
Near-transfer (untrained WM)	Digit recall	AWMA	18.24 (4.96)	-.46	18.69 (6.41)	-.80	17.88 (3.42)	.66	Children with concerns: moderate skewness towards high scores for digit recall and counting recall.
	Block recall	AWMA	10.74 (3.24)	-.28	11.65 (3.90)	-.73	10.00 (2.41)	-.39	
	Counting recall	AWMA	6.21 (3.19)	-.42	7.00 (3.60)	-.53	5.56 (2.71)	-.90	
	Nonword recall	AWMA	4.52 (3.56)	.15	3.96 (3.14)	.03	4.97 (3.86)	.08	
Far-transfer	Auditory Attention	NEPSY-II	19.54 (6.22)	-.69	20.62 (6.47)	-.94	18.70 (5.98)	-.62	Both groups: moderate skewness towards high scores
	Statue	NEPSY-II	22.64 (5.58)	-.81	25.69 (2.95)	-.61	20.24 (6.02)	-.23	Full sample: moderate skewness towards high end. Concerns group- approximates normality.
	Language	NRDLS*	61.06 (4.58)	-.74	62.75 (3.25)	.29	59.50 (5.11)	-.57	Both groups: NRDLS scores moderately skewed towards high performance; CELF-P scores moderately skewed towards lower end
		CELF-P† (Cumulative Raw Scores)	55.40 (8.53)	.44	61.5 (10.61)	-	53.80 (8.01)	.56	
	Behaviour in the classroom	BRIEF-P[4] Global Executive Composite	99.57 (30.21)	.90	88.73 (32.13)	1.67	107.85 (26.20)	.76	For both scales of this measure: scores are highly skewed to lower end (indicating better performance) for the TD group but not for the concerns group.
		BRIEF-P WM scale	62.20 (15.56)	.52	25.27 (10.48)	1.32	31.7 (8.34)	.26	
	Communication skills at home	FOCUS 34 baseline	189.39 (39.76)	-1.52	204.05 (36.76)	-2.51	179.13 (39.11)	-1.35	Highly skewed for full sample and both groups but to a greater degree for TD

Table 4. Descriptive statistics for raw scores at baseline for the full and stratified samples

[2] Skewness: 0=perfect normality; negative skewness values indicate a clustering of scores at the high end; positive skewness values indicate clustering at the low end (except on the BRIEF-P (Gioia et al., 2003) where lower scores indicate greater degrees of executive dysfunction so positive skewness = clustering of scores at the high end. Shaded cells =highly skewed values (>1 or <-1)

[3] Raw scores on AWMA subtests represent the number of trials correct (rather than memory span)

Outcome	Task	Test used	Time point	RECALL (*n*= 20)	RISE Active Control (*n*= 20)	No Intervention (*n*= 20)
				Mean (SD)	**Mean (SD)**	**Mean (SD)**
Trained task	Listening recall (ELWM)	AWMA	Baseline	.47 (.77)	1.22 (1.83)	1.41 (1.66)
			Post-intervention	4.11(3.12)	5.28 (4.51)	2.35 (3.74)
	Odd one out (ELWM)	AWMA	Baseline	7.00 (3.13)	5.94 (3.11)	8.06 (4.13)
			Post-intervention	8.42 (3.16)	10.44 (3.09)	9.24 (4.49)
	Phoneme awareness	PIPA Phoneme isolation subtest*	Baseline	6.33 (5.32)	9.47 (2.97)	9.05 (4.21)
			Post-intervention	7.56 (3.64)	9.63 (3.40)	7.16 (3.85)
		PIPA Phoneme segmentation subtest†	Baseline	.30 (.21)	-	-
			Post-intervention	2.10 (.31)	-	-
Near-transfer (untrained WM)	Digit recall	AWMA	Baseline	16.58 (5.78)	19.78 (4.25)	17.59 (4.32)
			Post-intervention	19.37 (4.04)	18.61 (4.64)	18.29 (4.95)
	Block recall	AWMA	Baseline	11.05 (2.80)	10.28 (3.48)	10.76 (3.7)
			Post-intervention	11.05 (2.55)	10.56 (5.22)	9.41 (3.97)
	Counting recall	AWMA	Baseline	16.58 (5.78)	19.78 (4.25)	17.59 (4.32)
			Post-intervention	19.37 (4.04)	18.61 (4.64)	18.29 (4.95)
	Nonword recall	AWMA	Baseline	3.58 (3.61)	6.39 (2.97)	3.35 (3.37)
			Post-intervention	7.26 (2.88)	8.61(4.13)	6.65 (3.23)
Far-transfer	Auditory Attention	NEPSY-II	Baseline	18.00 (6.29)	20.05 (6.69)	21.59 (5.83)
			Post-intervention	17.47 (6.78)	21.68 (5.45)	19.82 (5.33)
	Statue	NEPSY-II	Baseline	21.32 (5.82)	22.47 (6.01)	23.72 (5.13)
			Post-intervention	26.37 (4.14)	26.47 (6.60)	23.72 (5.10)
	Language	NRDLS Comprehension Scale*	Baseline	60.56 (5.72)	61.47 (3.79)	60.35 (4.76)
			Post-intervention	62.33 (2.74)	62.95 (2.70)	61.35 (5.15)
		CELF-P† (Cumulative Raw Scores)	Baseline	55.4 (8.53)	-	-
			Post-intervention	57.00 (7.24)	-	-
	Behaviour in the classroom	BRIEF-P[5] Global Executive Composite	Baseline	60.20 (12.61)	57.55 (14.40)	68.85 (17.66)
			Post-intervention	57.45 (11.68)	50.70 (9.75)	63.45 (15.40)
		BRIEF-P Working memory scale	Baseline	27.9 (7.37)	25.85 (9.63)	33.00 (11.11)
			Post-intervention	25.55 (6.97)	22.95 (6.02)	29.80 (9.62)
	Communication skills at home	FOCUS-34 (Change score)	Post-intervention minus baseline	13.46 (21.70)	12.58 (18.38)	2.12 (10.23)

Table 5. Baseline and post-intervention mean and standard deviations for raw scores at baseline and post-intervention (per group) for full sample (*n*= 60): rows are shaded to ease reading

[5] Note: higher scores on the BRIEF-P [42] indicate greater degrees of executive dysfunction. A reduction in scores over time indicates improvement. For tests marked* sample (*n*= 50); for tests marked† sample (*n*= 10). For the FOCUS-34 [43] change scores of >11 points indicate significant clinical change.

Acceptability of RECALL

Figure 2 shows that three major themes were identified in the qualitative data gathered through the semi-structured interviews with the HPs and teachers who delivered RECALL.

Some RECALL components are acceptable

All of the HPs and teachers liked the fantastical play component of RECALL, reporting that the puppet, fantastical themes and props were appropriate and fun for 4-5 year old children. The phoneme awareness tasks were easy to administer due to their similarity to usual classroom practice. The listening recall task was also quick and easy to administer. It was at an appropriate level of difficulty (with both the teachers and the HPs reporting that the children seemed to improve across the 6-week intervention period) and engaged the class. The fact that the sentences tied in with the fantastical themes and were funny seemed to appeal to even the most inattentive children. One of the teachers reported:

> *"I think, the listening recall one benefitted and involved every child…..It was actually boys I noticed who probably stick out with the listening recall and the boys who like imaginative play and who like a giggle. So, I actually found that really related to boys. It related to everybody, but they stood out. It surprised me that they were interested. It was just because they thought it was funny, so it just hooked them in and they wanted to be part of it."*

Odd one out is challenging

None of the HPs or teachers liked the odd one out task in its current format. The teachers were uncertain about the nature of this specific task and how to deliver it e.g., whether it was acceptable for children to place their fingers on the location of the odd one out picture in their booklets. As outlined earlier, the booklets were hard to manage and the stampers were distracting, meaning that the facilitators had to pause frequently to help the children, thereby disrupting the flow of the activity and elongating it. The participants all reported that there were too many trial items per session so the children became unmotivated, especially those with existing attention difficulties who tended to copy their peers' responses. The HPs and teachers all stated that the difficulty level increased too quickly and the children would have benefitted from additional practice at the 2-to-be-remembered item level. One of the teachers stated:

> *"I found it was a very big challenge for a lot of them [the children]. At the start it wasn't too bad, but then as it progressed and maybe you were at three odd one out on the one page, then four- it was really, really difficult. Again, those few [children] in the top group would have been trying to focus really well but so many just lost it and a lot of them were randomly stamping. The wee weaker groups, they just weren't focused at all.*

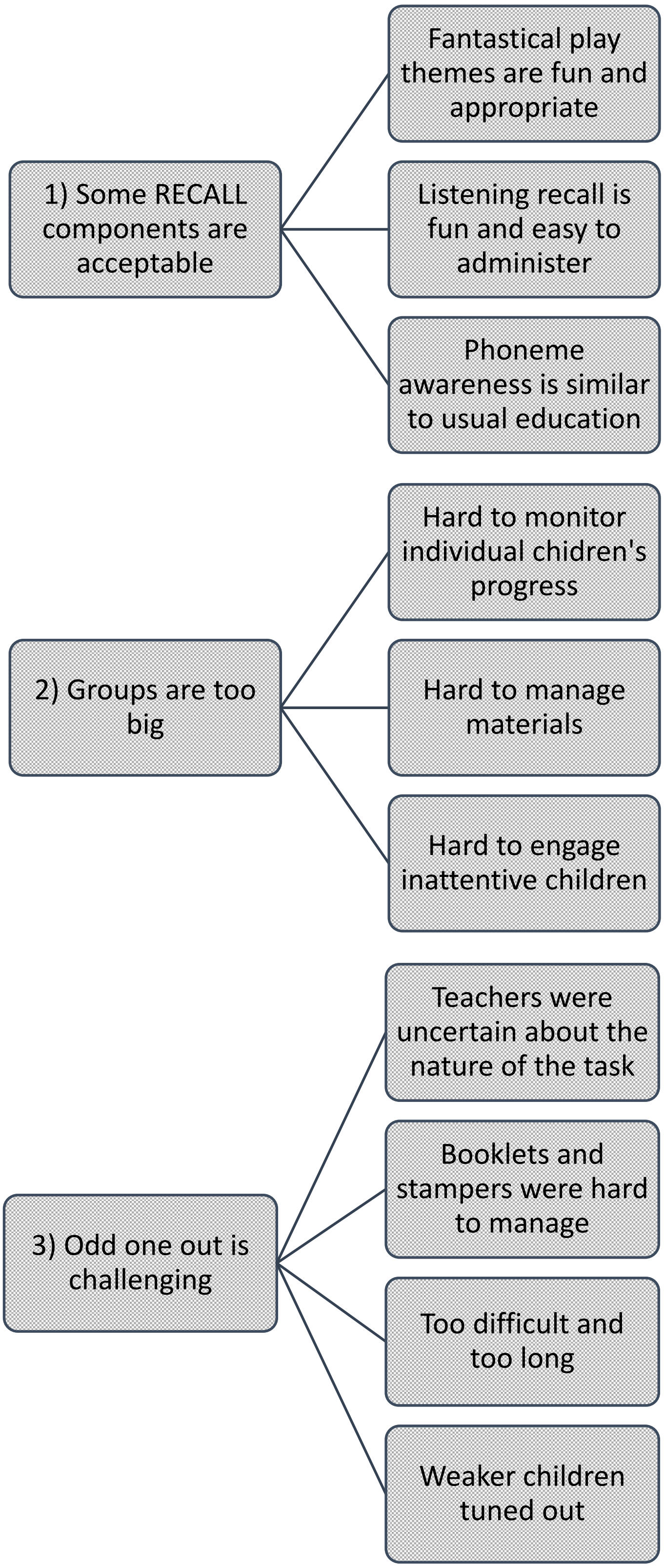


Figure 2. Qualitative data themes identified in semi-structured interviews with the HPs and teachers who delivered RECALL

Groups are too big

Whilst the use of booklets and stampers to record children's responses impacted on the acceptability of RECALL, the size of the groups was also identified as a barrier to the intervention delivery. The number of children in the class (divided into groups of 9 or 10) made it difficult to deliver the tasks and to monitor children's progress. This was noted by all of the HPs and teachers during the semi-structured interviews (even for the listening recall task which was universally liked by the participants).

This was summed up by one of the HPs:

> *"…..if there was less children it would be so much easier to guide and judge how they were doing. Because you were only getting a general idea [of how they were doing]."*

Compliance and fidelity to the intervention delivery

There was good compliance with the implementation of RECALL regarding the total number of sessions completed (95%) and the number of trials delivered (11 practice items of listening recall and odd one out, and 10-15 minutes of phoneme awareness training). In terms of the quality of delivery, fidelity to the intervention protocol varied between the 2 schools (there was a high degree of inter-rater consistency on the fidelity measure across the research team): school 1 (76%) and school 2 (45%).

This discrepancy related to the delivery of the odd one out task during the teacher-delivered RECALL sessions. In school 1, the teacher divided the class into three groups, as specified in the intervention protocol. In school 2, the teacher presented the task to all of the children at the same time, holding up the picture stimuli and walking around the classroom until each child had seen them. Then the children all stamped the location of the odd one out picture in their booklets. This lengthened the time that the children had to hold the information in their WM, both changing the nature of the task and making it too difficult. The overall duration of the session also increased and the children, especially those who were inattentive, became unmotivated and restless.

Discussion

This study responds to calls for globally significant, rigorous and ecologically-valid research into collaborative, classroom-based approaches for children at risk of language disorders and the factors that may impact on their delivery [3-7]. To our knowledge, RECALL is the first theoretically-underpinned, evidence-based, classroom-based intervention that specifically targets WM to enhance attention and language skills in 4-5-year-old children from areas of SD.

The first research aim was to determine whether it is possible to conduct a definitive CRT to evaluate whether RECALL is more effective than an existing intervention (ALP) and education as usual. The successful recruitment of HPs, schools and children from areas of SD, high completion rates and minimal loss to follow-up suggest that the trial processes could be scaled-up into a definitive trial. However, because staffing levels within the RISE teams may fluctuate, consultation with the service managers will be essential for the successful roll out of a large-scale study.

The stratified sampling method employed in the current study should be modified because this was affected by ambiguity around whether some children had a diagnosis or not. The three strata could be collapsed into two: typically developing children and those about whom teachers have concerns and may/may not have a diagnosis. Including children considered to be typically developing would be valuable in a large trial since high proportions of children in areas of SD are at risk of language disorders and little is known about the individual differences that moderate the effects of WM training [50] and language interventions [51]. A full trial will require a large sample with sufficient power to detect differences between subgroups of children as well as intervention groups [52].

Regarding the appropriateness of the pre-and post-intervention outcome measures, the descriptive statistics suggest that the following measures could be used in a full trial: the AWMA for working memory; the phoneme isolation subtest of the PIPA for phoneme awareness; the BRIEF-P and FOCUS-34 (completed according to the protocol) as proxy ratings of attention in the classroom and communication skills at home; and the NEPSY-II for attention (provided thorough training is provided for those administering it and the inter-rater reliability is assessed). The phoneme segmentation subtest of the PIPA could be used in addition to the phoneme isolation subtest. This would add minimal time to the assessment process and its inclusion would mitigate against any risk of reduced sensitivity of the phoneme isolation subtest. To assess language, the NRDLS should be replaced by the CELF-P since this takes less time to administer and should be more acceptable for both the child and RA administering it. The use of digital voice recorders to monitor verbal responses is not feasible in the classroom setting and the use of booklets impeded the completion of the odd one out task.

Therefore, alternative methods of monitoring children's performance on a weekly basis, perhaps by a trained observer, will be required in a definitive trial.

Exploration of the acceptability of RECALL produced mixed findings. The HPs and teachers liked the listening recall and fantastical play components. These were considered to be fun and at an appropriate level for 4—5 year olds. The phoneme awareness component was also acceptable. The fact that the teachers reported that these tasks are similar to their usual practice may suggest they are not required in RECALL. However, since the descriptive analysis of the post-intervention scores showed a trend towards improvement for the intervention groups, further investigation of the effectiveness of these tasks could be valuable in a full-scale trial.

The odd one out task is not acceptable to HPs or teachers in its current form for two key reasons. First, they found it difficult to manage the materials, which included picture stimuli, booklets and stampers. Second, many of the children became inattentive during this task. These factors relate to the task itself, but also to the classroom setting and the children's characteristics. The task delivery could be simplified by enabling the children to indicate the odd one out location by pointing. The dose delivered per session (11 practice items) and dose frequency (three times per week) may also have been too intense for 4-5 year olds. In addition, from week three onwards the task became too difficult i.e., there were too many items to-be-remembered. These findings are consistent with emerging evidence regarding the effects of dosage on the outcomes of language interventions, suggesting that if treatment is too intense it can be detrimental to children's learning [5,25,51]. The current study underscores the need for robust investigation of dosage in both WM and language interventions. Modifications to

RECALL, including the task delivery and its dosage could be explored through further co-production work and small group work with 4-5 year olds prior to a full-scale trial.

In relation to the classroom setting and the children's characteristics, the potential effectiveness of RECALL was impeded by the size of the groups set up for the task (9-10 children) and their composition, where the weaker children were observed copying their more-able peers. Many of the children, particularly the most at risk children (already presenting with inattentive behaviour in the classroom) became unmotivated by a task that was too challenging for them.

The third research aim was to measure the compliance and fidelity to the intervention protocol. The inconsistency between the high level of compliance observed and the variation in fidelity between the teacher-delivered sessions in the two schools highlights the importance of facilitator factors in intervention delivery. The teachers' uncertainty about how to deliver the tasks demonstrates that the detailed intervention manual and demonstration provided by the trained HPs were not sufficient. This supports the provision of direct training on the theoretical underpinning and delivery of RECALL for all teachers involved in a future definitive trial of the intervention. This should include a minimum of eight hours' direct instruction, as well as coaching and feedback [3]. These measures would better ensure fidelity of task delivery which is essential for the therapeutic effectiveness of the intervention, particularly the odd-one-out task (and was lost for half of the participants in the RECALL arm of this trial).

The evidence discussed so far has illuminated a dynamic interplay between the way a therapeutic task is presented and its difficulty level (dose form); the setting within which it is delivered such as group size; children's characteristics including their motivation and attention; and facilitator characteristics e.g., theoretical knowledge of the task and how to deliver it. This complex blend impacts on, and can dilute the number of trials accessed by individual children, particularly those who are most at risk of language disorder. Figure 3 graphically represents this.

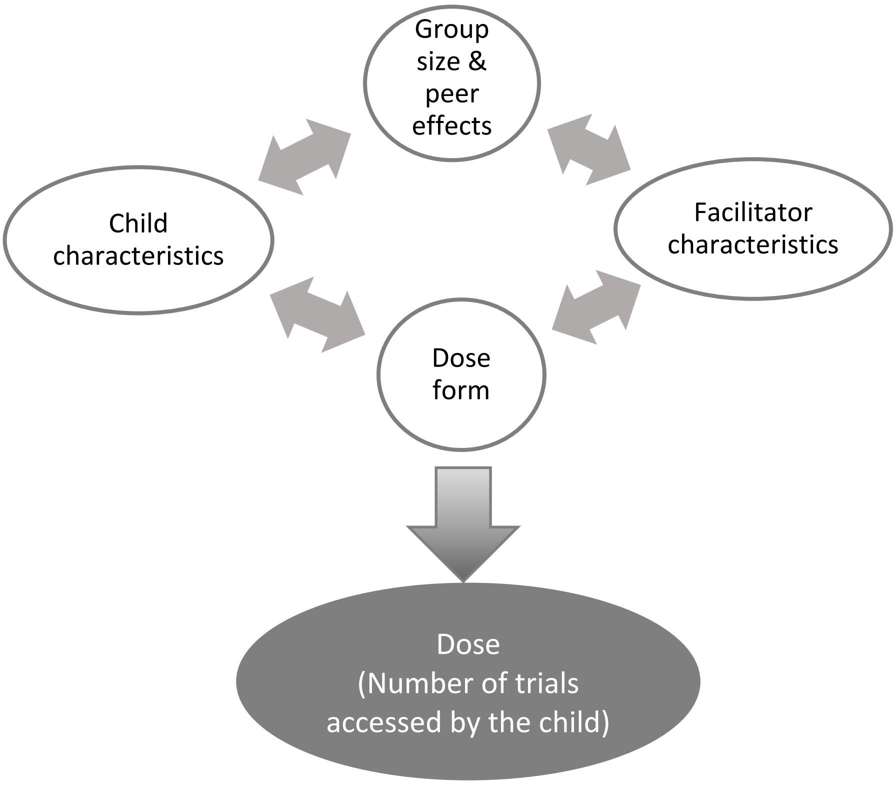


Figure 3. The factors impacting on dosage in classroom-based interventions

Limitations of the present study

This was a small scale study with just two schools in each arm of the trial. However, the findings are strengthened by the study design through the inclusion of an active control group receiving an intervention of comparable structure and dosage to the experimental RECALL intervention. The need to widen the school eligibility criteria to include those in the lowest quintile of SD means that half the sample were in less disadvantaged areas than originally anticipated. This raises questions about whether the findings are generalisable to schools in more disadvantaged areas of NI or beyond. The lack of blinding of the HPs and the fact that the teachers in the RECALL schools became unblinded to their group allocation may have introduced bias regarding their perspectives on the intervention. In addition, compliance and fidelity to the delivery of the active control intervention was not measured and this should be addressed in a definitive trial.

Conclusions

RECALL is a novel, multi-component intervention that targets WM to enhance attention and language skills. To our knowledge, this is the first paper to report on the feasibility of implementing a WM intervention in real-life contexts. With the exception of the methods used to monitor children's progress from week to week, the trial processes could be scaled-up into a future definitive trial to evaluate the effectiveness of RECALL.

In relation to the intervention components, this study has provided unique evidence of the potential effectiveness of the two directly trained WM tasks (listening recall and odd one out) for children as young as 4-5 years. Listening recall was implemented successfully and was acceptable to the HPs and teachers who delivered the intervention; and odd one out could be modified to enhance its acceptability and the fidelity of its delivery.

Overall, the potential effectiveness of RECALL for the children who may benefit most from it (i.e., those presenting as inattentive in the classroom and are at risk of low WM) could be optimised if it were implemented in small group settings.

This would enhance its acceptability to HPs and teachers and improve its potential effectiveness by maximising the dosage accessed by individual children. RECALL could be modified though further co-production work and feasibility testing involving small group work with 4-5 year olds. This study has highlighted the challenges of balancing empirically- evidenced dosage with the feasibility and acceptability of what can be delivered in real-life contexts. Furthermore, it emphasises the need for teachers to have thorough training on the theoretical underpinning to interventions for children with language disorders in the mainstream classroom.

List of abbreviations: ALP: Attention and listening programme; AWMA: Automated Working Memory Assessment; BRIEF-P: Behaviour Rating of Executive Functions-Preschool; CA: Classroom Assistant; CELF-P: Clinical Evaluation of Language Fundamentals—Preschool; CRT: Cluster Randomised Trial; ELWM: Executive-loaded working memory; FOCUS-34: Focus on Communication Skills Under Six-34; HSCT: Health and Social Care Trust; NEPSY-II: A Developmental Neuropsychological Assessment; NI: Northern Ireland; NRDLS: New Reynell Developmental Language; OT: Occupational Therapist; PIPA: Preschool Inventory of Phonological Awareness; PT: Physiotherapist: RA: Research Assistant; RA: Research Assistant; RISE: Regional Integrated Support for Education; RECALL: Recall to Enhance Children's Attention, Language and Learning programme; SD: social disadvantage; SEB: Social Emotional and Behaviour Specialist; SLT: Speech and Language Therapist; STM: short-term memory; WM: working memory.

Declarations

Ethics approval: Ethical approval for this study has been granted by the Ulster University Research Ethics Committee (REC/18/0036). The trial has been registered with the International Standard Randomised Controlled Trial Registry (ISRCTN13633886)

Consent for publication: Not applicable.

Availability of data and material: As this is a feasibility trial, sharing of the dataset is not anticipated. However, any requests for data or material should be made to the corresponding author. Requests will be reviewed by the Trial Steering Committee.

Competing interests: The authors declare that they have no competing interests.

Funding: This trial constitutes part of a doctoral research study funded by the Research and Development Division of the Public Health Agency, Northern Ireland. The funder was not involved in the design or conduct of any aspect of the trial.

Authors' contributions: AR, JT and LT conceived of the study and applied for the funding of the doctoral project within which this study took place. LH and JH contributed thinking and support to the study design for outcome measurement and intervention in particular. The first author wrote the first draft of the manuscript to which the co-authors then contributed. All of the authors have read and approved the final manuscript.

Acknowledgements: The authors thank Professor Mike Clarke (Director of MRC Methodology Hub, Queen's University Belfast) for his input to the methodological design of this feasibility trial and Professor Brendan Bunting (Ulster University) for advice in relation to the data analysis.

References

1. Law J, McBean K, Rush R. Communication skills in a population of primary school‐aged children raised in an area of pronounced social disadvantage International Journal of Language and Communication Disorders. 2011;46(6):657-664.
2. Locke A, Ginsborg J. Peers I. Development and disadvantage: implications for the early years and beyond. International Journal of Language and Communication Disorders. 2002;37(1):3-15.
3. Ebbels SH, McCartney E, Slonims V, Dockrell J, Norbury CF. Evidence based pathways to intervention for children with Language Disorders. International Journal of Language and Communication Disorders. 2019;54(1):3-19.
4. ICAN/RCSLT. (2018). Bercow: Ten Years on an Independent Review of Provision for Children and Young People With Speech, Language and Communication Needs in England. London: ICAN/RCSLT.
5. Schmitt MB, Justice LM, Logan AR. Intensity of language treatment: contribution to children's language outcomes. International Journal of Language and Communication Disorders. 2017;52(2):155-167.

6. Law J. Population woods and clinical trees. A commentary on 'Evidence-based pathways to intervention for children with language disorders'. International Journal of Language and Communication Disorders. 2019;54(1):26-27.
7. Murphy C. The limits of evidence and the implications of context: considerations when implementing pathways to intervention for children with language disorders. International Journal of Language and Communication Disorders. 2019;54(1):20-23.
8. Department of Health, Social Services and Public Safety (DHSSPS). Making Life Better. A whole system strategic framework for public health. 2014. https://www.health-ni.gov.uk/sites/default/files/publications/dhssps/making-life-better-strategic-framework-2013-2023_0.pdf Accessed 30 Sep 2016.
9. Health and Social Care Board (HSCB) (2011) *Transforming Your Care. A review of Health and Social Care in Northern Ireland.* Belfast: HSCB;2011.
10. Bengoa R. Systems, not structures. Changing health and social care – full report. 2016. https://www.healthni.gov.uk/sites/default/files/publications/ health/expert-panel-full-report.pdf Accessed 30 Nov 2016.
11. Gascoigne M. Supporting children with speech, language and communication needs within integrated children's services. RCSLT Position Paper. London: RCSLT;2006.
12. Harron A, Dickson F. Perspectives on trans-disciplinary working for children in mainstream education. Oral presentation: Rehabilitation and Therapy Research Society conference;2013.
13. Cowan N, Fristoe NM, Elliott EM, Brunner RP, Saults JS. Scope of attention, control of attention and intelligence in children and adults. Memory and Cognition. 2006;34(8):1754-1768.

14. Baddeley AD, Gathercole SE, Papagno C. The phonological loop as a language learning device. Psychological Review. 1998;105:158-173.
15. Holmes J, Butterfield S, Cormack F, Loenhoud AV, Ruggero L, Kashikar L, et al. Improving working memory in children with low language abilities. Frontiers in psychology. 2015;6:519.
16. Melby-Lervåg M, Hulme C. Is working memory training effective? A meta-analytic review. Developmental Psychology. 2013;49(2):270-291.
17. Gathercole SE, Holmes J, Dunning DL, Norris D. Working memory training involves learning new skills. 2019: Journal of Memory and Language. 2019;105:19–42.
18. Holmes J, Woolgar F, Hampshire A, Gathercole SE. Are working memory training effects paradigm-specific? Frontiers in Psychology. 2019;10: 1103.
19. Dunning D, Holmes J. Does working memory training promote the use of strategies on untrained working memory tasks? Memory and Cognition. 2014;2; 854-862.
20. Funnell SC, Rogers PJ. Purposeful program theories effective use of theories of change and logic models. San Francisco: John Wiley & Sons;2011.
21. Hawkins J, Madden K, Fletcher A, Midgley L, Grant A, Cox G. et al. Development of a framework for the co-production and prototyping of public health interventions. BMC Public Health. 2017;17:1-11.
22. Wight D, Wimbush E, Jepson R, Doi L. Six steps in quality intervention development (6SQuID). Journal of Epidemiology and Community Health. 2016;70:520-525.
23. Craig P, Dieppe P, McIntyre S, Mitchie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ. 2008;337:a1655.

24. Henry LA, Messer DJ, Nash G. Testing for near and far transfer effects with a short, face-to-face adaptive working memory training intervention in typical children. Infant and Child Development. 2014;23(1):84-103.
25. McGinty AS, Breit-Smith A, Fan X, Justice LM, Kaderavek JN. Early Childhood Research Quarterly Does intensity matter? Preschoolers' print knowledge development within a classroom-based intervention Early Childhood Research Quarterly. 2011;26:255-267.
26. Justice LM. Conceptualising "dose" in paediatric language interventions: Current findings and future directions. International Journal of Speech-Language Pathology, 2018;20(3):318-323.
27. Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. BMJ. 2016;355:i5239.
28. Authors (blinded for review)
29. Northern Ireland Multiple Deprivation Measure (NIMDM) (2017) https://www.nisra.gov.uk/statistics/deprivation/northern-ireland-multiple-deprivation-measure-2017-nimdm2017. Accessed 28 Mar 2018.
30. Hoffmann TC, Glasziou PP, Broutron I, Perera R, Moher D, Altman DG. et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. British Medical Journal. 2014;348:g1687.
31. Authors (blinded for review)
32. Thibodeau RB, Gilpin AT, Brown MM, Meyer BA. The effects of fantastical pretend-play on the development of executive functions: An intervention study. Journal of Experimental Child Psychology. 2016;145:120-138.

33. Melby-Lervåg M, Hulme C. Serial and free recall in children can be improved by training: evidence for the importance of phonological and semantic representations in immediate memory. Psychological Science. 2010;21(11)1694-1700.
34. Van Kleeck A, Gillam RB, Hoffman LM. Training in phonological awareness generalizes to phonological working memory: a preliminary investigation. The Journal of Speech and Language Pathology – Applied Behavior Analysis. 2006; 1(3):228-243.
35. Braun V, Clarke V, Using thematic analysis in psychology. Qualitative Research in Psychology. 2006;3(2):77-101.
36. Shipstead Z, Hicks KL, Engle RW. Working memory training remains a work in progress. Journal of Applied Research in Memory and Cognition. 2012;1:217-219.
37. Dodd B, Crosbie S, Macintosh B, Teitzel T, Ozanne A. Primary and Preschool Battery of Phonological Awareness (PIPA). London:Psychological Corporation; 2000.
38. Letts C, Edwards S, Sinka I, Schaefer B. Gibbons W. Socio-economic status and language acquisition: children 's performance on the new Reynell Developmental Language Scales. International Journal of Language and Communication Disorders. 2013;48:2:131-143.
39. Wiig EH, Secord WA, Semel E. Clinical evaluation of language fundamentals—Preschool, 2nd ed. (CELF Preschool-2). Toronto: The Psychological Corporation/A Harcourt Assessment Company; 2004.
40. Alloway TP. Automated working memory assessment. London: Pearson Assessment;2008.
41. Korkman M, Kirk U, Kemp S. NEPSY-II: a developmental neuropsychological assessment. San Antonio: The Psychological Corporation;2007.

42. Gioia GA, Espy KA, Isquith PK. The Behavior Rating Inventory of Executive Function-Preschool version (BRIEF-P). Odessa: Psychological Assessment Resources;2003.
43. Thomas-Stonell N, Oddson B, Robertson B, Walker J. Rosenbaum P. The FOCUS©-34: Focus on the Outcomes of Communication Under Six. Toronto: Holland Bloorview Kids Rehabilitation Hospital; 2015.
44. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions: Medical Research Council guidance. BMJ. 2012;350:h1258
45. Grant A, Treweek S, Dreischulte T, Foy R, Guthrie B. Process evaluations for cluster-randomised trials of complex interventions: a proposed framework for design and reporting. Trials. 2012;14:15.
46. Steckler A, Linnan L. eds. Process evaluation for public health interventions and research. San Franscisco: Jossey-Bass;2002.
47. Carroll C, Patterson M, Wood S, Booth A, Rick J, Balain S. A conceptual framework for implementation fidelity. Implementation Science. 2007;2(40).
48. Pallant J. SPSS Survival Manual. Buckingham Philadelphia: Open University Press;2016.
49. Bulmer MG. Principles of statistics. New York: Dover; 1979.
50. Jaeggi SM, Buschkuehl M. Working memory training and transfer: theoretical and practical considerations. In Toni B, editor. New Frontiers of Multidisciplinary Research in STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health). Springer Proceedings in Mathematics & Health, vol 90. Springer, Cham;2014.

51. Justice LM, Logan JA, Schmitt MB, Jiang H. Designing effective speech-language interventions for children in the public schools: Leverage the spacing effect. Policy Insights from the Behavioral and Brain Sciences. 2016;3(1):85-91.
52. Eldridge SM, Costelloe CE, Kahan BC, Lancaster GA. Kerry SM. How big should the pilot study for my cluster randomised trial be? Statistical Methods in Medical Research. 2015;25(3):1039-1056.

Appendix 1. Checklist for fidelity of intervention delivery

RECALL session observed (1- 6): __________________________

Programme facilitated by: RISE Team professional/Teacher (delete as appropriate)

Date of observation: ___________ Rated by (research team member): _____________

Element	Criteria	Rating 1 = low and 9= high. Circle as appropriate	Comments
Content	The executive-loaded nature of the trained tasks was maintained.	1 2 3 4 5 6 7 8 9	
	All of the tasks in the session plan were delivered.	1 2 3 4 5 6 7 8 9	
	Session delivered by RISE NI Team only – use of auditory recording	1 2 3 4 5 6 7 8 9	
Coverage	The specified number of trials were administered per activity (dose)	1 2 3 4 5 6 7 8 9	
Frequency	All of the children participated in each activity	1 2 3 4 5 6 7 8 9	
Duration	The session lasted 40 minutes.	1 2 3 4 5 6 7 8 9	
	Each activity was presented within its suggested timeframe.	1 2 3 4 5 6 7 8 9	
Intervention complexity	The resources were manageable.	1 2 3 4 5 6 7 8 9	
	The tasks appeared to be at an appropriate level for the children.	1 2 3 4 5 6 7 8 9	
Facilitation strategies	The programme manual was referred to during the session.	1 2 3 4 5 6 7 8 9	
Quality of delivery	The introductions/instructions to activities were given as specified in the programme manual.	1 2 3 4 5 6 7 8 9	
	The facilitator presented the session in an engaging way for the children.	1 2 3 4 5 6 7 8 9	
	Tasks were suitably differentiated for individual children.	1 2 3 4 5 6 7 8 9	
Participant responsive-ness.	The teacher and classroom assistant were engaged in the session.	1 2 3 4 5 6 7 8 9	
	The children found the activities engaging.	1 2 3 4 5 6 7 8 9	

Questions raised by participants:
Please note any guidance provided by research team:
Please note any additional barriers or facilitators to the programme implementation:
Any other comments/observations:

Reference: Based on a conceptual framework for implementation fidelity (Carroll *et al*. 2007) [46]

Appendix 2. Schedule for post-intervention semi-structured interview

Introduction
Use introductory script to explain the purpose of the interview participants' role in the study and assure participants of confidentiality and anonymity.
Exploring acceptability of the research processes
For RISE NI team members – How did you feel about the random allocation of schools? For teachers: How did you feel about being randomly allocated to a group? How did you feel about the selection of children for outcome measurement? How easy/challenging was the process of gaining parental consent? *Prompts for discussion: ratio of children in each group. Would they have liked more specific criteria for selection?*
Exploring participants' experience of delivering the RECALL
Programme content and resources What do you think about the use of the Memory Mack puppet? What do you think of the fantastical themes? What do you think about the 3 RECALL tasks? - Odd one out - Listening Recall - Phoneme awareness What do you think of the resources provided for these tasks? E.g., size, quality Did you refer to the program manual? If so, how often? How helpful is the manual? What do you think of the programme structure (working in small groups)? **Dosage** How easy was it for you to incorporate the program into your everyday work? What do you think about: - the number of practice trials of each activity? - the number of sessions per week? For RISE NI team members - were you able to deliver all six sessions? For teachers- were you able to provide two follow-up sessions per week? What factors impacted on this? **Difficulty level** What do you think of the difficulty level for each task specified in the program? Were you able to monitor the children's progress from week to week? Do you think the children's skills improved?

Overall What activities did you like? What activities did you not like? How did the children respond to the program? How effective did you feel the program was? *Prompts for discussion:* - *If people find it difficult to recall specific activities – use each session plan to jog their memory.* - *Can you tell me why you liked/did not like that activity? What was it about the task that made it difficult?* *What makes you say it was effective/ineffective?*
Exploring acceptability of the program and the outcome measures
How easy/difficult was it to use the digital voice recorders? For the teachers: What are your thoughts on completing the BRIEF-P? How easy was it to complete? Did it add to your understanding of children's skills? How likely do you think it is that other teachers would complete it?
Exploring barriers and facilitators to implementation in large scale RCT and longer-term practice
If you had access to RECALL, how likely is it that you would use it again? (use in full/use parts?) If unlikely to, how could it be altered so that you would want to use it? If you had to use the program again, how could this be made easier for you? Is there anything that would make it difficult for other health professionals/teachers to deliver the program? What resources/training/support would you need to use the program again? *Prompts for discussion:* - *Explore factors at personal, intrapersonal and organisational level* *Discuss group size, adult support in the classroom*
Close • Provide brief summary of information gathered. • Check if participants would like to make any additional comments • Thank participants for their time

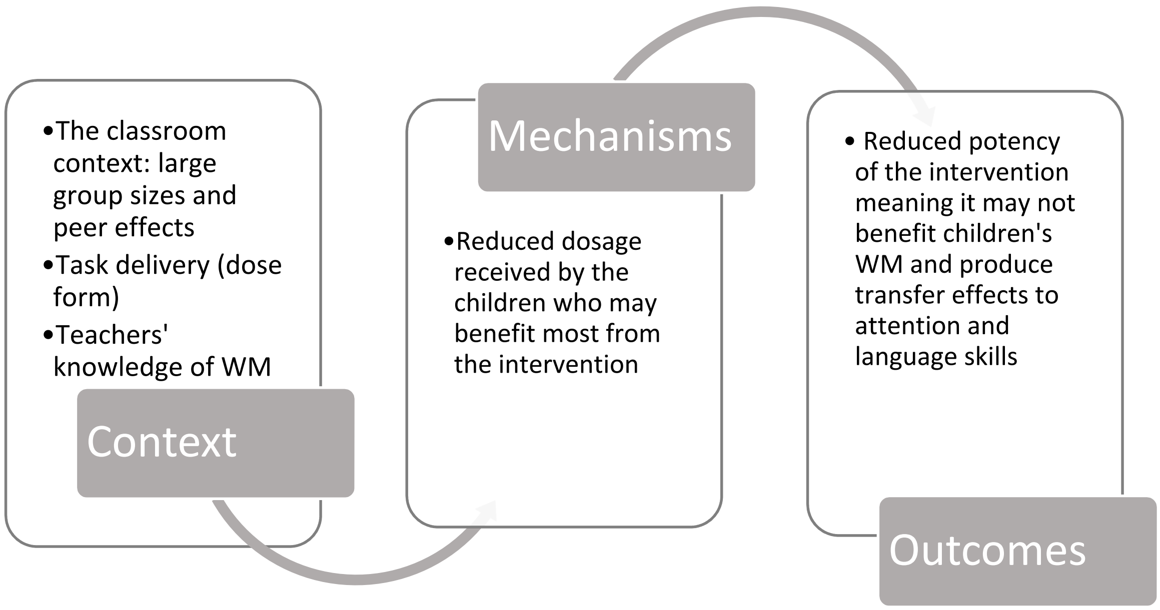
9.3 Conclusions and implications for RECALL

The cluster randomised feasibility trial of RECALL achieved its key aims in: determining whether it would be possible to conduct a full-scale trial of RECALL (which it would) and exploring the acceptability of the intervention (which requires modification). One of the key factors underpinning the rationale for the doctoral study was the gap in the evidence base for universal (whole class) interventions provided by services such as the RISE teams (Ebbels *et al.* 2019). The findings of the feasibility trial provided valuable evidence in this regard and the ramifications of this will be discussed in Chapter 10. This section focuses on the implications of the study findings for the future of the RECALL intervention.

9.3.1 Modifying the intervention

The feasibility study highlighted some concerns about RECALL due to the way it was delivered. The children who may benefit most from RECALL (those with limited attention skills) became disengaged during the sessions and could not access the evidence-based dosage within the intervention. Viewed from a context-mechanism-outcomes (CMO) perspective (Pawson and Tilley 1997), the intervention may not achieve its desired outcomes because the proposed mechanism embedded within it were compromised. The contextual factors impacting on this were the large group sizes and peer effects e.g., the children distracted each other and some copied the responses of their abler peers (Figure 3 in the feasibility study results paper). In addition to this, the way in which some of the tasks were presented (particularly the use of booklets and stampers to record responses in the odd one out task) became so distracting for the children that they could not selectively attend to the relevant aspects of the task. This exemplifies the type of difficulties children with low WM have when they are required to hold information in their minds and resist distraction at the same time (Gathercole 2008, Gathercole *et al.* 2019, Holmes *et al.* 2010, see Chapter 2). It became so difficult for the facilitators to keep the children engaged, that this aspect of the task delivery also reduced the acceptability of the odd one out task to the HPs and teachers. Figure 9-1 demonstrates these issues in the CMO framework (Pawson and Tilley 1997).

Figure 9-1 Updated CMO framework for RECALL



Another issue that may ultimately influence the potential effectiveness of RECALL is the difficulty level of the tasks and how this progresses over the course of the intervention. It is widely accepted that, in order to be effective, WM training should be continually challenging (adaptive) (e.g., Holmes *et al.* 2009, Klingberg 2010, Melby-Lervåg and Hulme 2013). In an attempt to make the trained tasks adaptive in RECALL, where they are delivered to groups of children who will be performing at various levels, the difficulty level of the practice items alternated between two levels e.g., from one to two to-be-remembered items in the listening recall task. It is hard to judge whether this strategy achieved its aim because the methods used to monitor the children’s performance and progress over time (audio recording and individual booklets with stampers) were not feasible and the data gathered was unreliable. This has significant implications for the feasibility of delivering adaptive WM training in the whole class setting. Furthermore, it challenges researchers interested in the effectiveness of classroom-based interventions for children at risk of language disorder to develop innovative means of reliably gathering data in this setting without compromising the integrity of the intervention they wish to evaluate.

To improve the feasibility of RECALL, two key modifications to the intervention are recommended. Firstly, the odd one out task should be modified to include an alternative system of monitoring the children's responses and progress. The use of booklets in the current study interfered with the task delivery to the extent that, if this had been a full-scale trial of RECALL, the effectiveness of the intervention would have been compromised. In conjunction with this, the data collected was unreliable. In a future study, the children should be asked to point to a blank grid to identify the odd one out (in the same way as the typical presentation of this task, see Chapter 6). Measuring the children's weekly performance would be an important aspect of a future trial. One possibility may be to have a Research Assistant observe one RECALL session per week to record a sample of the children's responses on this task. This could also be done for the phoneme awareness and listening recall tasks.

Secondly, RECALL should be repackaged as a small group, targeted intervention for children presenting with inattentive behaviour and language problems in the classroom (who are at risk of low WM). This would make it more accessible to the children who may benefit the most from it. It would also make it easier to monitor, and therefore adapt, the level of training according to each individual child's performance so that they could be continually challenged. i.e., to make the training adaptive.

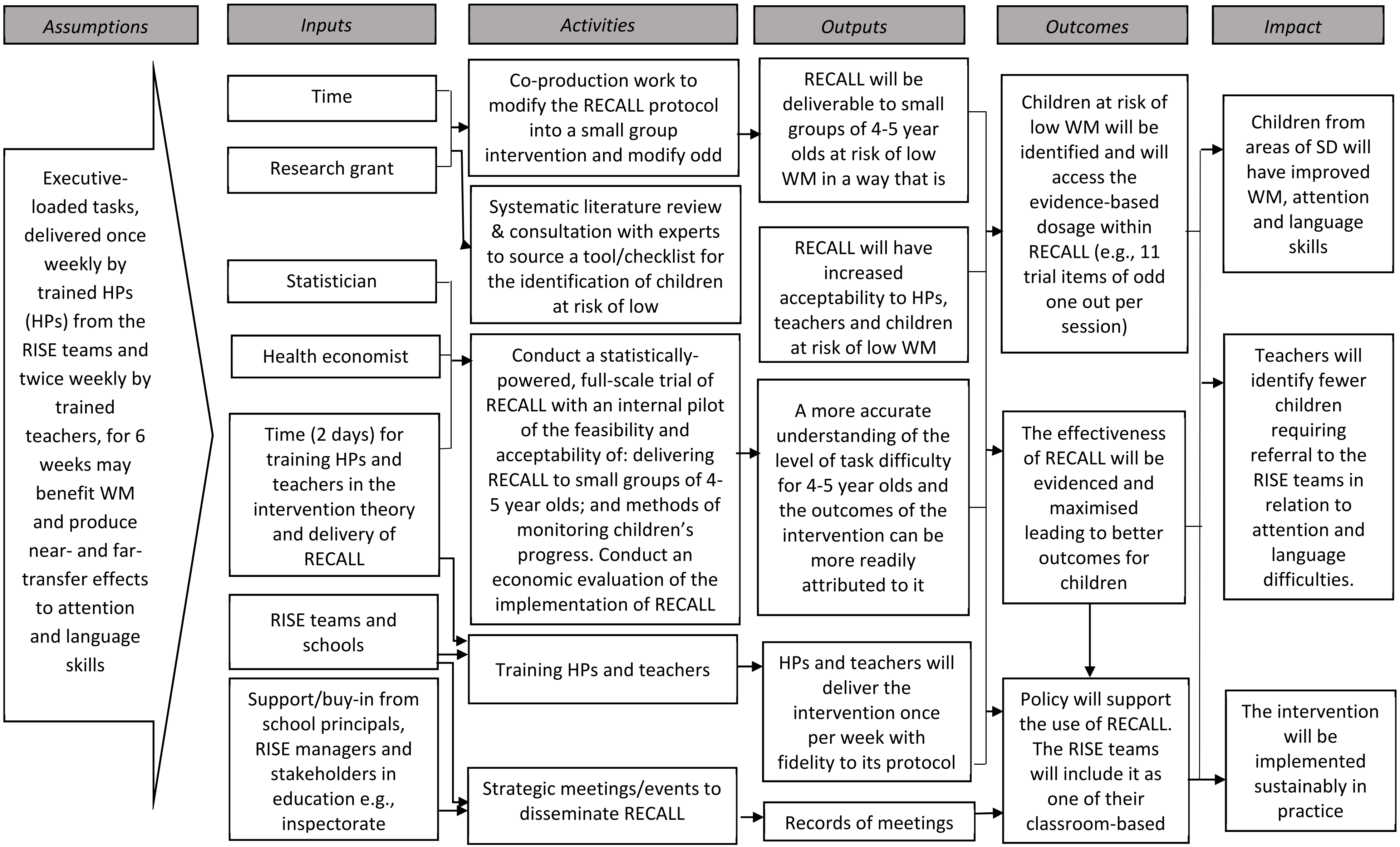
9.3.2 Proceeding to a full-scale trial

The findings from this feasibility trial should be interpreted in light of the fact that the schools recruited to the study were in areas of less social disadvantage (SD) than expected (see Table 3 in Paper 4). Consequently, it is possible that delivering RECALL in schools in areas of more disadvantage, where children may have more complex emotional and behavioural problems (Chowdry and McBride 2017), may be more challenging. Therefore, in a full-scale trial of RECALL, criterion around the level of SD deemed to be appropriate for inclusion or exclusion in the study will require thorough consideration.

RECALL appears to have potential as a small group, targeted intervention and its effectiveness should be tested in a full-scale, statistically powered, cluster randomised trial. The necessary modifications to the intervention could be made as part of a pilot study embedded within this. It could be modified through further co-production work with HPs and teachers and it could then be adapted incrementally through some test-retest cycles with purposefully sampled small groups of 4-5 year olds from areas of SD. In a full-scale trial, children who are at risk of low WM could be identified by teachers. A screening tool for this purpose should be identified through a systematic literature review and consultation with expert advisors.

The feasibility testing provided empirical evidence of the need to include the cost of teacher training in a future grant proposal for funding to run the full trial of RECALL. Whilst this had been suspected before the feasibility study (as discussed in Chapter 6), the provision of teacher training at this stage was clearly contra-indicated by the resource limitations highlighted in the qualitative study (Chapter 5) and consultation with key stakeholders. Table 9-1 shows the RECALL logic model that was revised by the PhD researcher on the basis of the changes recommended above. Since logic models are now a requirement in grant applications for many research funders (Moore *et al.* 2015), this could be used as a basis for the grant proposal for funding to conduct a full-scale trial of RECALL.

Table 9-1 Refined intervention logic model to inform a full-scale trial of RECALL (WK Kellogg Foundation 2014)



Chapter 10 - Conclusions and recommendations

10.1 Introduction

This doctoral thesis presents the co-production and trialling of a complex intervention (RECALL) targeting working memory (WM) to enhance attention and language skills in 4-5 year olds from areas of social disadvantage (SD). RECALL is underpinned by individual and systems theories of change and this study addresses gaps in the evidence base regarding the feasibility and acceptability of WM training embedded within typical educational activities (Dunning *et al.* 2013, Dunning and Holmes 2014, Jaeggi and Buschkuehl 2014). It also contributes to the current debate around the effectiveness of universal (whole class) interventions that, in line with national and regional policy objectives, aim to support children who are at risk of language disorder and academic underachievement (Archibald 2017a, Cirrin *et al.* 2010, Ebbels *et al.* 2019). Specifically, this study focuses on the context of the transdisciplinary Regional Integrated Support for Education (RISE) Teams and their dynamic, complex interaction with mainstream primary schools in Northern Ireland (NI), where 100% of referred children have attention and listening difficulties as identified by their teachers. This chapter provides a summary of the unique contributions of this doctoral study and the implications of its four main phases: the systematic review; the qualitative study; the intervention co-production; and the feasibility trial. This is followed by an overview of the strengths and limitations of the doctoral study and the recommendations for research, policy and practice arising from it. The chapter ends with some concluding remarks.

10.2 Unique contributions of this thesis to knowledge, theory and practice

10.2.1 Study design and methods

This doctoral study was underpinned by a realist research paradigm (Bhaskar 2008), within which interventions are viewed as events within complex systems (Moore and Evans 2017, Moore *et al.* 2019). From this perspective, interventions are understood as the interaction between their *context, mechanism and outcomes* (CMO) (Pawson and Tilley 1997). On this basis, the Six Steps for Quality Intervention Development (6SQuID) model (Wight *et al.* 2016) was selected to frame the study. This was combined with: the socio-ecological model (McLeroy *et al.* 1988) to explore the intervention context; and logic modelling to tie all of these aspects together and present a clear understanding of how the intervention should work in practice (WK Kellogg 2014). This thesis highlights the way in which these combined approaches can work together to support the development of a theoretically underpinned intervention with reasonable acceptability for use in real-life contexts. Therefore, this thesis makes a novel contribution to the field of intervention development where there are recognised gaps in the literature (Hoddinott 2015, O'Cathain *et al.* 2019a, Moore *et al.* 2019).

In particular, this doctoral thesis demonstrates how the application of the Context-Mechanism-Outcomes (CMO) (Pawson and Tilley 2007) configuration can enhance the understanding of an intervention's mechanism and 'open the black box' of the intervention (Hoddinott 2015). Figures 6-1 and 9-1, reproduced here, demonstrate the impact of an iterative use of the CMO framework used in the current study.

Figure 6-1 Context-Mechanism-Outcomes configuration for the to-be-developed intervention

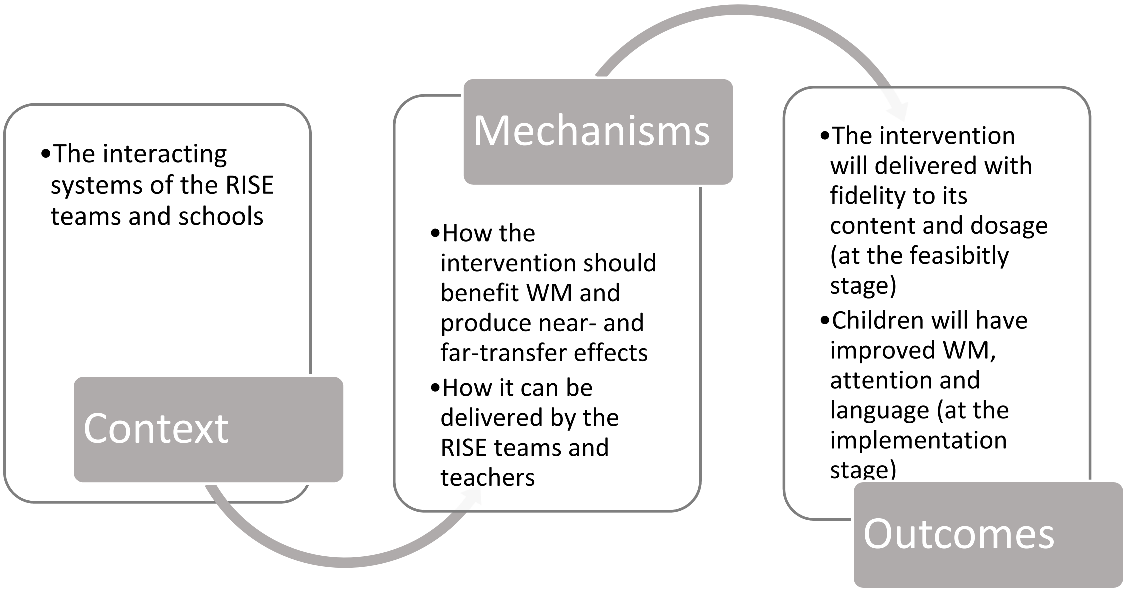
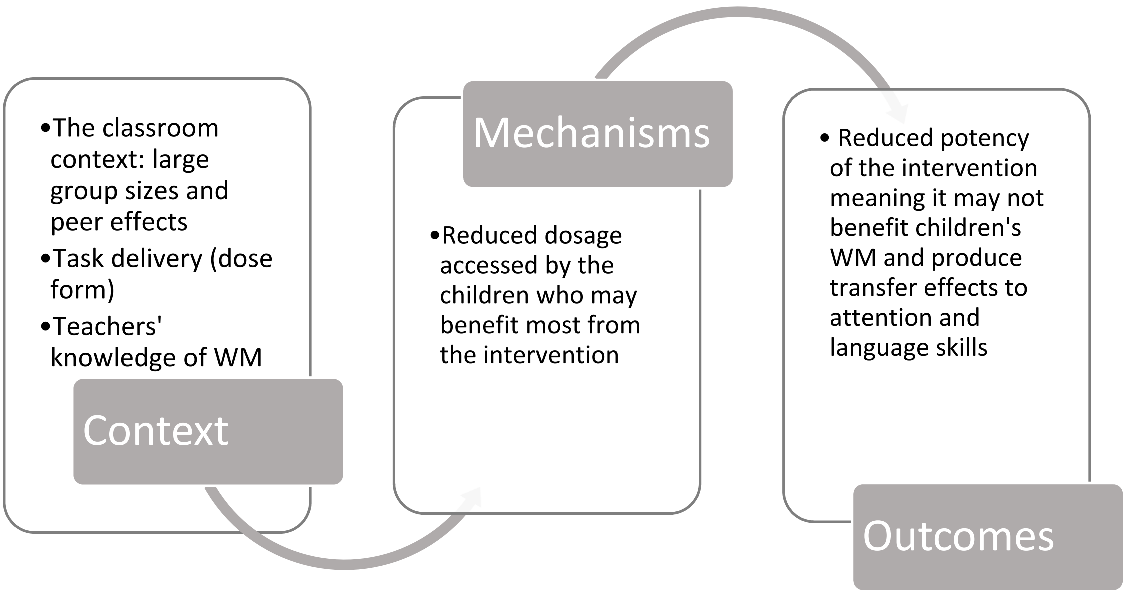


Figure 9-1 Updated CMO framework for RECALL



This approach could be applied in further research when considering the optimal models of support for children at risk of language disorder, where there have been calls for greater sensitivity to the impact of local contexts on service delivery i.e., on mechanisms and outcomes (Law 2019, Murphy 2019). Furthermore, the methods used in the current study could be used to support clinical practice. There is a clear need for clinical decision-making to be underpinned by sound theoretical assumptions (Chapter 5 of this thesis, Roulstone 2015, Lof 2011). Practitioners, such as the RISE Teams, interested in developing ecologically valid interventions in response to local needs, could apply CMO configurations to identify and articulate theories of change. This may enhance both the effectiveness and the evaluation of their interventions.

10.2.2 The systematic review (Chapter 4)

As outlined in Chapter 2, the lack of consistent evidence for transfer effects from computerised WM training has resulted in considerable debate in recent years. This has led to some skepticism around the therapeutic value of all WM training and perhaps a reluctance to investigate alternative intervention approaches, despite repeated suggestions that they may be beneficial (Morra and Borella 2015). Therefore, in addition to supporting the identification of the components for the to-be-developed intervention, the systematic review paper (Rowe *et al.* 2019a, Chapter 4) made a significant contribution to the field of WM research.

This was the first systematic review of interventions targeting WM in children's everyday contexts and therefore speaks directly to the speculation around the potential effectiveness of WM training embedded within typical educational activities (Diamond 2012, Dunning *et al.* 2013, Dunning and Holmes 2014). The review highlighted that diverse interventions applied within young children's everyday contexts have produced improvements in their WM skills and have the potential to produce near- and far-transfer effects. Both direct training on WM tasks and practicing certain skills that may impact indirectly on WM (physical activity, fantastical play and inhibition) were beneficial. Through the forensic examination of the trained tasks and the outcomes measured in the included studies, the common ingredient across the effective interventions was identified as the executive-loaded nature of the trained tasks (i.e., tasks that tap into attentional resources under executive control, not just the storage of information). This finding contributed directly to the development of a theory of change and the selection of the trained tasks in the novel intervention developed in this doctoral study. Furthermore, through the publication of the paper, the review made an original contribution to the field of WM research internationally.

The review highlighted that, in many of the included studies, the strength of the evidence was constrained by the lack of a clear theoretical underpinning and poorly specified and/or incomplete outcome measurement. Some studies did not measure transfer effects while others measured far-transfer without measuring near-transfer meaning it is impossible to judge the therapeutic value of the interventions. These same issues fuelled the debate around the effectiveness of computerised WM training (Melby-Lervåg and Hulme 2013, 2016). Therefore, there is a high degree of possibility that research into alternative training regimes applied in children's everyday context will face the same criticisms as the computerised approach to training. This cautions researchers to consider that, unless future studies are hypothesis-driven and robustly designed, potentially effective WM interventions may be disregarded (Rowe *et al.* 2019a). This study also exposed gaps in the current evidence base for interventions applied in young children's everyday contexts and the need for more research with under-studied populations including young children (<7 years); those from areas of social disadvantage; and those with low WM (Rowe *et al.* 2019a).

10.2.3 Qualitative study (Chapter 5)

The aim of the qualitative study was to explore the contextual factors that may impact on the development and testing of a novel classroom-based intervention targeting WM, attention and language skills in 4-5 year olds. The findings contributed clearly to the subsequent steps of the doctoral study and also addressed gaps in the literature regarding teachers' and health professionals' (HPs) perceptions of WM (where only one previous study had been conducted with teachers and none had been carried out with HPs). This study provided rich evidence that teachers and HPs are uncertain about WM and, consequently, that children with low WM who are at risk of academic underachievement may go undetected in the classroom and not receive the support needed to maximise their learning potential (Holmes *et al.* 2010). This has far-reaching implications for practice across the health and education sectors, especially in light of policies that emphasise the need to tackle academic underachievement (DENI 2006, DfES 2003, DFE 2017, DHSSPS 2014, HSCB 2011).

A lack of training was reasoned to have influenced this finding because the study clearly demonstrated that the teachers and HPs involved had received limited training on WM, or at least did not recall this. Teachers and HPs working with school-aged children would benefit from training on WM and its associations with inattentive behaviour in the classroom, language, other developmental skills and academic achievement. This recommendation was corroborated by discussions with the Research Advisory Group for the doctoral study, with representatives from both the health and education sectors agreeing that training on WM would enhance current practice. Ongoing collaboration with key stakeholders from across health and education services will be important in taking forward this recommendation in order to: overcome the barriers (time and financial factors) that prevented teacher training being carried out in the current feasibility study; and ensure that any training initiatives directly address the needs of frontline practitioners to enhance evidence-based practice.

The qualitative study also provided valuable insights into the factors that influence teachers' and HPs' decision-making. In the context of the transdisciplinary RISE teams and their dynamic interaction with schools, practice is based on lay theories (a belief in the transdisciplinary model and a belief that children learn when tasks are functional and fun). These lay theories were examined in the light of scientific theories, demonstrating that there are some shared features between scientific theories and the lay theories held by teachers and HPs. This suggests that the classroom-based interventions currently used to support children at risk of low WM, language disorder and academic underachievement may be effective. Certainly, evidence from service evaluations carried out by the RISE teams support this (see Chapter 1). However, the lack of a more robust theoretical underpinning to the current interventions is a threat to evidence-based practice. When interventions are based on unspecified *mechanisms,* it is difficult to predict and evaluate their *outcomes* (Pawson and Tilley 1997). This finding constitutes a significant contribution to practice, because previous studies have focused on *evidence-based* practice and there has been limited exploration of the links between theory and practice (Roulstone 2015).

An additional novel finding arising from the qualitative study was that teachers and HPs perceive that dosage is not key to children's outcomes. This is another timely finding from the current study in relation to the optimal models of support for children at risk of language disorder. There are major gaps in the evidence base in relation to dosage for such children (Justice 2018). However, this is an area of increasing research interest and evidence is emerging, and should continue to emerge, in the coming years. As it does, it will have no bearing on practice unless the professionals working with this population are ready to engage with it and, if need be, alter their practice.

10.2.4 Intervention co-production (Chapter 7)

The third main phase of the doctoral study involved: the co-production of the novel classroom-based intervention targeting WM, attention and language skills in 4-5 year old children; and the refinement of the intervention logic model in light of the participants' knowledge of the complex system (the interaction between the RISE teams and schools) within which it would be implemented (Wight *et al.* 2016). This study contributed to the development of the novel intervention called Recall to Enhance Children's Attention, Language and Learning (RECALL) and the findings also supported the data triangulation across the full doctoral study. Furthermore, this study adds to the limited evidence base regarding the benefits and limitations of co-production.

Despite its popularity as a concept, there has been limited evaluation of the value of co-production (Clarke *et al.* 2017, Voorberg *et al.* 2015). The current study provided evidence that stakeholder input enhances intervention development through the generation of creative ideas. However, these benefits must be balanced with the time and financial investment required to carry out co-production. Researchers must have clear and realistic expectations about what stakeholders will be able to contribute to intervention co-production so that their involvement is meaningful and does not result in time delays or unnecessary expense. This evidence is important since co-production is an inherent part of Personal and Public Involvement (PPI) that is a statutory requirement for public services (DoHNI 2016).

Future co-production work could be preceded by some preliminary engagement with participants, perhaps short semi-structured interviews, so that researchers can build a picture of their lived experience and how this might contribute to achieving the research aims. Although this additional step in the research process may appear time-consuming, time invested in preparatory work could make the process more efficient in the long run. Furthermore, formalising terms of reference and standard operating principles (agreed informally in the current study) at the start of co-production work may help all parties to have realistic expectations about what is achievable through the process.

10.2.5 Recall to Enhance Children's Attention, Language and Learning

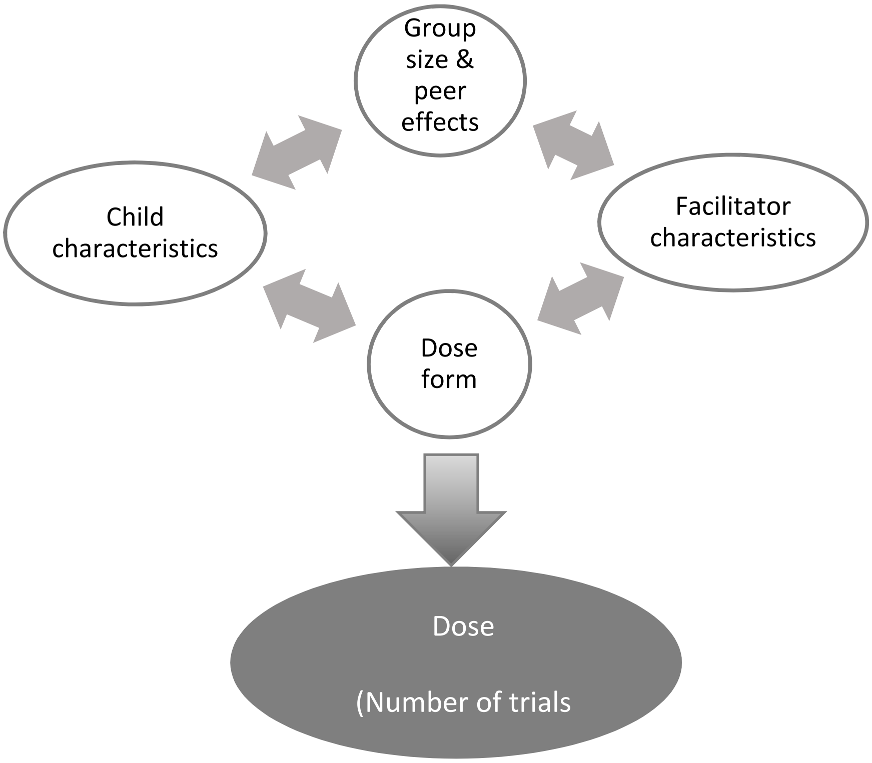
The development of RECALL, a theoretically underpinned classroom-based intervention targeting WM, attention and language in 4-5 year olds is a major contribution of this doctoral study. There are three innovative aspects of the intervention. Firstly, it is a multi-component intervention that combines direct executive-loaded WM training, phoneme awareness training and fantastical play. Secondly, it specifically aims to support younger children (4-5 year olds) where previous studies (of computerised and non-computerised WM training) have focused on children over seven years of age. Thirdly, it was designed for whole classes of children. The feasibility trial conducted in the current doctoral study (see Section 10.2.6 below), demonstrated the potential for a full-scale trial of RECALL and its contribution to WM research.

10.2.6 Feasibility study (Chapters 8 and 9)

The feasibility trial addressed the uncertainties regarding the feasibility of conducting a full-scale trial of the effectiveness of RECALL and the acceptability of the intervention to teachers and HPs. Insights were also gained into the acceptability of the intervention to children. The trial enabled identification of the factors that impact on the delivery, dosage and potential effectiveness of classroom-based interventions. Therefore, this study generated a novel evidence that has direct implications for research, policy and practice.

The key finding was that it would be possible to conduct a full-scale cluster randomised trial of the effectiveness of RECALL compared to an active control group and education as usual. However, there is a need to optimise the intervention prior to a full trial (Campbell *et al.* 2007). This includes repackaging it as a small group, targeted intervention on the basis that large groups reduced the intervention dosage accessed by the children who may benefit most from it. This finding resulted in the creation of an innovative model of dosage for classroom-based interventions that is reproduced here (Figure 10-1).

Figure 10-1 Model of the factors impacting on dosage in classroom-based interventions



This model has potential international implications for policy and practice in relation to the best models of service delivery for children at risk of language disorder. As described in Chapter 1, many Speech and Language Therapy (SLT) services currently use a three-tiered model of support including universal, targeted and specialist provision (Ebbels *et al.* 2019). This has been driven by the public health perspective on language disorder and policies that aim to narrow the achievement gap between children from areas of social disadvantage and their more-advantaged peers (DENI 2006, DfES 2003, DFE 2017, DHSSPS 2014, HSCB 2011). However, in recent years there has been worldwide debate around the effectiveness and efficiency of this approach (Ebbels *et al.* 2019). Policy-makers and service managers need to reflect carefully on the model proposed in this thesis. If intervention dosage is diluted for the most at risk children, then it may be that small group, targeted interventions could be delivered with greater potency, effectiveness and efficiency. Of course, since there is still much to learn about the optimal dosage of interventions intended to improve language skills and more research is clearly required to shape policy and practice. In current practice, SLTs and their HP colleagues need to: take cognizance of the effect of group size and context on dosage; consider carrying out small group work where possible; and perhaps increase the dose (number of practice items per session) to compensate for those items that may be missed by those children who are inattentive.

10.3 Strengths and limitations of the study

10.3.1 Strengths

This was an ambitious study to undertake at doctoral level, with four substantial phases, integrating mixed methods evidence, and including a substantial feasibility trial with a process evaluation. It has a number of methodological and theoretical strengths, which, in addition to enhancing the trustworthiness of the findings, supported the actual completion of the study within its allocated timescale. The use of the 6SQuID model (Wight *et al.* 2016), underpinned by a realist perspective, supported a practical methodology with minimal waste during the conduct of the research i.e., every step in the study added value to the intervention development and testing (O'Cathain *et al.* 2019a). Theoretically, step 3 (Identify which causal and contextual factors are malleable) and step 4 (Identify the change mechanism) of the 6SQuID model ensured that RECALL was underpinned by a clear change mechanism. Consequently, this addressed the need for WM research to be based on clear causal pathways (Redick *et al.* 2015).

In terms of the methods used, the integration and triangulation of mixed methods evidence afforded by the 6SQuID model strengthened the findings. For example, as discussed in Chapter 9, the evidence from the feasibility study reinforced the findings of the qualitative study regarding teachers' uncertainty about WM. A further strength of the study is the forensic approach applied to the development of the RECALL. Close scrutiny was paid to every aspect of the intervention during its development, including: the manual; the picture stimuli for the odd one out task; the formulation of sentences for the listening recall task; and the selection of target words and phonemes for the phoneme awareness task. This enabled the clear evaluation of the proposed mechanism within the intervention. This demonstrates how theory and methods interrelate in research. The rigorous design of the intervention supported its implementation in the schools and its evaluation.

The design of the feasibility study was robust in several ways: the inclusion of an active control group as well as a no-intervention control group; the comprehensive measurement of outcomes (trained tasks, near-transfer and far-transfer); and the blinding of the teachers and outcomes assessors (Redick *et al.* 2015, Shipstead *et al.* 2012). The use of a strong trial design at the feasibility-testing stage means it can be easily up-scaled into a full trial of the effectiveness of RECALL (Eldridge *et al.* 2016b).

10.3.2 Limitations

Although this study has considerable strengths, the evidence found may be constrained by some limitations to the methods used. Overall, the 6SQuID model (Wight *et al.* 2016) was a very helpful framework for the design of the study. However, in places the authors of the model provide limited guidance around some steps of the model. To be specific, there was a lack of clarity around what exactly should be done during step 5 (test and refine on a small scale) and step 6 (collect evidence to support rigorous evaluation or implementation). These two steps could be interpreted in several ways e.g., feasibility testing could be defined within either of these steps. The result of this lack of clarity within the 6SQuID model (Wight *et al.* 2016) was that the PhD researcher's view on these did alter during the course of the study. Although this meant that the PhD researcher had to consider carefully the design of the study, it reflects the flexibility with which intervention development models can (and often should) be applied to fit local needs and contexts (O'Cathain *et al.* 2019a).

Regarding the main phases of the research, the systematic review findings should be viewed in light of the methodological and theoretical issues identified in the included studies. However, it must be noted that the theoretical underpinning of the potential intervention components extracted from the review findings was thoroughly considered prior to their inclusion in RECALL. Caution should be taken in generalising the findings from the qualitative study due to the small sample size. Nonetheless, at the very least, this study identified the need for further research into teachers' and HP's perceptions of WM and the factors that influence decision-making for school-aged children.

The findings from the feasibility study have significant implications for policy and practice. However, the inclusion of an economic evaluation would have added value in this regard. This was not done due the lack of availability of a health economist whose expertise would be required to carry out such an evaluation reliably. However, precise records of the costs incurred in the roll out of the trial were maintained. These included: the purchase of RECALL materials; printing costs for the manuals and booklets; the cost of the standardised assessments used as outcome measures and payment of Research Assistants (RAs) who administered them. These records will support the accurate estimation of the funding required for a full-scale trial of RECALL and inform a grant application for this purpose. The future trial should include a full economic evaluation that would also encompass costings of RISE team members, teachers, their time, and PPI involvement in the prospective trial's advisory panel.

During the feasibility trial, two of the outcome measures were changed in one of the schools. This meant that there were very small numbers of children (n= 10) in some aspects of the data analysis. However, since the aim was to look at the appropriateness of the tools (and not effect sizes) this did not have a major impact on the findings. Essentially, trialling additional measures allowed a comparison of tools and supported decision-making regarding which ones should be used in a full trial.

It should also be noted that there was a limited use of technology in the current feasibility study and there may be ways of using this to support the trial processes. For example, if RAs were deployed to observe and capture children's weekly progress on the trained tasks, perhaps tablet devices could support the recording and transfer of (anonymised) data from the school setting to the Chief Investigator. In addition, technology could be used to provide a platform for the RECALL manual and some of its resources, and interactive whiteboards in the classroom could be utilised to present some of the ELWM activities.

Regarding the fidelity of the intervention, it is unfortunate that the teachers' theoretical knowledge of WM impacted on the delivery of RECALL. However, this data corroborates the findings from the qualitative study regarding teachers' uncertainty about WM and adds weight to the argument made in the qualitative paper around the need for teacher training on this topic. It raises additional concerns that children with low WM may go undetected and unsupported in the classroom.

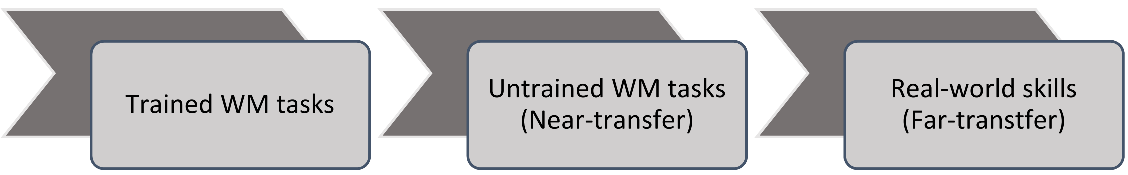
10.4 Recommendations

10.4.1 Recommendations for research

This doctoral study has demonstrated the potential for future research into the implementation and effectiveness of diverse interventions that train executive-loaded tasks to impact on WM and produce transfer effects. This should include the conduct of a full-scale cluster randomised trial of the novel RECALL intervention within which the intervention should be repackaged and optimised as a small group targeted approach.

There is a need for further well-designed, hypothesis-driven research to expand the evidence base. Study designs need to: include active control groups receiving interventions of comparable intensity to the experimental intervention and outcomes assessors should be blinded to group allocation (Redick *et al.* 2019). Crucially, since the lack of consistent evidence for near- and far-transfer effects has been at the heart of the WM training debate for several years, it is essential that all WM training studies provide a theoretical account for transfer. However, it must be noted that generating and testing theories of transfer in WM research is not straightforward because there is a lot still to learn about the cognitive mechanisms underlying WM (Shipstead *et al.* 2014). Making and testing predictions about training-induced transfer requires a detailed understanding of the features of the trained and untrained tasks and the boundaries between them (Gathercole *et al.* 2019). This means understanding the ways in which tasks are similar or different in terms of their input and output modalities and the cognitive sequences needed to completed them (Holmes *et al.* 2019). This will require repeated studies with various training regimes that carefully manipulate task features in order to understand where and how they overlap. Furthermore, to have a strong evidence base, positive effects will have to be replicated several times in studies with statistically-powered samples and active control group designs (Gathercole *et al.* 2019, von Bastian and Oberauer 2014). This underscores the need for comprehensive outcome measurement in WM intervention studies. As discussed in Chapter 2, this must include measures of the trained tasks, untrained WM tasks (near-transfer) and real-world skills (far-transfer) (Redick *et al.* 2015). Figure 2-3 is reproduced here.

Figure 2-3 Causal pathway required in WM research to demonstrate transfer effects



More research is also required to build on the evidence found here regarding teachers', and particularly HP's, perceptions of WM. The conduct of a survey could be useful in this regard, as this could facilitate the gathering of data from a much larger sample including international participants. The conduct of a feasibility trial, underpinned by a realist perspective, highlighted the need for more studies in clinically relevant, real-life settings that take account of how context may influence on fidelity, efficacy and ultimate effectiveness (Moore *et al.* 2019).

10.4.2 Recommendations for policy

Policy-makers and practitioners should reflect on the clinical and cost effectiveness of whole-class (universal) interventions, considering the potential dilution of the potency of interventions in this setting. Small group (targeted) interventions may provide a more optimal setting for the most at risk children but further research should be funded to explore this.

10.4.3 Recommendations for practice

Teachers and HPs working with school-aged children should have specific training on WM, its associations with attention and other developmental disorders and the impact of low WM on academic achievement. Third-level educators, policy-makers and senior leaders across the health and education sectors should work together to ensure good pre-and post-registration training opportunities are available in working memory, attention and language. The issues around the fidelity of the teachers' delivery of RECALL underscored the need for teachers to have direct training on the theoretical underpinning of interventions implemented by HPs in the classroom (Ebbels *et al.* 2019.

In addition to training on WM, these practitioners may benefit from training on realist principles, including CMO configurations, and systems thinking (Pawson and Tilley 1997). This may support them to understand how their decision-making is influenced by contextual factors and encourage reflection on the mechanism underpinning their practice, which may in turn promote evidence-based practice.

10.5 Dissemination of the findings from the doctoral thesis

Throughout the conduct of this doctoral study the findings and recommendations arising from it have been disseminated internationally, nationally and regionally through written publications, conference presentations and strategic meetings.

10.5.1 Written publications

The systematic review and study protocol for the feasibility trial have been published in international, peer-reviewed journals (Rowe *et al.* 2019a, 2019b). Two further papers have been submitted, as follows: the qualitative study has been submitted to the *Journal of Educational Psychology*; and a paper on the findings from the feasibility study has been submitted to *Pilot and Feasibility Studies*. Furthermore, a short report on this doctoral study has been provided for the Research and Development Division of the Public Health Agency (PHA) Northern Ireland that funded the research. This report will be made available to the public via the PHA website.

10.5.2 Conference presentations

The PhD researcher has presented the findings from the study at international, national and regional conferences through oral and poster presentations.

Oral presentations

- The American Speech and Hearing Association Convention - Boston, USA, Nov 2018: "Developing a classroom-based intervention targeting working memory, attention and language using an interprofessional, co-production model"
- The Royal College of Speech and Language Therapists conference - Nottingham, UK, Sept 2019: "Co-producing a complex intervention targeting working memory, attention and language"

Poster presentations

- The Royal College of Speech and Language Therapists NI Hub conference - Belfast, Nov 2016: "The development and testing of a universal trans-disciplinary programme to enhance working memory which will target attention and language skills in 4-5 year old children."
- The Royal College of Speech and Language Therapists conference - Glasgow, UK, Sept 2017: "The development of a school-based programme to support attention and language skills"
- The Royal College of Speech and Language Therapists conference - Glasgow, UK, Sept 2017: "The effectiveness of non-computerised working memory interventions with 4-11 year olds: a systematic review"
- The American Speech and Hearing Association Convention - Boston, USA, Nov 2018: "The effectiveness of non-computerised working memory interventions with 4-11 year olds: a systematic review"

- The Royal College of Speech and Language Therapists NI Hub conference - Belfast, Nov 2018: “Developing a classroom-based intervention targeting working memory, attention and language: an interprofessional, co-production model”
- The Royal College of Speech and Language Therapists conference - Nottingham, UK, Sept 2019: “The impact of context on the implementation of classroom-based interventions for children with language disorders: lessons from the RECALL feasibility trial”

In addition to these large conferences, the PhD researcher was also invited to, and presented the study at the ‘Working Memory Discussion Meeting’ (Yorkshire, June 2019). This is not a formal conference; rather it is an informal event that provides international researchers with the opportunity to engage in discussion about WM-related research. The attendees present data, work-in-progress, and discuss recent theoretical and methodological developments. This provided an excellent opportunity for the PhD researcher to share the study with world-renowned WM researchers.

10.5.3 Strategic meetings

The PhD researcher has also presented the findings to policy-makers across the health and education sectors in Northern Ireland, including: the Lead Officer for Allied Health Professions (AHPs) at the Department of Health NI; the AHP consultant at the Public Health Agency (PHA); and the Children and Young People’s Committee of the Education Authority for Northern Ireland.

10.5.4 Future dissemination

The PhD researcher is actively pursuing more opportunities to further disseminate the research findings. As noted previously, there is a lack of empirically based evidence about the use of intervention development models (Hoddniott 2015). Therefore, the PhD researcher aims to write a discussion paper on how the 6SQuID model (Wight *et al.* 2016) was applied in the current study. To date the findings of this doctoral study have been disseminated mostly at SLT-related conferences and this will have limited the audience. The PhD researcher intends to disseminate the findings more widely to other professional groups including teachers and cognitive and educational psychologists.

To disseminate the study findings and recommendations to key stakeholders in NI, the PhD researcher and the supervisory team plan to host a small Working Memory conference at Ulster University in 2020. Invitations to attend this event will be extended to: the research participants (HPs, teachers and parents); members of the Research Advisory Group who supported this study; senior staff from the Education Authority and the Health and Social Care Trusts; third-level educators of HPs and teachers; educational psychologists; and staff from mainstream schools in NI. It will include presentations by the PhD researcher and the supervisory team. It will also have input from the leading WM researchers who collaborated on this study; Dr Joni Holmes (MRC Cognition and Brain Sciences Unit, Cambridge) and Professor Lucy Henry (City, University of London).

10.6 Conclusion

This doctoral study makes a substantial, internationally relevant contribution to the field of WM research by demonstrating the potential effectiveness of WM interventions applied with young children in everyday contexts. Through the explicit application of individual and systems theories of change, a theoretically underpinned, ecologically valid and evidence-based intervention has been developed. RECALL is the first multi-component intervention, incorporating direct ELWM training, phoneme awareness training and fantastical play, to have been tested with 4-5 year old children from areas of social disadvantage. This study has proven that, following some modification, RECALL shows promise for the investigation of WM training in young children from areas of SD. In addition, the feasibility study addresses specific gaps in both WM and speech and language therapy research about the contextual factors that influence HPs' and teachers' decision-making. As a result, this thesis includes a novel model of intervention dosage in classroom interventions that can be used to support decision-making around the optimal service delivery for children at risk of language disorder.

References

Adams, E.J., Nguyen, A.T. and Cowan, N (2018) Theories of working memory: differences in definition, degree of modularity, role of attention, and purpose. *Language, Speech and Hearing Services in Schools,* 49, 340-355.

Alesi, M., Bianco, G.L., Palma, A. and Pepi, A. (2016) Improving children's coordinative skills and executive functions: the effects of a football exercise program. *Perceptual and Motor Skills*, 122(1), 27-46.

Allen, R.J., Hitch, G.J. and Baddeley, A.D. (2009) Cross-modal binding and working memory. *Visual Cognition*, 17(1-2), 83-102.

Alloway, T.P. (2018) *Working memory and clinical developmental disorders: theories, debates and interventions.* London and New York: Routledge.

Alloway, R.G. and Alloway, T.P. (2015a) *Understanding working memory.* 2nd ed. Los Angeles: SAGE.

Alloway, R.G. and Alloway, T.P (2015b) The working memory benefits of proprioceptively demanding training: a pilot study. *Perceptual and Motor Skills,* 120, 766-75.

Alloway, T. P., Bibile, V. and Lau, G. (2013) Computerized working memory training: can it lead to gains in cognitive skills in students? *Computers & Human Behavior*, 29, 632-638.

Alloway, T.P., Doherty-Sneddon, G. and Forbes, L. (2012) Teachers' perceptions of classroom behaviour and working memory. *Educational Research and Reviews,* 7(6), 138-142.

Alloway, T.P., Gathercole S.E., Kirkwood, H. and Elliott, J. (2009) The cognitive and behavioural characteristics of children with low working memory. *Child Development,* 80(2), 606-621.

Anderson, J. R. (1982) Acquisition of cognitive skill. *Psychological Review*, 89(4), 369.

Ang, S. Y., Lee, K., Cheam, F., Poon, K. and Koh, J. (2015) Updating and working memory training: immediate improvement, long-term maintenance, and generalisability to non-trained tasks. *Journal of Applied Research in Memory and Cognition*, 4, 121-128.

Anguera, M. T., Blanco-Villaseñor, A., Losada, J. L., Sánchez-Algarra, P. and Onwuegbuzie, A. J. (2018) Revisiting the difference between mixed methods and multimethods: is it all in the name? *Quality & Quantity*, 1-14.

Archibald, L.M. (2017a) SLP-educator classroom collaboration: a review to inform reason-based practice. *Autism & Developmental Language Impairments*, 2, 1-17.

Archibald, L.M. (2017b) Working memory and language learning: a review. *Child Language Teaching and Therapy*, 33 (1), 5-17.

Archibald, L.M. (2018) The reciprocal influences of working memory and linguistic knowledge on language performance: considerations for the assessment of children with Developmental Language Disorder. *Language Speech and Hearing Services in Schools*, 49, 424-433.

Archibald L. M. and Gathercole, S E. (2006) Short-term and working memory in specific language impairment. *International Journal of Language and Communication Disorders,* 41(6), 675-694.

Archibald, L. M. and Gathercole, S. E. (2007) Nonword repetition in specific language impairment: more than a phonological short-term memory deficit. *Psychonomic Bulletin & Review,* 14, 919-924.

Archibald, L.M. and Joanisse, M.F. (2009) On the sensitivity and specificity of nonword repetition and sentence recall to language and memory impairments in children. *Journal of Speech, Language, and Hearing Research*, 52, 899-914.

American Speech-Language-Hearing Association (ASHA) (2004) *Preferred Practice Patterns for the Profession of Speech-Language Pathology*. Maryland: ASHA.

Baddeley, A.D. (1996) Exploring the central executive. *The Quarterly Journal of Experimental Psychology*, 49A(1), 5-28.

Baddeley, A.D. (2000) The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, 4(11), 417-423.

Baddeley, A.D. (2007) *Working memory, thought and action*. Oxford: OUP.

Baddeley, A.D. (2012) Working memory: theories, models and controversies. *Annual Review of Psychology*, 63(1), 1-29.

Baddeley, A.D., Gathercole, S.E. and Papagno, C. (1998) The phonological loop as a language learning device. *Psychological review,* 105, 158-173.

Baddeley, A.D. and Hitch, G.J. (1974) Working Memory. *In:* Bower, G.H. ed. *The psychology of learning and motivation, Vol 8.* London: Academic Press, 47-89.

Baddeley, A.D., Hitch, G.J. and Allen, R.J. (2019) From short-term store to multicomponent working memory: the role of the modal model. *Memory & Cognition*, 47(4), 585-588.

Baddeley, A. and Logie, R.H. (1999) Working memory: the multiple-component model. *In:* Miyake, A. and Shah, P. eds. *Models of Working Memory.* New York: Cambridge University Press, 28-61.

Barrouillet, P., Bernardin, S. and Camos, V. (2004) Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology General*, 133, 83-100.

Barrouillet, P. and Camos, V. (2001) Developmental increase in working memory span: resource sharing or temporal decay? *Journal of Memory and Language*, 45, 1-20.

Bartholomew, L.K., Markham, C.M., Ruiter, R.A., Fernandez, M.E., Kok, G. and Parcel, G.S. (2016) *Planning health promotion programs: an intervention mapping approach*. 4th ed. San Francisco: Jossey-Bass.

Bell, A., Corfield, M., Davies, J. and Richardson, N. (2010) Collaborative transdisciplinary intervention in early years - putting theory into practice. *Child: Care, Health and Development*, 36(1), 142-148.

Belzile, J.A. and Orberg, G. (2012) Where to begin? Grappling with how to use participant interaction in focus group design. *Qualitative Research*, 12(4), 459-472.

Bengoa, R. (2016) *Systems, not structures. Changing health and social care – full report.* Available at: https://www.healthni.gov.uk/sites/default/files/publications/health/expert-panel-full-report.pdf [Accessed: 30 November 2016].

Bercow, J. (2008) *The Bercow Report: A Review of Services for Children and Young People with Speech, Language and Communication Needs*. Nottingham: DCSF Publications.

Betts, J., Mckay, J., Maruff, P. and Anderson, V. (2006) The development of sustained attention in children: the effect of age and task load. *Child Neuropsychology,* 12, 205-221.

Bhaskar, R (1997) *A realist theory of science.* London and New York: Verso.

Bhaskar, R. (2008) *A realist theory of science*. 2nd ed. London: Verso.

Bishop, D. V. M., North, T. and Donlan, C. (1996) Nonword repetition as a behavioural marker for inherited language impairment: evidence from a twin study. *Journal of Child Psychology and Psychiatry,* 37, 391-403.

Bishop, D. V. M. and Snowling, M. J. (2004) Developmental dyslexia and specific language impairment: Same or different? *Psychological Bulletin*, 130, 858-886.

Bishop, D. V. M., Snowling, M. J., Thompson, P. A., Greenhalgh, T. and CATALISE Consortium. (2016) CATALISE: A multinational and multidisciplinary Delphi consensus study. Identifying language impairments in children. *PLoS ONE*, 11 (7), e0158753.

Bishop, D.V.M., Snowling M.J., Thompson, P.A. Greenhalgh, T. and CATALISE-2 Consortium. (2017) Phase 2 of CATALISE: A multinational and multidisciplinary Delphi consensus study of problems with language development: Terminology. *Journal of Child Psychology and Psychiatry*, 58(10), 1068-1080.

Bleijenberg, N., de Man-van Ginkel, J.M., Trappenburg, J.C.A., Ettemab, R.G.A., Sino, C.G. and Heim, N. *et al.*(2018) Increasing value and reducing waste by optimizing the development of complex interventions: enriching the development phase of the Medical Research Council (MRC) Framework. *International Journal of Nursing Studies,* 79, 86-93.

Botting, N. (2006) The interplay between language and cognition. *In:* Clegg, J. and Ginsborg, J. eds. *Language and Social Disadvantage*. Chichester: Wiley, 28-43.

Botting, N. and Conti-Ramsden, G. (2001) Non-word repetition and language development in children with specific language impairment (SLI). *International Journal of Language and Communication Disorders*, 36(4), 421-432.

Botting, N., Psarou, P., Caplin, T. and Nevin, L. (2013) Short-term memory skills in children with specific language impairment: the effect of verbal and nonverbal task content. *Topics in Language Disorders*, 33(4), 313-327.

Botting, N., Toseeb, U., Pickles, A., Durkin, K. & Conti-Ramsden, G. (2016) Depression and anxiety change from adolescence to adulthood in individuals with and without language impairment. *PLoS ONE*, 11(7), 1-13.

Bowling, A. (2014) *Research methods in health. Investigating health services.* 4th ed. Berkshire: Open University Press.

Brainard, J. and Hunter, P. R. (2016) Do complexity-informed health interventions work? A scoping review. *Implementation Science,* 11, 1-11.

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101.

Braun, V. and Clarke, V. (2013) *Successful qualitative research. A practical guide for beginners.* London: SAGE.

Braun, V. and Clarke, V. (2014) What can ‘‘thematic analysis’’ offer health and wellbeing researchers? *International Journal of Qualitative Studies on Health and Well-being*, 9, 9-10.

Braun, V., Clarke, V., Hayfield, N. and Terry, G. (2019) Thematic analysis. *In:* Liamputtong, P. ed. *Handbook of research methods in health social sciences.* Singapore: Springer, 843-860.

Bunting, M.F. and Cowan, N. (2005) Working memory and flexibility in awareness and attention. *Psychological Research,* 69, 412-419.

Byrne, D. (1998) *Complexity theory and the social sciences: an introduction*. London: Routledge.

Campbell, M., Fitzpatrick, R., Haines, A., Kinmonth, A.L., Sandercock, P. and Spiegelhalter, D. *et al.*(2000) Framework for design and evaluation of complex interventions to improve health. *British Medical Journal*, 321, 694-696.

Campbell, N.C., Murray, E., Darbyshire, J., Emery, J., Farmer, A. and Griffiths, F., *et al.*(2007) Designing and evaluating complex interventions to improve health care. *British Medical Journal,* 334, 455.

Carey, M.A. (2016) Focus Groups—what is the same, what is new, what is next? *Qualitative Health Research*, 26(6), 731-733.

Chan, A-W., Tetzlaff, J.M., Altman, D.G., Laupacis, A., Gøtzsche, P.C. and Krleža-Jerić, K. *et al.* (2013) SPIRIT 2013 Statement: Defining standard protocol items for clinical trials. *Annals of Internal Medicine*, 158, 200-207.

Chiat, S. and Roy, P. (2007) The preschool repetition test: An evaluation of performance in typically developing and clinically referred children. *Journal of Speech and Hearing Research*, 50, 429-443.

Chowdry, H. and McBride, T. (2017) *Disadvantage, behavior and cognitive outcomes: Longitudinal analysis from age 5 to 16.* London: Early Intervention Foundation.

Chowdry, H. and Oppenheim, C. (2015) *Spending on late intervention: how we can do better for less*. London: Early Intervention Foundation.

Cirrin, F.M., Schooling, T.L., Nelson, N.W., Diehl, S.F., Flynn, P.F. and Staskowski, M., *et al.*(2010) Evidence-based systematic review: effects of different service delivery models on communication outcomes for elementary school–age children. *Language, Speech and Hearing Services in Schools*, 41, 233-264.

Clarke, M. and Chalmers, I. (2018) Reflections on the history of systematic reviews. *BMJ Evidence-Based Medicine*, 23, 121-122.

Clarke, D., Jones, F., Harris, R. and Robert, G. (2017) What outcomes are associated with developing and implementing co-produced interventions in acute healthcare settings? A rapid evidence synthesis. *BMJ Open*, 7:e014650.

Clavering, E.K. and McLaughlin, J. (2007) Crossing multidisciplinary divides: exploring professional hierarchies and boundaries in focus groups. *Qualitative Health Research*, 17(3), 400-410.

Conti-Ramsden, G. and Botting, N. (2008) Emotional health in adolescents with and without a history of specific language impairment (SLI). *Journal of Child Psychology and Psychiatry*, 49(5), 516-525.

Conti-Ramsden, G., Durkin, K., Mok, P. L.H. Toseeb, U. and Botting, N. (2016) Health, employment and relationships: correlates of personal wellbeing in young adults with and without a history of childhood language impairment. *Social Science and Medicine,* 160, 20-28.

Conti-Ramsden, G., Durkin, K., Toseeb, U., Botting, N. and Pickles, A. (2018) Education and employment outcomes of young adults with a history of developmental language disorders. *International Journal of Language and Communication Disorders*, 53(2), 237-255.

Conti-Ramsden, G., Mok, P. L H., Pickles, A. and Durkin, K. (2013) Adolescents with a history of specific language impairment (SLI): strengths and difficulties in social, emotional and behavioral functioning. *Research in Developmental Disabilities*, 34, 4161-4169.

Conway, A.R.A., Cowan, N. and Bunting, M.F. (2001) The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review*, 8, 331-335.

Corbin Dwyer, S. and Buckle, J.L. (2009) The space between: on being an insider-outsider in qualitative research. *International Journal of Qualitative Methods*, 8(1), 54-63.

Cornoldi, C., Carretti, B. Drusi, S. and Tencati, C. (2015) Improving problem solving in primary school students: the effect of a training programme focusing on meta-cognition and working memory. *British Journal of Educational Psychology*, 85, 424-439.

Corry, M., Porter, S. and McKenna, H. (2019) The redundancy of positivism as a paradigm for nursing research. *Nursing Philosophy,* 20, e12230.

Cowan, N. (2008) What are the differences between long-term, short-term, and working memory? *Prog Brain Res*., 169, 323-338.

Cowan, N., Fristoe, N.M., Elliott, E.M, Brunner, R.P. and Saults, J.S. (2006) Scope of attention, control of attention and intelligence in children and adults. *Memory and Cognition,* 34(8), 1754-1768.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I. and Petticrew, M. (2008) Developing and evaluating complex interventions: the new Medical Research Council guidance. *British Medical Journal*, 337, 979-983.

Creswell, J.W. (2007) *Qualitative inquiry and research design. Choosing among five approaches*. 2nd ed. Thousand Oaks, CA: SAGE.

Creswell, J.W. and Creswell, J.D. (2018) *Research design: quantitative and mixed methods approaches*. 5th ed. Los Angeles: SAGE.

Creswell, J.W. and Plano Clark, V.L. (2011) *Designing and conducting mixed methods research*. 2nd ed. Thousand Oaks, CA: SAGE.

Cunningham, A.E. (1990) Explicit versus implicit instruction in phonemic awareness. *Journal of Experimental Child Psychology*, 50, 429-444.

Dahlin, E., Neely, A. S., Larsson, A., Backman, L. and Nyberg, L. (2008) Transfer of learning after updating training mediated by the striatum. *Science*, 320(5882), 1510-1512.

D'Amour, D., Ferrada-Videla, M., San Martin Rodriguez, L. and Beaulieu, M.D. (2005) The conceptual basis for interprofessional collaboration: core concepts and theoretical frameworks. *Journal of Interprofessional Care*, 19(1), 116-131.

Department of Education Northern Ireland (DENI) (2006) *Budget 2006-08 Children and young people funding package.* Belfast: DENI.

Denzin, N.K. (1989) *The research act*. 3rd ed. Englewood Cliffs: Prentice Hall.

Department for Communities (DfC) (2019) *2018/19 Report on the Northern Ireland Executive's Child Poverty Strategy*. Belfast: DfC.

Department for Education (DFE) (2017) *Unlocking talent, fulfilling potential. A plan for improving social mobility through education*. Available at: https://www.gov.uk/government/publications/improving-social-mobility-through-education [Accessed 3 August 2019].

Department for Education and Skills (DfES) (2003) *Every child matters.* London: The Stationery Office.

De Simoni, C. and von Bastian, C. C. (2018) Working memory updating and binding training: Bayesian evidence supporting the absence of transfer. *Journal of Experimental Psychology: General*, 147(6), 829–858.

Department of Health, Social Services and Public Safety (DHSSPS) (2012) *Improving health and well- being through positive partnerships. A strategy for the Allied Health Professions in Northern Ireland 2012-2017.* Belfast: DHSSPS.

Department of Health, Social Services and Public Safety (DHSSPS) (2014) *Making life better. A whole system strategic framework for public health.* Available at: https://www.health-ni.gov.uk/sites/default/files/publications/dhssps/making-life-better-strategic-framework-2013-2023_0.pdf [Accessed 30 September 2016].

Diamond, A., Barnett, W.S., Thomas, J., Munro, S. (2007) Preschool program improves cognitive control. *Science*, 318, 1387-1388.

Diamond, A. (2012) Activities and programs that improve children's executive functions. *Current Directions in Psychological Science,* 21(5), 335-341.

Diamond, A. (2013) Executive Functions. *Annual Review of Clinical Psychology*, 64, 135-168.

Dittman, C.K. (2016) Associations between inattention, hyperactivity and pre-reading skills before and after formal reading instruction begins. *Reading and Writing*, 29, 1771-1791.

Department of Health Northern Ireland (DoHNI) (2016) *Health and wellbeing 2026. Delivering together*. Belfast: DoHNI.

Dunning, D. and Holmes, J. (2014) Does working memory training promote the use of strategies on untrained working memory tasks? *Memory and Cognition*, 2, 854-862.

Dunning, D., Holmes, J. and Gathercole, S.E. (2013) Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial. *Developmental Science,* 1-12.

Durkheim, E. (1966[1895]) *The rules of sociological method*. Trans. S. Solovay, S. and Mueller, J. New York: Free Press.

Ebbels, S., McCartney, E., Slonims, V., Dockrell, J. and Norbury, C. (2019) Evidence-based pathways to intervention for children with language disorders. *International Journal of Language and Communication Disorders,* 54(1), 3-19.

Eldridge, S.M., Chan, C.L., Campbell, M.J., Bond, C.M. and Hopewell, S. (2016a) CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *British Medical Journal,* 355, i5239.

Eldridge, S.M., Lancaster, G.A., Campbell, M.J., Thabane, L., Hopewell, S. and Coleman, C. L. *et al.*(2016b) Defining feasibility and pilot studies in preparation for randomised controlled trials: development of a conceptual framework. *PLoS ONE*, 11(3), e0150205.

Ellis Weismer, S., Evans, J. and Hesketh, L. (1999) An examination of verbal working memory capacity in children with specific language impairment. *Journal of Speech. Language and Hearing Research*, 42, 1249-1260.

Ellis Weismer, S., Davidson, M. M., Gangopadhyay, I., Sindberg, H., Roebuck, H. and Kaushanskaya, M. (2017) The role of nonverbal working memory in morphosyntactic processing by children with specific language impairment and autism spectrum disorders. *Journal of Neurodevelopmental Disorders*, 9, 28.

Engle, R. W., Carullo, J. J. and Collins, K. W. (1991) Individual differences in working memory for comprehension and following directions. *Journal of Educational Research*, 84, 253-262.

Engel de Abreu, P.M.J., Gathercole, S.E. and Martin, R. (2011) Disentangling the relationship between working memory and language: the roles of short-term storage and cognitive control. *Learning and Individual Differences*, 21(5), 569-574.

Engel de Abreu, P.M J., Puglisi, M.L., Cruz-Santos, A., Befi-Lopes, D.M. and Martin, R. (2014) Effects of impoverished environmental conditions on working memory performance. *Memory*, 22(4), 323-331.

Engle, R. W. (2002) Working memory capacity as executive attention. *Current Directions in Psychological Science,* 11, 19-23.

Estes, D., Wellman, H. M. and Woolley, J. (1989) Children's understanding of mental phenomena. *In:* Reese, H. ed. *Advances in child development and behavior*. New York: Academic Press, 41-86.

Fargas Malet, M., McSherry, D., Larkin, E. and Robinson, C. (2010) Research with children: methodological issues and innovative techniques. *Journal of Early Childhood Research*, 8(2), 175-192.

Ferguson, M. and Spence W. (2012) Towards a definition: what does 'health promotion' mean to speech and language therapists? *International Journal of Language and Communication Disorders*, 47(5), 522-533.

Finneran, D., Francis, A.L. and Leonard, L.B. (2009) Sustained attention in children with specific language impairment (SLI). *Journal of Speech, Language and Hearing Research*, 52(4), 915-929.

Fisher, E. L. (2017) A systematic review and meta-analysis of predictors of expressive-language outcomes among late talkers. *Journal of Speech, Language, and Hearing Research*, 60, 2935-2948.

Fletcher, A., Jamal, F., Moore, G., Evans, R.E., Murphy, S. and Bonell, C. (2016) Complex intervention science: applying realist principles across all phases of the Medical Research Council framework for developing and evaluating complex interventions. *Evaluation*, 22(3), 286-303.

Foley, G. M. (1990) Portrait of the arena evaluation: assessment in the transdisciplinary approach. *In:* Biggs, E. and Teti, D. eds. *Interdisciplinary assessment of infants: A guide for early intervention professionals.* Baltimore: Paul H. Brookes, 271-286.

Friedman, N.P. and Miyake, A. (2017) Unity and diversity of executive functions: individual differences as a window on cognitive structure. *Cortex*, 86, 186-204.

Frizelle, P. and Fletcher, P. (2015) The role of memory in processing relative clauses in children with specific language impairment. *American Journal of Speech-Language Pathology*, 24, 47-59.

Frizelle, P., Harte, J., O'Sullivan, K., Fletcher, P. and Gibbon, F. (2007) The relationship between information carrying words, memory and language skills in school age children with language impairment. *PLoS ONE*, 12(7), e0180496.

Funnell, S.C. and Rogers, P.J. (2011) *Purposeful program theories effective use of theories of change and logic models*. San Francisco, CA: John Wiley & Sons.

Gascoigne M. (2006) *Supporting children with speech, language and communication needs within integrated children's services*. *RCSLT Position Paper.* London: RCSLT.

Gascoigne, M. (2008) Change for children with language and communication needs: creating sustainable integrated services. *Child Language Teaching and Therapy*, 24(2), 133-154.

Gascoigne, M.T. (2013) *The balanced system: definition of tiers.* Available at:

https://www.bettercommunication.org.uk/defnitions%20of%20universal,%20targeted%20and%20specialist%20levels%202013.pdf [Accessed: 14 January 2017].

Gathercole, S.E. (2008) Working memory in the classroom. *The Psychologist*, 21(5), 382-385.

Gathercole, S.E. and Alloway, T.P. (2008) *Working memory and learning: a practical guide for teachers*. London: Sage.

Gathercole, S. E., Alloway, T. P., Willis, C. S. and Adams, A. M. (2006) Working memory in children with reading disabilities. *Journal of Experimental Child Psychology,* 93, 265-281.

Gathercole, S.E., Alloway, T.P., Kirkwood, H.J., Elliott, J.G., Holmes, J. and Hilton, K. A. (2008) Attentional and executive function behaviours in children with poor working memory. *Learning and Individual Differences*, 18, 214-223.

Gathercole, S. E. and Baddeley, A. D. (1990) The role of phonological memory in vocabulary acquisition: a study of young children learning new names. *British Journal of Psychology,* 81, 439-454.

Gathercole, S. E., Durling, E., Evans, M., Jeffcock, S. and Stone, S. (2008) Working memory abilities and children's performance in laboratory analogues of classroom activities. *Applied Cognitive Psychology*, 2, 1019-1037.

Gathercole, S.E., Hitch, G.J., Service, E. and Martin, A.J. (1997) Phonological short-term memory and new word learning in children. *Developmental Psychology*, 33(6), 966-979.

Gathercole, S.E., Holmes, J., Dunning, D.L. and Norris, D. (2019) Working memory training involves learning new skills. *Journal of Memory and Language*, 105, 19-42.

Gathercole, S.E. and Pickering, S.J. (2000) Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *The British Journal of Educational Psychology,*70(2), 177-194.

Gathercole, S. E., Pickering, S. J., Knight, C. and Stegmann, Z. (2004a) Working memory skills and educational attainment: Evidence from National Curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology*, 18, 1-16.

Gathercole, S. E., Pickering, S. J., Ambridge, B. and Wearing, H. (2004b) The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, 40, 177– 190.

Gathercole, S. E., Willis, C.S., Emslie, H. and Baddeley, A.D. (1992) Phonological memory and vocabulary development during the early school years: A longitudinal study *Developmental Psychology*, 28(5), 887-898.

Gazzaley, A. and Nobre, A.C. (2012) Top-down modulation: bridging selective attention and working memory. *Trends in Cognitive Sciences*, 16(2), 129-135.

Gill, C.B., Klecan-Aker, J. Roberts, T. and Fredenburg, K.A. (2003) Following directions: rehearsal and visualization strategies for children with SLI. *Child Language, Teaching & Therapy*, 19(1), 85-103.

Gillam, R. B., Cowan, N. and Marler, J. A. (1998) Information processing by school-age children with specific language impairment: evidence from a modality effect paradigm. *Journal of Speech, Language and Hearing Research*, 41, 913-926.

Gillon, G.T (2000) The efficacy of phonological awareness intervention for children with spoken language impairment. *Language Speech and Hearing Services in Schools,* 31, 126-141.

Gillon, G. T. (2002) Follow-up study investigating benefits of phonological awareness intervention for children with spoken language impairment. *International Journal of Language and Communication Disorders*, 37(4), 381–400.

Glanz, K. and Rimer, B.K. (2005) *Theory at a glance. A guide for health promotion*. National Cancer Institute, National Institutes of Health, U.S. Department of Health and Human Services. NIH Pub. No. 97-3896. Washington: NIH.

Glasziou, P., Chalmers, I., Altman, D.G., Bastian, H., Boutron, I. and Brice, A. *et al.*(2010) Taking healthcare interventions from trial to practice. *British Medical Journal*, 341, c3852.

Glouberman, S. and Zimmerman, B. (2002) Complicated and complex systems: what would successful reform of Medicare look like? Discussion paper No.8. Canada: Commission for the future of health care in Canada.

Gough, D., Thomas, J. and Oliver, S. (2012) Clarifying differences between review designs and methods. *Systematic Reviews*, 1(28), 1-28

Goyette, C.H., Conners, C.K. and Ulrich, R.F. (1978) Normative data on revised Conners parent and teacher rating scales. *Journal Abnormal Child Psychology*, 6 (2), 221–36.

Golumb, C. and Kuersten, R. (1996) On the transition from pretense play to reality: what are the rules of the game? *British Journal of Developmental Psychology*, 14, 203-217.

Grant, A., Treweek, S., Dreischulte, T., Foy, R. and Guthrie, B. (2013) Process evaluations for cluster-randomised trials of complex interventions: a proposed framework for design and reporting. *Trials,* 14, 15.

Greenhalgh, T., Jackson, C., Shaw, S. and Janamian, T. (2016) Achieving research impact through co-creation in community-based health services: literature review and case study. *The Milbank Quarterly*, 94, 392-429.

Guye, S. and von Bastian, C. C. (2017) Working memory training in older adults: Bayesian evidence supporting the absence of transfer. *Psychology and Aging, 32*(8), 732-746.

Hall, P. (2005) Interprofessional teamwork: professional cultures as barriers. *Journal of Interprofessional Care*, 19(1), 188-196.

Hall, K.L., Vogel, A.L., Stipelman, B. A., Stokols, D., Morgan, G. and Gehlert, S. (2012) A four-phase model of transdisciplinary team-based research: goals, team processes, and strategies. *Translational Behavioral Medicine* 2(4), 415-430.

Hallingberg, B., Turley, R., Segrott, J., Wight, D., Craig, P. and Moore, L. *et al.*(2018) Exploratory studies to decide whether and how to proceed with full-scale evaluations of public health interventions: a systematic review of guidance. *Pilot and Feasibility Studies*, 4, 104.

Halperin, J.M., Marks, D.J., Bedard, A.C., Chacko, A., Curchack, J.T. and Yoon, C.A. (2015) Training executive, attention, and motor skills: a proof-of-concept study in preschool children with ADHD. *Journal of Attention Disorders*, 17(8), 711-721.

Hanania, R. and Smith, L.B. (2010) Selective attention and attention switching: towards a unified developmental approach. *Developmental Science,* 13(4), 622-635.

Harron, A. and Dickson, F. (2013) Perspectives on trans-disciplinary working for children in mainstream education. *Rehabilitation and Therapy Research Society conference*. Belfast, June 2013.

Hawe, P. (2015) Lessons from complex interventions to improve health. *Annual Review of Public Health*, 36, 307-323.

Hawe, P., Shiell, A. and Riley, T. (2009) Theorising interventions as events in systems. *American Journal of Community Psychology*, 43, 267-276.

Hawe, P., Shiell, A., Riley, T. and Gold, L. (2004) Methods for exploring implementation variation and local context within a cluster randomised community intervention trial. *Journal of Epidemiology and Community Health*, 58(9), 788-793.

Hawkins, J., Madden, K., Fletcher, A., Midgley, L., Grant, A. and Cox, G. *et al.*(2017) Development of a framework for the co-production and prototyping of public health interventions. *BMC Public Health,* 17, 1-11.

Henry, L. (2012) *The development of working memory in children.* London: SAGE.

Henry, L. and Botting, N. (2017) Working memory and developmental language impairments. *Child Language Teaching and Therapy,* 33(1), 19-32.

Henry, L., Messer, D. J. and Nash, G. (2012) Executive functioning in children with specific language impairment. *Journal of Child Psychology and Psychiatry*, 53(1), 37-45.

Henry, L.A., Messer, D. J. and Nash, G. (2014) Testing for near and far transfer effects with a short, face-to-face adaptive working memory training intervention in typical children. *Infant and Child Development,* 23(1), 84-103.

Hewitt, G., Sims, S. and Harris, R. (2014) Using realist synthesis to understand the mechanisms of interprofessional teamwork in health and social care. *Journal of Interprofessional Care*, 28(6), 501-506.

Higgins, J.P.T. and Green, S. eds. (2008) *Cochrane handbook for systematic reviews of interventions*. Chichester: John Wiley & Sons.

Hoddinott, P. (2015) A new era for intervention development studies. *Pilot and Feasibility Studies*, 1(1), 36.

Hoffmann, T.C., Glasziou, P.P., Broutron, I., Perera, R., Moher, D. and Altman, D.G. *et al.*(2014) Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *British Medical Journal,* 348, g1687.

Holmes, J., Butterfield, S., Cormack, F., Loenhoud, A.V., Ruggero, L., Kashikar, L. and Gathercole, S. (2015) Improving working memory in children with low language abilities. *Frontiers in Psychology,* 6, 519.

Holmes, J., Gathercole, S.E. and Dunning, D.L. (2009) Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, 12(4), 9-15.

Holmes, J., Gathercole, S.E. and Dunning, D. (2010) Poor working memory: impact and interventions. *Advances in Child Development and Behaviour,* 39, 1-43.

Holmes, J., Woolgar, F., Hampshire, A. and Gathercole, S. E. (2019) Are working memory training effects paradigm-specific? *Frontiers in Psychology*, 10, 1103.

Howarth, E., Devers, K., Moore, G., O'Cathain, A. and Dixon-Woods, M. (2016) Contextual issues and qualitative research. *In:* Raine, R., Fitzpatrick, R., Barratt, H., Bevan, G., Black, N. and Boaden, R., *et al.*Challenges, solutions and future directions in the evaluation of service innovations in health care and public health. *Health Services Delivery Research*, 4(16), 105–20.

Health and Social Care Board (HSCB) (2011) *Transforming Your Care. A review of Health and Social Care in Northern Ireland.* Belfast: HSCB.

Health and Social Care (Reform) Act (Northern Ireland) 2009. Belfast: HMSO.

Hulme, C., Snowling, M.J., Caravolas, M. and Carroll, J. (2005) Phonological skills are (probably) one cause of success in learning to read: a comment on Castles and Coltheart. *Scientific Studies of Reading*, 9 (4), 351-365.

Hulme, C., Bowyer-Crane, C., Carroll, J.M., Duff, F.J. and Snowling, M.J. (2012) The causal role of phoneme awareness and letter-sound knowledge in learning to read: combining intervention studies with mediation analyses. *Psychological Science,* 23(6), 572–577.

Hutchison, K. A. (2007) Attentional control and the relatedness proportion effect in semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 33, 645-662.

ICAN/RCSLT (2018) *Bercow: Ten Years On. An Independent Review of Provision for Children and Young People With Speech, Language and Communication Needs in England*. London: ICAN/RCSLT.

Im-Bolter, N., Johnston, J. and Pascual-Leone, J. (2006) Processing limitations in children with specific language impairment: The role of executive function. *Child Development*, 77(6), 1822-1841.

Jacob, R. and Parkinson, J. (2015) The potential for school-based interventions that target executive function to improve academic achievement: a review. *Review of Educational Research*, 85(4), 512-552.

Jaeggi, S.M. and Buschkuehl, M. (2014) Working memory training and transfer: theoretical and practical considerations. *In:* Toni. B. ed. *New Frontiers of Multidisciplinary Research in STEAM-H (Science, Technology, Engineering, Agriculture, Mathematics, and Health). Springer Proceedings in Mathematics & Health,* 19-44.

Jaeggi, S. M., Buschkuehl, M., Jonides, J. and Perrig, W. J. (2008) Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences of the United States of America,* 105, 6829-6833.

Jaeggi, S. M., Buschkuehl, M., Jonides, J. and Shah, P. (2012) Cogmed and working memory training-Current challenges and the search for underlying mechanisms. *Journal of Applied Research in Memory and Cognition,* 1(3), 185-193.

Jaroslawska, A.J., Gathercole, S.E., Allen, R.J. and Holmes, J. (2016) Following instructions from working memory: why does action at encoding and recall help? *Memory and Cognition,* 44, 1183-1191.

Jaroslawska, A.J., Gathercole, S.E. and Holmes, J. (2018) Following instructions in a dual-task paradigm: evidence for a temporary motor store in working memory. *Quarterly Journal of Experimental Psychology*, 71(11), 2439-2449.

Johnson, C.J., Beitchman, J.H. and Brownlie, E.B. (2010) Twenty-year follow-up of children with and without speech-language impairments: Family, educational, occupational, and quality of life outcomes. *American Journal of Speech-Language Pathology*, 19, 51–65.

Johnson, R.B. and Onwuegbuzie, A.J. and Turner, L.A. (2012) Toward a definition of mixed methods research. *Journal of Mixed Methods Research,* 1(2), 162-180.

Justice, L.M. (2018) Conceptualising "dose" in paediatric language interventions: Current findings and future directions. *International Journal of Speech-Language Pathology*, 20(3), 318-323.

Kane, M.J., Conway, A.R.A., Hambrick, D.Z. and Engle, R.W. (2007) Variation in working-memory capacity as variation in executive attention and control. *In:* Conway, A.R.A., Jarrold, C., Kane, M.J., Miyake, A. and Towse, J.N. eds. *Variation in working memory*. New York: Oxford University Press, 21-48.

Kapa, L.L. and Plante, E. (2015) Executive function in SLI: recent advances and future directions. *Current Developmental Disorders Reports,* 2 (3), 245-252.

Kellogg Foundation, W.K. (2004) Logic Model Development Guide. Battle Creek, MI: W.K. Kellogg Foundation.

King, G., Stachan, D. Tucker, M., Duwyn, B., Desserud, S. and Shillington, M. (2009) The application of a transdisciplinary model for early intervention services. *Infants and Young Children*, 22(3), 211-223.

Kitzinger, J. (1995) Qualitative research: introducing focus groups. *British Medical Journal*, 311, 299.

Klingberg, T. (2010) Training and plasticity of working memory. *Trends in Cognitive Sciences,* 14, 317-324.

Krueger, R.A. and Casey, M.A. (2015) *Focus groups. A practical guide for applied research*. 5th ed. London: SAGE.

Kuhlmann, M. (2004) Transdisciplinary Team: An evolving approach in rehabilitation. *American Congress of Rehabilitation Medicine*. Available at: https://www.utmb.edu/pmch/GSO/Evolving_Approach_to_Rehabilitation.html [Accessed: 10 Oct 2016].

Kuhn, T. S. (1962) *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Law, J. (2019) Population woods and clinical trees. A commentary on 'Evidence-based pathways to intervention for children with language disorders'. *International Journal of Language and Communication Disorders,* 54(1), 26-27.

Law, J., Charlton, J., Dockrell, J., Gascoigne, M., McKean, C. and Theakston, A. (2017b) *Early Language Development: Needs, provision and intervention for pre-school children from socio-economically disadvantaged backgrounds.* London: Education Endowment Fund.

Law, J., McBean, K and Rush, R. (2011) Communication skills in a population of primary school‐aged children raised in an area of pronounced social disadvantage *International Journal of Language and Communication Disorders*, 46(6), 657-664.

Law, J., Levickis, P., McKean, C., Goldfeld, S., Snow, P. and Reilly, S. (2017a) *Child Language in a Public Health Context*. Melbourne: Murdoch Children's Research Institute.

Law, J., Reilly, S. and Snow, P.C. (2013) Child speech, language and communication needs re-examined in a public health context: a new direction for the speech and language therapy profession. *International Journal of Language and Communication Disorders*, 48(5), 486-496.

Law J., Rush R., Schoon, I. and Parsons, S. (2009) Modelling developmental language difficulties from school entry into adulthood: literacy, mental health, and employment outcomes. *Journal of Speech, Language and Hearing Research*, 52(6), 1401-1416.

Leather, C. V. and Henry, L. A. (1994) Working memory span and phonological awareness tasks as predictors of early reading ability. *Journal of Experimental Child Psychology,* 58(1), 88-111.

Leclercq, M. (2002) Theoretical aspects of the main components and functions of attention. *In:* Leclercq, M. and Zimmermann, P. eds. *Applied neuropsychology of attention: Theory, diagnosis and rehabilitation*. New York: Psychology Press, 3-55.

Leeman, J. and Sandelowski, M. (2012) Practice-based evidence and qualitative inquiry. *Journal of Nursing Scholarship,* 44(2), 171-179.

Lincoln, Y.S. and Guba, E.G. (1985) *Naturalistic Inquiry*. Beverly Hills: SAGE.

Locke, A., Ginsborg, J. and Peers, I. (2002) Development and disadvantage: implications for the early years and beyond. *International Journal of Language and Communication Disorders*, 37(1), 3-15.

Lof, G.L. (2011) Science-based practice and the speech-language pathologist. *International Journal of Speech-Language Pathology*, 13(3), 189-196.

Logie, R. H. (1995) *Visuo-spatial working memory*. Hove, UK: Lawrence Erlbaum Associates.

Logie, R.H. and Pearson, D.G. (1997) The inner eye and the inner scribe of visuo-spatial working memory: evidence from developmental fractionation. *European Journal of Cognitive Psychology*, 9(3), 241-257

Loosli, S. V., Buschkuehl, M., Perrig, W. J. and Jaeggi, S. M. (2012) Working memory training improves reading processes in typically developing children. *Child Neuropsychology*, 18, 62-78.

Lyons, R. and Roulstone, S. (2018) Well-being and resilience in children with speech and language disorders. *Journal of Speech, Language and Hearing Research*, 61, 324-344.

Mackey, S. and McQueen, J. (1998) Exploring the association between integrated therapy and inclusive education. *British Journal of Special Education,* 25(1), 22-27.

Malin, N. and Morrow, G. (2007) Models of interprofessional working within a Sure Start "Trailblazer" Programme. *Journal of Interprofessional Care*, 21(4), 445-457.

Manly, T., Anderson, V., Nimmo-Smith, I., Turner, A., Watson, P. and Robertson, I.H. (2001) The differential assessment of children's attention: The Test of Everyday Attention for Children (TEA-Ch), Normative sample and ADHD performance. *Journal of Child Psychology and Psychiatry*, 42(8), 1065-108.

Marton, K. and Schwartz, R. G. (2003) WM capacity and language processes in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, 46, 1138-1153.

Mason, J. (2002) *Qualitative Researching*. 2nd ed. London: SAGE.

McCabe, P.J. (2018) Elizabeth Usher Memorial Lecture: How do we change our profession? Using the lens of behavioral economics to improve evidence-based practice in speech-language pathology. *International Journal of Speech-Language Pathology*, 20(3), 300-309.

McClafferty, I. (2004) Focus group interviews as a data collecting strategy. *Journal of Advanced Nursing*, 48(2), 187-194.

McKenna, H. P. (1997) *Nursing models and theories*. London, UK: Routledge.

McLeroy, K.R., Bibeau, D., Steckler, A. and Glanz, K. (1988) An ecological perspective on health promotion programs. *Health Education and Behaviour*, 15, 351-377.

Melby-Lervåg, M. and Hulme, C. (2010) Serial and free recall in children can be improved by training: evidence for the importance of phonological and semantic representations in immediate memory. *Psychological Science*, 21(11), 1694-1700.

Melby-Lervåg, M. and Hulme, C. (2013) Is working memory training effective? A meta-analytic review. *Developmental Psychology*, 49(2), 270-291.

Melby-Lervåg, M., Redick, T.S. and Hulme, C. (2016) Working memory training does not improve performance on measures of intelligence or other measures of “far transfer”: evidence from a meta-analytic review. *Perspectives on Psychological Science*, 11(4), 512-534.

McPherson, K., Kersten, P., George, S., Lattimer, V., Breton, A. and Ellis, B. *et al.*(2006) A systematic review of evidence about extended roles for allied health professions. *Journal of Health Service Research and Policy*, 11(4), 240-247.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A. and Wager, T.D. (2000) The unity and diversity of executive functions and their contributions to complex ‘‘frontal lobe’’ tasks: a latent variable analysis. *Cognitive Psychology,* 41, 49-100.

Montgomery, J.W., Magimairaj, B.M. and Finney. M.C. (2010) Working memory and specific language impairment: an update on the relation and perspectives on assessment and treatment. *American Journal of Speech-Language Pathology*, 19, 78-94.

Moore, G.F., Audrey, S., Barker, M., Bond, L., Bonell, C. and Hardeman, W. *et al.*(2015) Process evaluation of complex interventions: Medical Research Council, *British Medical Journal,* 350, h1258.

Moore, G. and Evans, R. (2017) What theory, for whom and in which context? Reflections on the application of theory in the development and evaluation of complex population health interventions. *SSM Population Health*, 3, 132-135.

Moore, G., Evans, R., Hawkins, J., Littlecott, H., Melendez-Torres, G.J. and Bonell, C. *et al.*(2019) From complex social interventions to interventions in complex social systems: future directions and unresolved questions for intervention development and evaluation. *Evaluation,* 25(1), 23-45.

Morra, S. and Borella, E. (2015) Working memory training: from metaphors to models. *Frontiers in Psychology,* 6, 1097.

Morse, J. (1991) Approached to qualitative-quantitative methodological triangulation. *Nursing Research*, 40(2), 120-123.

Meaux, J.B. and Bell, P.L. (2001) Balancing recruitment and protection: children as research subjects. *Issues in Comprehensive Pediatric Nursing*, 24(4), 241-251.

Medical Research Council (MRC) (2000) A framework for development and evaluation of RCTs for complex interventions to improve health. London: MRC.

Medical Research Council (MRC) (2008) Developing and evaluating complex interventions: new guidance. London: MRC.

Medical Research Council (MRC) (2019) Developing and evaluating complex interventions: following considerable development in the field since 2006, MRC and NIHR have jointly commissioned an update of this guidance to be published in 2019. London: MRC.

Murphy, C. (2019) The limits of evidence and the implications of context: considerations when implementing pathways to intervention for children with language disorders. *International Journal of Language and Communication Disorders*, 54(1), 20-23.

Navarro, J. I., Aguilar, M., Alcalde, C., Ruiz, G., Marchena, E. and Menacho, I. (2011) Inhibitory processes, working memory, phonological awareness, naming speed, and early arithmetic achievement. *The Spanish Journal of Psychology*, 14, 580-588.

Newell, K. M. (1991) Motor skill acquisition. *Annual Review of Psychology*, 42(1), 213-237.

Newell, R. and Burnard, P. (2011) *Research for evidence-based practice in healthcare.* Chichester: Wiley and Blackwell.

Nippold, M.A. (2011) Language intervention in the classroom: what it looks like. *Language, Speech, and Hearing Services in Schools*, 42, 393-394.

Nippold, M. A. (2012) Different service delivery models for different communication disorders. *Language, Speech and Hearing Services in Schools*, 43(2), 117-120.

Nippold, M. (2015) Call for studies in implementation science: Improving reading comprehension in school-age children. *Language, Speech and Hearing Services in Schools*, 46(2), 65-67.

Noble, K.G., McCandliss, B.D. and Farah, M.J. (2007) Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science,* 10(4), 464-480.

Noble, H. and Smith, J. (2018) Reviewing the literature: choosing a review design. *Evidence-based nursing*, 21(2), 39-41.

Noonan, B. N., Redmond, S. M. and Archibald, L. M. D. (2014) Contributions of children's linguistic and working memory proficiencies to their grammaticality judgments. *Journal of Speech, Language, Hearing Research*, 57, 978-979.

Norbury, C. F. (2017) Editorial: New frontiers in the scientific study of developmental language disorders. *Journal of Child Psychology and Psychiatry*, 58(10), 1065-1067.

Norbury, C. F., Gooch, D., Wray, C., Baird, G., Charman, T. and Simonoff, E. *et al.*(2016) The impact of nonverbal ability on prevalence and clinical presentation of language disorder: evidence from a population study. *Journal of Child Psychology and Psychiatry*, 57(11), 1247-1257.

Noyes, J., Gough, D., Lewin, S., Mayhew, A., Michie, S. and Pantoja, T. *et al.*(2013) A research and development agenda for systematic reviews that ask complex questions about complex interventions. *Journal of Clinical Epidemiology*, 66(11), 1262-1270.

Nutley, S. B., Soderqvist, S., Bryde, S., Thorell, L. B., Humphreys, K. and Klingberg, T. (2011) Gains in fluid intelligence after training non-verbal reasoning in 4-year-old children: a controlled, randomized study. *Developmental Science*, 14, 591-601.

Oakhill, J. and Kyle, F. (2000) The relation between phonological awareness and working memory. *Journal of Experimental Child Psychology,* 75, 152-164.

O'Cathain, A., Croot, L., Duncan, E., Rousseau, N. Sworn, K. and Turner, K.M. *et al.*(2019a) Guidance on how to develop complex interventions to improve health and healthcare. *BMJ Open,* 9, e029954

O'Cathain, A., Croot, L., Sworn, K., Duncan, E., Rousseau, N. and Turner, K. (2019b) Taxonomy of approaches to developing interventions to improve health: a systematic methods overview. *Pilot and Feasibility Studies*, 5(41), 1-27.

O'Cathain, A., Hoddinott, P., Lewin, S., Thomas, K. J., Young, B. and Adamson, J. *et al.*(2015) Maximising the impact of qualitative research in feasibility studies for randomised controlled trials: guidance for researchers. *Pilot and Feasibility Studies*, 1, 32.

O'Cathain, A., Murphy, E. and Nicholl, J. (2007) Integration and publications as indicators of "yield" from mixed methods studies. *Journal of Mixed Methods Research*, 1(2), 147-163.

O'Cathain, A., Murphy, E. and Nicholl, J. (2010) Three techniques for integrating data in mixed methods studies. *British Medical Journal*, 341, c4587.

Ocloo, J. and Matthews, R. (2016) From tokenism to empowerment: progressing patient and public involvement in healthcare improvement. *BMJ Quality and Safety*, 25, 626-632.

Office of the First Minister and Deputy First Minister (OFMDFM) (2006) *Our children and young people – our pledge: a ten year strategy for children and young people in Northern Ireland 2006 – 2016*. Belfast: OFMDFM.

Papagno, C., Cecchetto, C., Reati, F. and Bello, L. (2007) Processing of syntactically complex sentences relies on verbal short-term memory: evidence from a STM patient. *Cognitive Neuropsychology*, 24(3), 292e311.

Parahoo, K. (2014) *Nursing research: principles, process and issues*. 3rd ed. London: Palgrave Macmillan.

Parsons, S. (2019) A service perspective on 'Evidence-based pathways to intervention for children with language disorders'. *International Journal of Language and Communication Disorders*, 54(1), 24-25.

Passolunghi, M.C. and Costa, H.M. (2016) Working memory and early numeracy training in preschool children. *Child Neuropsychology*, 22(1), 81-98.

Pawson, R. (2006) *Evidence-based policy: a realist perspective*. London: SAGE.

Pawson, R, (2013) The science of evaluation: a realist manifesto. London: SAGE.

Pawson, R., Greenhalgh, T., Harvey, G. and Walshe, K. (2005) Realist review - a new method of systematic review designed for complex policy interventions. *Journal of Health Services Research and Policy*, 10(1), 21-34.

Pawson, R. and Tilley, N. (1997) *Realistic Evaluation*. London: SAGE.

Pennington, B. F. and Bishop, D. V. (2009) Relations among speech, language, and reading disorders. *Annual Review of Psychology*, 60, 283-306.

Perkins, S., Finegood E.D. and Swain, J.E., (2013) Poverty and language development: roles of parenting and stress. *Innovations in Clinical Neuroscience*, 10(4), 10-19.

Petticrew, M. (2015) Time to rethink the systematic review catechism? Moving from 'what works' to 'what happens'. *Systematic Reviews*, 4(36).

Petticrew, M., Rehfuess, E., Noyes, J., Higgins, J.P.T., Mayhew, A. and Pantoja, T. *et al.*(2013) Synthesizing evidence on complex interventions: how meta-analytical, qualitative, and mixed-method approaches can contribute. *Journal of Clinical Epidemiology*, 66(11), 1230-1243.

Peyton, D.J. and Scicchitano, M. (2017) Devil is in the details: using logic models to investigate program process. *Evaluation and Program Planning*, 65, 156-162.

Public Health Agency (PHA) (2011) *A Delphi Study to Identify Research Priorities For The Therapy Professions In Northern Ireland.* Available at: http://www.publichealth.hscni.net/sites/default/files/NI_Delphi_Study_Main_Report_July2011.pdf [Accessed 2 July 2015].

Public Health Agency (PHA) (2014) *Strategy for Personal and Public Involvement in Health and Social Care Research*. Belfast: Public Health Agency.

Pickering, S.J., Gathercole, S.E. and Peaker, S.M. (1998) Verbal and visuospatial short-term memory in children: Evidence for common and distinct mechanisms. *Memory and Cognition*, 26, 1117-1130.

Pintrich, P.R. (1999) The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research*, 31, 459-470.

Pring, T., Flood, E., Dodd, B. and Joffe, V. (2012) The working practices and clinical experiences of paediatric speech and language therapists: a national UK survey. *International Journal of Language and Communication Disorders*, 47, 696-708.

Rode, C., Robson, R., Purviance, A., Geary, D. C. and Mayr, U. (2014) Is working memory training effective? A study in a school setting. *PLoS ONE*, 9, e104796.

Royal College of Speech and Language Therapists (RCSLT) (2015) *The National Prospectus Grants Programme 2015-16. The RCLST Outcome Project Key Policy and Research Pack*. London: RCLST.

Royal College of Speech and Language Therapists (RCSLT) (2018) *Placing children and young people at the heart of delivering quality speech and language therapy: Guidance on principles, activities and outcomes*. London: RCSLT.

Redick, T.S., Shipstead, Z., Wiemers, E.A., Melby-Lervåg, M. and Hulme, C. (2015) What's working in working memory training? An educational perspective. *Educational Psychology Review*, 27, 617-633.

Ricarte, J.J., Ros, L. and Latorre, J.M. (2015) Mindfulness-based intervention in a rural primary school: effects on attention, concentration and mood. *International Journal of Cognitive Therapy*, 8, 1-11.

Roberts, G., Quach, J., Spencer-Smith, M., Anderson, P., Gathercole, S. and Gold, L. *et al.*(2016) Academic outcomes 2 years after working memory training for children with low working memory: a randomized clinical trial. *JAMA Pediatr.* 170(5), e154568.

Rodriguez, K.L., Schwartz, J.L., Lahman, M.K.E. and Geist, M.R. (2011) Culturally responsive focus groups: reframing the research experience to focus on participants. *International journal of Qualitative Methods*, 10(4), 400-417.

Roulstone, S. (2015) Exploring the relationship between client perspectives, clinical expertise and research evidence. *International Journal of Speech-Language Pathology*, 17(3), 211-221

Rowe, A., Titterington, J., Holmes, J., Henry, L. and Taggart, L. (2019a) Interventions targeting working memory in 4–11 year olds within their everyday contexts: A systematic review. *Developmental Review*, 52, 1-23.

Rowe, A., Titterington, J. and Taggart, L. (2019b) A classroom-based intervention targeting working memory, attention and language skills in 4-5 year olds (RECALL): study protocol for a cluster randomised feasibility trial. *Pilot and Feasibility Studies*, 5(82).

Royal College of Speech and Language Therapists (RCSLT) (2015) *The National Prospectus Grants Programme 2015-16. The RCLST Outcome Project Key Policy and Research Pack.* London: RCLST.

Royal College of Speech and Language Therapists (RCSLT) (2018) *Placing children and young people at the heart of delivering quality speech and language therapy: Guidance on principles, activities and outcomes*. London: RCLST.

Rycroft-Malone, J., Burton, C.R., Bucknall, T., Graham, I.D., Hutchinson, A.M. and Stacey, D. (2016) Collaboration and co-production of knowledge in healthcare: Opportunities and challenges. *International Journal of Health Policy Management*, 5(4) 221-223.

Sala, G. and Gobet, F. (2017) Working memory training in typically developing children: a meta-analysis of the available evidence. *Developmental Psychology*, 53, 671-685.

Sandelowski, M. (1993) Rigor or rigor mortis: the problem of rigor in qualitative research revisited. *Advances in Nursing Science,* 16(2), 1-8.

Sandelowski, M. and Leeman, J. (2012) Writing usable qualitative health research findings. *Qualitative Health Research,* 22, 1404–1413.

Save the Children (2016) *Early language development and children's primary school attainment in English and Maths: new research findings*. Available at: https://www.savethechildren.org.uk/content/dam/global/reports/education-and-child-protection/early_language_development_briefing_paper.pdf [Accessed 20 June 2017].

Saxon, R.L., Gray, M.A. and Oprescu, F.I. (2014) Extended roles for allied health professionals: an updated systematic review of the evidence. *Journal of Multidisciplinary Healthcare*, 7, 479-488.

Schmitt, M.B., Justice, L.M. and Logan, A.R. (2017) Intensity of language treatment: contribution to children's language outcomes. *International Journal of Language and Communication Disorders*, 52(2), 155-167.

Schwaighofer, M., Fischer, F. and Bühner, M. (2015) Does working memory training transfer? a meta-analysis including training conditions as moderators. *Educational Psychologist*, 50(2), 138-166.

Shiell, A., Hawe, P. and Gold, L. (2008) Complex interventions or complex systems? Implications for health economic evaluation. *British Medical Journal*, 336, 1281-1283.

Shipstead, Z., Hicks, K.L. and Engle, R.W. (2012) Working memory training remains a work in progress. *Journal of Applied Research in Memory and Cognition*, 1, 217-219.

Shipstead, Z., Lindsey, D.R.B., Marshall, R.L. and Engle, R.W. (2014) The mechanisms of working memory capacity: primary memory, secondary memory and attention control. *Journal of Memory and Language*, 72, 116-141.

Shearn, K., Allmark, P., Piercy, H. and Hisrt, J. (2017) Building realist program theory for large complex and messy interventions. *International Journal of Qualitative Methods*, 16, 1-11.

Shriberg, L.D. (1993) Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech and Hearing Research*, 36, 105-140.

Sims, S., Hewitt, G. and Harris, R. (2015) Evidence of collaboration, pooling of resources, learning and role blurring in interprofessional healthcare teams: A realist synthesis. *Journal of Interprofessional Care*, 29(1), 20-25.

Snowling M, C Hulme (2012) Interventions for children's language and literacy difficulties. *International Journal of Language and Communication Disorders*, 47(1), 27-34

Song, M., Sandelowski, M. and Happ, M. B. (2010) Current practices and emerging trends in conducting mixed methods intervention studies in the health sciences. *In:* Tashakkori, A. and Teddlie, C. eds. *Sage handbook of mixed methods in social & behavioral research.* 2nd ed. Thousand Oaks, CA: SAGE, 725-747.

Soveri. A., Antfolk, J., Karlsson, L., Salo, B. and Laine, M. (2017) Working memory training revisited: a multi-level meta-analysis of n-back training studies. *Psychonomic Bulletin & Review,* 24, 1077-1096.

Spaulding, T. J. (2010) Investigating mechanisms of suppression in preschool children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, 53, 725-738.

Spaulding, T.J., Plante, E., and Vance, R. (2008) Sustained selective attention skills of preschool children with specific language impairment: Evidence for separate attentional capacities. *Journal of Speech, Language, and Hearing Research,* 51, 16-34.

Speech Pathology Australia (SPA) (2009) *Transdisciplinary Practice Position Statement*. Melbourne: The Speech Pathology Association of Australia Limited.

Spencer, S., Clegg, J., Stackhouse, J. and Rush, R. (2017) Contribution of spoken language and socio-economic background to adolescents' educational achievement at age 16 years. *International Journal of Language and Communication Disorders,* 52(2), 184-196.

Stackhouse, J. (1997) Phonological awareness: connecting speech and literacy problems. *In:* Hodson, B. and Edwards, M.L. eds. *Perspectives in Applied Phonology*. Maryland: Aspen, 157-196.

St Clair-Thompson, H.L. and Gathercole, S.E. (2006) Executive functions and achievements in school: shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology,* 59(4), 745-759.

St. Clair-Thompson, H. L., Stevens, R., Hunt, A. and Bolder, E. (2010) Improving children's working memory and classroom performance. *Educational Psychology,* 30, 203-220.

Steckler, A. and Linnan, L. (2002) eds. *Process evaluation for public health interventions and research*. San Franscisco: Jossey-Bass.

Stokols, D. (2006) Toward a science of transdisciplinary action research. *Annual Journal of Community Psychology*, 38(6), 63-77.

Swanson, H.L., Jerman, O. and Zheng, X. (2008) Growth in working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology,* 100*,* 343-379.

Tambyraja, S.R., Rhoad-Drogalis, A., Khan, K.S., Justice, L.M. and Sawyer, B.E. (2019) Inattentiveness and language abilities in pre-schoolers: a latent profile analysis. *Journal of Abnormal Child Psychology,* 47(2), 45-257.

Thibodeau, R.B., Gilpin, A.T., Brown, M.M. and Meyer, B.A. (2016) The effects of fantastical pretend-play on the development of executive functions: an intervention study. *Journal of Experimental Child Psychology,* 145, 120-138.

Tong, A. Sainsbury, P. and Craig, J. (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal of Qualitative in Health Care*, 19(6), 349-357.

Thorell, L. B., Lindqvist, S., Bergman, S., Bohlin, N. G. and Klingberg, T. (2009) Training and transfer effects of executive functions in preschool children. *Developmental Science*, 12, 106-113.

Underbjerg, M., George, M.S., Thorsen, P., Kesmodel, U.K., Mortensen, E.L. and Manly, T. (2013) Separable sustained and selective attention factors are apparent in 5-year-old children. *PLOS ONE*, 8(12), e82843.

Unsworth, N. and Spillers, G. J. (2010) Working memory capacity: attention, memory, or both? a direct test of the dual-component model. *Journal of Memory and Language,* 62, 392-406.

Unsworth, N., Spillers, G. J. and Brewer, G. A. (2009) Examining the relations among working memory capacity, attention control, and fluid intelligence from a dual-component framework. *Psychology Science Quarterly*, 4, 388-402.

Vaismoradi, M., Turunen, H. and Bondas, T. (2013) Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nursing & Health Sciences*, 15(3), 398-405.

Van Kleeck, A., Gillam, R.B. and McFadden, T.U. (1998) A study of classroom-based phonological awareness training for pre-schoolers with speech and/or language disorders. *American Journal of Speech-Language Pathology*, 7, 65-76.

Van Kleeck, A., Gillam, R.B. and Hoffman, L.M. (2006) Training in phonological awareness generalizes to phonological working memory: a preliminary investigation. *The Journal of Speech and Language Pathology – Applied Behavior Analysis*, 1(3), 228-243.

Van Meijel, B., Gamel, C., van Swieten-Duijfjes, B. and Grypdonck, M.H.F. (2004) The development of evidence-based nursing interventions: methodological considerations. *Journal of Advanced Nursing*, 48(1), 84-92.

Verschuere, B., Brandsen, T. and Pestoff, V. (2012) Co-production: the state of the art in research and the future agenda. *Voluntas*, 23, 1083-1101.

Volckaert, A.M.S. and Noël, M. (2015) Training executive function in preschoolers reduce externalizing behaviors. *Trends in Neuroscience and Education*, 4, 37–47.

Von Bastian, C. C. and Oberauer, K. (2014) Effects and mechanisms of working memory training: a review. *Psychological Research*, 78, 803-820.

Voorberg, W.H., Bekkers, V.J.J.M. and Tummers, L.G. (2015) A systematic review of co-creation and co-production: embarking on the social innovation journey. *Public Management Review*, 17, 1333-13357.

Vugs, B., Hendriks, M., Cuperus, J. and Verhoeven, L. (2013) Visuospatial working memory in specific language impairment: a meta-analysis. *Research in Developmental Disabilities* 34, 2586-2597.

Vugs, B., Hendriks, M., Cuperus, J. and Verhoeven, L. (2014) Working memory performance and executive function behaviors in young children with SLI. *Research in Developmental Disabilities*, 35, 62-74.

Vugs, B., Knoors, H., Cuperus, J., Hendriks, M. and Verhoeven, L. (2015) Interactions between working memory and language in young children with specific language impairment (SLI). *Child Neuropsychology*, 22 (8), 955-978.

Vygotsky, L.S. (1978) *Mind in Society*. Cambridge: Harvard University Press.

Walker, L. O. and Avant, K. C. (2011) *Strategies for theory construction in nursing*. 5th ed. Saddle River: Pearson/Prentice Hall.

Ward, J. (2006) *The Student's Guide to Cognitve Neuroscience*. 2nd ed. Hove and New York: Psychology Press.

Warren, S.F., Fey, M. E. and Yoder, P. J. (2007) Differential treatment intensity research: a missing link to creating optimally effective communication interventions. *Mental Retardation and Developmental Disabilities Research Reviews*, 13, 70-77.

Wass, S.V., Scerif, G. and Johnston, M.H. (2012) Training attentional control and working memory- is younger better? *Developmental Review*, 32, 360-387.

Westhorp, G. (2012) Using complexity-consistent theory for evaluating complex systems. *Evaluation,* 18(4), 405-420.

Westhorp, G. (2013) Developing complexity-consistent theory in a realist investigation. *Evaluation,* 19(4), 364-382.

Wight, D., Wimbush, E., Jepson, R. and Doi, L. (2016) Six steps in quality intervention development (6SQuID). *Journal of Epidemiology and Community Health*, 70, 520-525.

Witt, M. (2011) School based working memory training: Preliminary finding of improvement in children's mathematical performance. *Advances in Cognitive Psychology*, 7(1), 7-15.

Wong, G. (2015) Special invited editorial: getting started with realist research. *International Journal of Qualitative Methods*, 14, 1-2.

Wong, G. Greenhalgh. T., Westhorp, G., Buckingham, J. and Pawson, R. (2013) RAMESES publication standards: realist syntheses. *BMC Medicine*, 11(21).

Wong, G., Greenhalgh, T., Westhorp, G. and Pawson, R. (2014) Development of methodological guidance, publication standards and training materials for realist and meta-narrative reviews: the RAMESES (Realist and Meta-narrative Evidence Syntheses – Evolving Standards) project. *Health Services and Delivery Research*, 2 (30).

Worthen, E. (2010) Sensory-based interventions in the general educational classroom: a critical appraisal of the topic. *Journal of Occupational Therapy, Schools and Early Intervention,* 3(1), 76-94.

Appendices

Appendix A - Confirmation of ethical approval: focus groups and co-production work

UNIVERSITY OF ULSTER RESEARCH GOVERNANCE

RG3 Filter Committee Report Form

Project Title	The development of a universal trans-disciplinary programme to enhance working memory which will target attention and language skills; the perspectives of clinicians, teachers and parents
Chief Investigator	Dr Jill Titterington
Filter Committee	Institute of Nursing and Health Research

This form should be completed by Filter Committees for all research project applications in categories A to D (*for categories A, B, and D the University's own application form – RG1a and RG1b – will have been submitted; for category C, the national, or ORECNI, application form will have been submitted).

Where substantial changes are required the Filter Committee should return an application to the Chief Investigator for clarification/amendment; the Filter Committee can reject an application if it is thought to be unethical, inappropriate, incomplete or not valid/viable.

Only when satisfied that its requirements have been met in full and any amendments are complete, the Filter Committee should make one of the following recommendations:

The research proposal is complete, of an appropriate standard and is in

- category A and the study may proceed* ☐
- category B and the study must be submitted to the University's Research Ethics Committee** Please indicate briefly the reason(s) for this categorisation ☐
- category C and the study must be submitted for external approval along with the supporting materials from the Research Governance Section*** ☒
- category D and the study must be submitted to the University's Research Ethics Committee** ☐

Signed: George Kernohan Date: 02.02.17
Chairperson of Filter Committee

*The application form and this assessment should now be returned to the Chief Investigator. The Filter Committee should retain a copy of the complete set of forms.

** The application form and this assessment should now be returned to the Chief Investigator so that he/she can submit the application to the UUREC via the Research Governance section. The Filter Committee should retain a copy of the complete set of forms for their own records.

***** The application form and this assessment should now be returned to the Chief Investigator so that he/she can prepare for application to a suitable committee. The Filter Committee should retain a copy of the complete set of forms for their own records.**

For all categories, details of the application and review outcome should be minuted using the agreed format and forwarded to the Research Governance section

Version 3 (10/07) 1

Appendix B - Confirmation of ethical approval: feasibility study

Ulster University

Ulster University
Shore Road
Newtownabbey
County Antrim
BT37 0QB
Northern Ireland
T: +44 (0)28 9036 6552/6518/6629
ulster.ac.uk

Our Ref: NC:GOV

06 June 2018

Dr J Titterington
Room 17J16
School of Health Sciences
Ulster University
Jordanstown Campus

Dear Dr Titterington

Research Ethics Committee Application Number: REC/18/0036

Study Title: A cluster randomised feasibility trial of a whole-class intervention (RECALL programme) targeting working memory, attention and language skills in 4-5 year olds in mainstream schools in low socio-economic status areas

Thank you for your recent response to matters raised by the committee. This has been considered and the decision of the committee is that the research should proceed.

Please also note the additional documentation relating to research governance and indemnity matters, including the requirements placed upon you as Chief Investigator.

The committee's decision is valid for a period of three years from today's date (this means that the study should be completed by that date). If you require this period to be extended, please contact the Research Governance section.

1. **Please complete and return the Chief Investigator Statement of Compliance prior to commencing the study and keep a copy for your file.**
2. **Please retain all other documents.**

Further details of the University's policy along with guidance notes, procedures, terms of reference and forms are available on the Ulster University Portal.

If you need any further information or clarification of any points, please do not hesitate to contact me.

Yours sincerely

Nick Curry
Head of Research Governance
028 9036 6629
n.curry@ulster.ac.uk

Appendix C - Participant Information Sheet: focus groups (Chapter 5)

Anita [illegible] PIS and Consent Form: Clinicians & teachers, Phase 1. Version 2, 19th Jan 2017.

Developing a school- based programme for working memory, attention and language.

Participant Information Sheet Phase 1

HSC staff and teachers

Title of study: Developing a school- based programme for working memory, attention and language

We would like to invite you to take part in a research study we are undertaking. It is important that you understand the purpose of the research and what it will entail before you make your decision. Please take time to read the following information carefully.

What is the aim of this study?

The aim of this study is to develop a school- based programme to enhance working memory which will target attention and language skills in 4 – 5 year old children. [Teachers across Northern Ireland have identified concerns about young children's attention control. Research shows working memory is fundamentally linked to attention control and other developmental skills including language, sensory and motor development. Indeed, working memory is known to be the best single predictor of academic attainment.

Most research has focused on computerised approaches to training working memory. The results have been mixed and there are questions about whether any improvements made on training actually transfer to 'real world' tasks including attention, language and academic skills. There is a need to research non- computerised approaches in which training is embedded in educational activities, especially with younger children. We want to address this gap in the research by developing a unique programme to support working memory in the mainstream school setting. The programme will maximise on the integration of skills which are associated with working memory and attention by incorporating language, sensory, motor and cognitive tasks. We hope to pilot the programme in the mainstream setting at a later stage in the research (2018-2019) and that this trial will inform a larger piece of research in the future.

Why have you been approached?

In order to develop the programme we want to draw on the skills and expertise of teachers and health professionals. Teachers have specialist knowledge of the educational curriculum, classroom practice and the practicalities of delivering programmes in the mainstream school context. Clinicians (speech and language therapists; occupational therapists; physiotherapists and social emotional behavior specialists) have specialist knowledge of the developmental areas associated with working memory and attention. You have been approached because you either: teach year one children in a mainstream school; or you work in a multidisciplinary team in a HSC trust which supports children in this setting.

What is involved for you?

This will involve taking part in two focus group sessions along with 3 – 7 other professionals. You would not need to do any preparation in advance of the sessions as we just want to hear about your current practice and what you think might work in the programme we are going to develop. The aim of the first session is to explore how you currently support working memory and attention difficulties in the school setting. The second session will take place approximately one month later and aims to explore what you feel may work in the school-based programme we are going to develop, and the factors which may prevent or enable its use. The sessions will take place in your workplace or in a centre or school near you. They will each last 90 minutes (maximum) and, with your agreement, we will record what is said.

Do you have to take part?

It is up to you whether or not you wish to participate. If you decide to take part, you are still free to withdraw at any time. In this case your contribution to the study up to that point would also be removed, unless you give us permission to use it.

What are the possible disadvantages and risks of taking part?

We hope that careful attention to the content and management of the group discussion process will ensure everyone will feel supported to contribute their thoughts and experiences without any ill effect.

What are the possible benefits of taking part?

During the focus groups we will discuss evidence from the most up to date research on working memory, and delve into how working memory is involved in classroom activities and its links to other developmental skills. This, along with discussion with colleagues in the group, may enhance your knowledge and skills in this area and support you in your everyday practice.

What happens to the information?

Your involvement will be entirely anonymous and confidential. At no point will your name be identifiable in the transcripts or the final report. We will give you a code which will be used instead of your name during the transcription of the audio recordings. These files will be destroyed once an accurate transcript has been made. The content of the discussion will then be carefully analysed to identify emerging themes. All data will be stored securely and subsequently destroyed after ten years, in accordance with Ulster University's policy. A summary report of the findings will be circulated to each participant and we will be happy to discuss this with you at any time. We will also inform participants should the study be published in the future.

How can you make a complaint?

This study has been approved through the Ulster University's governance and ethical approval process. The University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously and should be made to the Principal Investigator: Dr Jill Titterington, Room 17J16, University of Ulster, Jordanstown Campus/ j.titterington@ulster.ac.uk. In the unlikely event that Dr Titterington is unavailable, or the nature of the complaint means that you don't wish to discuss it with Dr Titterington, please contact Mr Nick Curry, Senior Administration Officer, Research and Innovation, Room 01H12, Ulster University, Jordanstown campus, 028-90366629 (n.curry@ulster.ac.uk).

Who is organising funding the study?

The study is being funded by the Research & Development Division of the Public Health Agency, Belfast and is being undertaken as part of a PhD at Ulster University.

What should you do now?

If you are willing to participate, please email Anita Harron (details below) by (date for submission) to express your interest in the study. In the event of a high response rate, participants will be randomly selected. Everyone who returns a consent form will be contacted to either outline the next steps or to thank you for your interest in this study. Please read the consent sheet attached. We will provide participants with a copy of this for you to sign at the start of the first focus group.

Thank you for reading this information sheet and considering taking part in this study. Please feel free to contact us should you have any questions (details below).

Yours sincerely

Dr Jill Titterington (Principal Investigator)
Tel: 028 90 368855
Email: j.titterington@ulster.ac.uk

Anita Harron (Research Officer)
Tel: 0280 90 368127
Email: Harron-A@email.ulster.ac.uk

If you have any concerns or complaints about this study, please contact:

Mr Nick Curry,
Senior Administration Officer,
Research and Innovation,
Room 01H12,
Ulster University,
Jordanstown campus,
Tel: 028 90 366629
Email: n.curry@ulster.ac.uk

Research Study: Developing a school- based programme for working memory, attention and language.

Please initial each box.

1. I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without my rights being affected. ☐

3. I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give permission for the researchers to hold relevant personal data. ☐

4. I agree to take part in the above study. ☐

5. I agree to the focus group being audio recorded. ☐

Name of participant: ……………………………………………………………………………

Signed: …………………………………………………… Date: …………………………

Name of person obtaining consent:

………………………………………………………………………………………………………

Signed: …………………………………………………… Date:…………………………

Appendix D - Participant Information Sheet: co-production work (Chapter 7)

Title of study: Developing a school- based programme for working memory, attention and language

We would like to invite you to take part in a research study we are undertaking. It is important that you understand the purpose of the research and what it will entail before you make your decision. Please take time to read the following information carefully.

What is the aim of this study?

The aim of this study is to develop a school- based programme to enhance working memory which will target attention and language skills in 4 – 5 year old children. Teachers across Northern Ireland have identified concerns about young children's attention control. Research shows working memory is fundamentally linked to attention control and other developmental skills including language, sensory and motor development. Indeed, working memory is known to be the best single predictor of academic attainment.

Most research has focused on computerised approaches to training working memory. The results have been mixed and there are questions about whether any improvements made on training actually transfer to 'real world' tasks including attention, language and academic skills. There is a need to research non- computerised approaches in which training is embedded in educational activities, especially with younger children. We want to address this gap in the research by developing a unique programme to support working memory in the mainstream school setting. The programme will maximise on the integration of skills which are associated with working memory and attention by incorporating language, sensory, motor and cognitive tasks. We hope to pilot the programme in the mainstream setting at a later stage in the research (2018-2019) and that this trial will inform a larger piece of research in the future.

Why have you been approached?

In order to develop the programme we want to draw on the skills and expertise of teachers and health professionals. Teachers have specialist knowledge of the educational curriculum, classroom practice and the practicalities of delivering programmes in the mainstream school context. Clinicians (speech and language therapists; occupational therapists; physiotherapists and social emotional behavior specialists) have specialist knowledge of the developmental areas associated with working memory and attention. You have been approached because you have significant experience and specialist knowledge in developing and implementing this type of school-based programme.

What is involved for you?

This will involve taking part in a series of 6 workshops with along with 6- 11 other teachers and health professionals and a small number of parents. You would not need to do any preparation in advance of the sessions. Each workshop will last 2 - 3 hours and will involve a combination of some practical exercises and group discussion to help identify the activities that will be included in the programme we are developing and how they could be effectively delivered with year one children. With your agreement, part of the discussion may be recorded. If so, you will be notified when the recording is starting and ending. Participants for this phase of the research may be based across Northern Ireland and we aim to facilitate these at a central location. We will reimburse any travel costs you incur and will provide refreshments.

Do you have to take part?

It is up to you whether or not you wish to participate. If you decide to take part, you are still free to withdraw at any time. In this case your contribution to the study up to that point would also be removed, unless you give us permission to use it.

What are the possible disadvantages and risks of taking part?

We hope that careful attention to the content and management of the group discussion process will ensure everyone will feel supported to contribute their thoughts and experiences without any ill effect.

What are the possible benefits of taking part?

During the workshops we will discuss evidence from the most up to date research on working memory, its involvement in classroom activities and its links to other developmental skills. This, along with discussion with colleagues in the group, may enhance your knowledge and skills in this area and support you in your everyday practice.

What happens to the information?

Your involvement will be entirely anonymous and confidential. At no point will your name be identifiable in the transcripts or the final report. We will give you a code which will be used instead of your name during the transcription of the audio recordings. These files will be destroyed once an accurate transcript has been made. The content of the discussion will then be carefully analysed to identify emerging themes. All data will be stored securely and subsequently destroyed after ten years, in accordance with Ulster University's policy. A summary report of the findings will be circulated to each participant and we will be happy to discuss this with you at any time. We will also inform participants should the study be published in the future.

How can you make a complaint?

This study has been approved through the Ulster University's governance and ethical approval process. The University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously and should be made to the Principal Investigator: Dr Jill Titterington, Room 17J16, University of Ulster, Jordanstown Campus/ j.titterington@ulster.ac.uk. In the unlikely event that Dr Titterington is unavailable, or the nature of the complaint means that you don't wish to discuss it with Dr Titterington, please contact Mr Nick Curry, Senior Administration Officer, Research and Innovation, Room 01H12, Ulster University, Jordanstown campus, 028-90366629 (n.curry@ulster.ac.uk).

Who is funding the study?

The study is being funded by the Research & Development Division of the Public Health Agency, Belfast and is being undertaken as part of a PhD at Ulster University.

What should you do now?

If you are willing to participate, please email Anita Harron (details below) by (6th February 2018). We will then contact you to arrange the date, time and location of the first workshop. Please read the consent sheet attached. We will ask you to sign a copy of this at the start of the first workshop.

Thank you for reading this information sheet and considering taking part in this study. Please feel free to contact us should you have any questions (details below).

Yours sincerely

Dr Jill Titterington (Principal Investigator)
Tel: 028 90 368855
Email: j.titterington@ulster.ac.uk

Anita Rowe (née Harron) (Researcher)
Tel: 0280 90 368127
Email: Harron-A@email.ulster.ac.uk

If you have any concerns or complaints about this study, please contact:

Mr Nick Curry,
Senior Administration Officer,
Research and Innovation,
Room 01H12,
Ulster University,
Jordanstown campus,
Tel: 028 90 366629
Email: n.curry@ulster.ac.uk

Research Study: Developing a school- based programme for working memory, attention and language.

1. I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without my rights being affected. ☐

3. I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give permission for the researchers to hold relevant personal data. ☐

4. I agree to take part in the above study. ☐

5 I agree to the focus group being audio recorded. ☐

Name of participant: ……………………………………………………………………………

Signed: …………………………………………………… Date: ………………………

Name of person obtaining consent:

………………………………………………………………………………………………………

Signed: …………………………………………………… Date:……………………...

Appendix E - Participant Information Sheet: feasibility study - health professionals

A pilot study of the RECALL programme: a whole-class approach to supporting attention and language skills in 4- 5 year olds.

Ulster University

INFORMATION FOR PARTICIPANTS

We would like to invite you to take part in a research study. It is important that you understand what the study entails before you make your decision. The research information leaflet (attached) explains the background and aims of the research study. Some more details about what taking part in the study would mean for you are provided here.

Please read this information carefully.

What is the aim of this study?

The aim of this study is to investigate the use of the Recall to Enhance Children's Attention, Language and Learning (RECALL) programme in the school setting.

What does the study involve?

The pilot study will include six classes of year one children in Northern Ireland (NI) which will be randomly allocated to three groups as follows:

- Group A: Two classes in NI will receive the novel RECALL programme
- Group B: Two classes will receive another programme that also targets attention and language skills
- Group C: Two classes in NI will receive their usual education with no additional programme

Why have you been approached?

You are being asked to take part in this study because you work in a RISE team that was not involved in the co-production of the RECALL programme and we would like your objective opinion about the feasibility of its use in future research or practice.

What is involved for you?

We are looking for professionals from the RISE teams to deliver the two whole-class interventions i.e., to deliver the RECALL programme with one class in one school, and to deliver an existing RISE programme to one class in another school.

How much of your time will this take?

You will need time for:

- Training: you will be asked to attend a two-day course covering the theory that and underpins RECALL and how to deliver the programme. A manual will be provided.
- Delivering the programmes: The RECALL programme and the existing RISE programme are both six-week interventions with each session lasting about 40 minutes each.

Preparation time should be minimal as all session plans will be provided. You may need a short time before each session to gather equipment, similar to your everyday practice.

- Travel to the schools: the schools will be selected at random so we cannot as yet predict how far they will be from your team's base.
- Post-intervention evaluation: at the end of the six weeks, you will be asked to complete a semi-structured interview to explore what you like and/or don't like about the RECALL programme. This should last approximately 30 minutes.

Do you have to take part?

It is up to you whether or not you wish to participate. If you decide to take part, you are still free to withdraw at any time. In this case your contribution to the study up to that point would also be removed, unless you give us permission to use it.

What are the possible disadvantages and risks of taking part?

We recognise that taking part in this study will require time and could impact on your workload.

What are the possible benefits of taking part?

It is widely recognised that there is a lack of robust evidence for the effectiveness of targeted interventions. We hope that this research will make a significant contribution to evidence-based practice for the RISE NI teams and to other similar services in the United Kingdom and beyond. We hope that the training provided will support you in your everyday practice.

What happens to the information?

Your involvement will be entirely anonymous and confidential. At no point will your name be identifiable in the transcripts or the final report. We will give you a code which will be used instead of your name during the transcription of the interview recordings. These files will be destroyed once an accurate transcript has been made. All data will be stored securely and subsequently destroyed after ten years, in accordance with Ulster University's policy. A summary report of the findings will be circulated to participants. We will be happy to discuss this with you at any time and will inform you should the findings be published in the future.

How can you make a complaint?

This study has been approved through the Ulster University's governance and ethical approval process. The University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously and should be made to the Chief Investigator: Dr Jill Titterington, Room 17J16, University of Ulster, Jordanstown Campus/ j.titterington@ulster.ac.uk. In the unlikely event that Dr Titterington is unavailable, or the nature of the complaint means that you don't wish to discuss it with Dr Titterington, please contact Mr Nick Curry, Head of Research Governance, Research and Impact, Room 26A20, Ulster University, Jordanstown campus, 028-90366629 (n.curry@ulster.ac.uk).

Who is funding the study?

The study is being funded by the Research & Development Division of the Public Health Agency, Belfast and is being undertaken as part of a PhD at Ulster University.

What should you do now?

If you are willing to participate in the study, please carefully read the consent form (attached) and sign accordingly.

Please feel free to contact us should you have any questions (details below).

Yours sincerely

Dr Jill Titterington (Chief Investigator)
Tel: 028 90 368855
Email: j.titterington@ulster.ac.uk

Anita Rowe (Research Officer)
Tel: 0280 90 368127
Email: Harron-A@email.ulster.ac.uk

If you have any concerns or complaints about this study, please contact:

Mr Nick Curry,
Head of Research Governance,
Research and Impact,
Room 26A20,
Ulster University,
Jordanstown campus,
Tel: 028 90 366629
Email: n.curry@ulster.ac.uk

A pilot study of the RECALL programme: a whole-class approach to supporting attention and language skills in 4- 5 year olds.

Ulster University

CONSENT FORM

Please initial each box.

1. I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without my rights being affected. ☐

3. I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give permission for the researchers to hold relevant personal data. ☐

4. I agree to take part in the above study. ☐

5. I agree to the interviews being audio recorded. ☐

Name of participant: ………………………………………………………………………

Signed: …………………………………………………… Date: ………………………

Name of person obtaining consent:

……………………………………………………………………………………………

Signed: …………………………………………………… Date:………………………

Appendix F - Participant Information Sheet: feasibility study - teachers

A pilot study of the RECALL programme: a whole-class approach to supporting attention and language skills in 4- 5 year olds.

Ulster University

INFORMATION FOR PARTICIPANTS

We would like to invite you to take part in a research study. It is important that you understand what the study entails before you make your decision. The research information leaflet (attached) explains the background and aims of the research study. Some more details about what taking part in the study would mean for you are provided here.

Please read this information carefully.

What is the aim of this study?

The aim of this study is to investigate the use of the Recall to Enhance Children's Attention, Language and Learning (RECALL) programme in the school setting.

What does the study involve?

The pilot study will include six classes of year one children in Northern Ireland (NI) which will be randomly allocated to three groups as follows:

- Group A: Two classes in NI will receive the novel RECALL programme
- Group B: Two classes will receive another programme that also targets attention and language skills
- Group C: Two classes in NI will receive their usual education with no additional programme

Why have you been approached?

You have been approached because you are a teacher or classroom assistant in a year one class and your school is supported by the Regional Support for Education (RISE) service.

What is involved for you?

If you take part in the study, your class will be randomly assigned to one of three groups: A (to receive RECALL); B (to receive another RISE programme) or C (education as usual).

If your class is allocated to group A or group B:

- 10 children in your class will be selected (with parental consent) to complete standardised assessments of their working memory, attention and language skills. The children will be withdrawn individually for about one hour to complete the assessments.
- For each of the 10 selected children, you will be asked to complete a rating scale of their attention in the classroom. This will take around 5 minutes to complete per child.
- The RISE team will provide programme A or B with your class. Both programmes include six sessions lasting about 40 minutes each. The RISE team will deliver one session per week and you will be asked to carry out the same session a further two times before the

next week i.e., the children will receive the programme three times per week. You will be given a manual to help you carry out the programme.

- All of the activities are designed to be fun and interactive. Some of the sessions will be observed by one or two members of the research team. They will not be assessing your performance or skills. We will be looking at how easy or difficult it is to use the programme.
- At the end of the six weeks, the children's skills will be re-assessed and we will arrange a meeting with you to explore what you like and/or don't like about the programme. This will last about 30 minutes and, with your consent, we will audio-record it.
- We will complete the same assessments again three-months after the study.
- During the study period, you will not be told which programme your class is receiving as this could cause our results to be biased. We will be able to tell you at the end of the study.

If your class is allocated to group C:

You will be asked to deliver the NI curriculum as usual and we will measure the children's working memory, attention and language as above.

Do you have to take part?

It is up to you whether or not you wish to participate. If you decide to take part, you are still free to withdraw at any time. In this case your contribution to the study up to that point would also be removed, unless you give us permission to use it.

What are the possible disadvantages and risks of taking part?

If your class is assigned to group A or B, you will receive a programme that has not yet been proven to be effective. However, the lack of evidence for their effectiveness does not necessarily mean they don't work. Both programmes include activities that are designed to be fun and engaging for 4- 5 year olds and that have potential to enhance their skills.

What are the possible benefits of taking part?

If your class is assigned to group A or B: we hope that you will enjoy and benefit from working alongside professionals from the RISE team. You will have the opportunity to observe and practice new activities that may support children's attention and language.

If your class is assigned to group C: although you will not receive an additional classroom programme at this time, your involvement could significantly inform our future research that could greatly benefit you and the children you work with in the future.

What happens to the information?

Your involvement will be entirely anonymous and confidential. At no point will your name be identifiable in the transcripts or the final report. We will give you a code which will be used instead of your name during the transcription of the interview recordings. These files will be destroyed once an accurate transcript has been made. All data will be stored securely and subsequently destroyed after ten years, in accordance with Ulster University's policy. A summary report of the findings will be circulated to participants. We will be happy to discuss this with you at any time and will inform you should the findings be published in the future.

How can you make a complaint?

This study has been approved through the Ulster University's governance and ethical approval process. The University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously and should be made to the Chief Investigator: Dr Jill Titterington, Room 17J16, University of Ulster, Jordanstown Campus/ j.titterington@ulster.ac.uk. In the unlikely event that Dr Titterington is unavailable, or the nature of the complaint means that you don't wish to discuss it with Dr Titterington, please contact Mr Nick Curry, Head of Research Governance, Research and Impact, Room 26A20, Ulster University, Jordanstown campus, 028-90366629 (n.curry@ulster.ac.uk).

Who is funding the study?

The study is being funded by the Research & Development Division of the Public Health Agency, Belfast and is being undertaken as part of a PhD at Ulster University.

What should you do now?

If you are willing to participate in the study, please carefully read the consent form (attached) and sign accordingly.

Please feel free to contact us should you have any questions (details below).

Yours sincerely

_____________________ _____________________

Dr Jill Titterington (Chief Investigator)
Tel: 028 90 368855
Email: j.titterington@ulster.ac.uk

Anita Rowe (Research Officer)
Tel: 0280 90 368127
Email: Harron-A@email.ulster.ac.uk

If you have any concerns or complaints about this study, please contact:

Mr Nick Curry,
Head of Research Governance,
Research and Impact,
Room 26A20,
Ulster University,
Jordanstown campus,
Tel: 028 90 366629
Email: n.curry@ulster.ac.uk

A pilot study of the RECALL programme: a whole-class approach to supporting attention and language skills in 4- 5 year olds.

Ulster University

CONSENT FORM

Please initial each box.

1. I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without my rights being affected. ☐

3. I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give permission for the researchers to hold relevant personal data. ☐

4. I agree to take part in the above study. ☐

5. I agree to the interviews being audio recorded. ☐

Name of participant: ....

Signed: .... Date: ....

Name of person obtaining consent:
....

Signed: .... Date:...............................

Appendix G - Participant Information Sheet: feasibility study - parents and children

A pilot study of the RECALL programme: a whole-class approach to supporting attention and language skills in 4- 5 year olds.

Ulster University

INFORMATION FOR PARTICIPANTS

Your child's class is taking part in a research study we are undertaking. We would like to invite you to take part in the study and to tell your child about it. It is important that you understand the purpose of the research and what it involves before you decide if you want to take part. you make your decision. The information leaflet (attached) explains the background and aims of the study. Please take time to read the leaflet carefully and please read the children's information sheet to your child. Some more details about your involvement are provided here:

What is involved for you?

If your child's first language is English and you give permission for your child to be assessed, they may be selected. If so, we will ask you to answer a few, short questions about your child and to complete a questionnaire about their language and communication skills. We would like you to fill this at the same three time points.

Do you have to take part?

It is up to you whether or not you wish to take part. If you do decide to take part, you are free to withdraw at any time. If you no longer want to take part, any information you have given us will not be used in the research, unless you tell us we can still use it.

What are the possible disadvantages of taking part?

The tests that we will use with your child are easily carried out and are similar to everyday school tasks. We do not expect any harmful effects for you or your child.

What are the possible benefits of taking part?

We hope this study is going to give us valuable information that will help teachers and health professionals to improve the ways they support children's learning. Our findings will inform future research studies that have the potential to benefit young children. If your child is selected, and you complete the questionnaire three times for us, we will enter your name into a prize draw for a £100 voucher for a supermarket of your choice.

What happens to the information?

All information about your child will be entirely anonymous and confidential.

Your names will not be used in any information about the study. A code will be used instead of their name when we are writing up the study.

All of the information about the study will be stored securely for ten years and then destroyed, according to Ulster University's policy.

When the study is over, we will send you some information about what it tells us.

When the study is over, we will send you some information about what it tells us. We'll be happy to talk to you about the research at any time.

How can you make a complaint?

This study has been approved through the Ulster University's governance and ethical approval process. The University has procedures in place for reporting, investigating, recording and handling adverse events. Any complaints will be taken seriously and should be made to the Chief Investigator: Dr Jill Titterington, Room 17J16, University of Ulster, Jordanstown Campus/ j.titterington@ulster.ac.uk. In the unlikely event that Dr Titterington is unavailable, or the nature of the complaint means that you don't wish to discuss it with Dr Titterington, please contact Mr Nick Curry, Head of Research Governance, Research and Impact, Room 26A20, Ulster University, Jordanstown campus, 028-90366629 (n.curry@ulster.ac.uk).

Who is funding the study?

The study is being funded by the Research & Development Division of the Public Health Agency, Belfast and is being undertaken as part of a PhD at Ulster University.

What should you do now?

If you are willing for us to complete the tests with your child, please read the attached consent from carefully and return it to your child's teacher.

Please feel free to contact us should you have any questions (details below).

Yours sincerely

Dr Jill Titterington (Chief Investigator)	Anita Rowe (Research Officer)
Tel: 028 90 368855	Tel: 0280 90 368127
Email: j.titterington@ulster.ac.uk	Email: Harron-A@email.ulster.ac.uk

If you have any concerns or complaints about this study, please contact:
Mr Nick Curry,
Head of Research Governance,
Research and Impact,
Room 26A20,
Ulster University,
Jordanstown campus,
Tel: 028 90 366629 Email: n.curry@ulster.ac.uk

Hello!

My name is Memory Mack! I want to tell you how about memory.

You use your memory to help you remember things that you:

hear

and see.

Your memory is really important because it helps you to

listen to your teacher and learn.

Some visitors might be coming to your class

every week to play games that they think will

help children's memory.

*Ms/Mr____ and *Ms/Mr___ will be there

and everyone will work together.

I think it will be fun!

The visitors need to find out if the games help children to remember things, listen and learn. Some boys and girls will be asked to play some extra memory games to help the visitors find this out. If you are picked, you will play these games in the *_______with a special visitor who will come to your school 3 times.

He/she will give you a special sticker when you finish the games!

If you are not sure or have any questions you can talk to your teacher.

Thank you!

Please note this leaflet will be professionally designed by the Ulster University branding team.

*Personalised details for school staff and room to be inserted reduce uncertainty for children

**A pilot study of the RECALL programme:
a whole-class approach to
supporting attention
and language skills in 4- 5 year olds.**

Ulster University

CONSENT FORM

Please initial each box.

1. I confirm that I have been given and have read and understood the information sheet for the above study and have asked and received answers to any questions raised. ☐
2. I confirm I have read the children's information leaflet to my child. ☐
3. I understand that my child's participation is voluntary and that I am free to withdraw my child at any time, without giving any reason, and without my rights being affected. ☐
4. I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant in the study (except as might be required by law) and I give permission for the researchers to hold relevant personal data. ☐
5. I agree to my child taking part in the above study. ☐

Name of child: ……………………………………………………………………………………

Name of person with parental responsibility: ………………………………………………

Signed: …………………………………………………… Date: ……………………

Name of person obtaining consent:

……………………………………………………………………………………………………

Signed: …………………………………………………… Date:……………………

Appendix H - Research Information Leaflet: feasibility study - parents

Ulster University

Institute of Nursing and Health Research

Research study:

A pilot study of the Recall to Enhance Children's Attention, Language and Learning (RECALL) programme

Your child's class is taking part in a research study. Why is this research being done?

- Parents and teachers often have concerns about children's ability to pay attention and to follow instructions.
- The Regional Integrated Support for Education (RISE) teams in Northern Ireland include: speech and language therapists, occupational therapists; physiotherapists; and social, emotional and behaviour specialists.
- The RISE teams work with teachers to support children with skills such as attention and language. They use a range of games and activities, often with the whole class.
- Research tells us that good memory skills help children with lots of other aspects of their learning. Improving memory skills might lead to better attention, language and learning in the classroom. Based on this, we have developed a new programme for the RISE teams to use in schools and we need to find out if it works.

What is the new programme?

Recall to Enhance Children's Attention, Language and Learning (RECALL) aims to support the memory, attention and language skills of 4 – 5 year old children.

RECALL was developed by:

- researchers from Ulster University
- health professionals from the RISE teams
- teachers, and parents of year one children

RECALL

What does RECALL involve?

RECALL includes 6 sessions of fun activities that the whole class can join in with. A new session is introduced every week, so the whole programme lasts 6 weeks. Each session lasts about 40 minutes and will be carried out 3 times per week in the classroom – once with the RISE team and two more times with the class teacher.

What is the aim of this research study?

We believe RECALL is very promising because it is based on the best research we could find, but we don't know if it works.
To find this out, we will need to carry out a large research study in the future which will be very expensive. So we are starting with a smaller study that will give us an initial idea about:

- whether RECALL can be used easily in the classroom
- what people like or don't like about it
- how to carry out the large research study

What does this research involve?

6 primary one classes in Northern Ireland are taking part:

- two classes will get the RECALL programme
- two classes will get another similar programme with the RISE team
- two classes will continue in school as usual with no additional programme

What does this mean for your child?

Your child's class is taking part in our study. This means that they may take part in RECALL or a similar programme, or they may be part of the group that does not get any additional programme.

In any of these cases, we need to select 10 children in each class to assess their:

- ability to identify the sound they hear at the start of a word
- memory
- attention
- language skills

We will do this at the start and at the end of the study. It will take about one hour each time. The tests involve things like remembering a series of numbers and following instructions. They will be carried out in the school by a trained research assistant. We will not be using video during the programme, but we will record some of the children's voices during a few of the activities. This will be done using a portable voice recorder that they will carry in a small bag worn across the body. We will only assess or record your child if you give your permission.

If you agree to your child being assessed, we will ask you to fill out a short questionnaire about your child's language and communication skills.
If you fill it in for us two times (at the start and end of the study), we will enter you into a draw for a £100 voucher for a supermarket of your choice.

Please feel free to contact us for further information:

Anita Rowe (Researcher)
E: Harron-a@ulster.ac.uk
T: 028 90 368127

Dr Jill Titterington (Chief Investigator)
E: j.titterington@ulster.ac.uk
T: 028 90 368855

Dr Laurence Taggart (Academic Supervisor)
E: l.taggart@ulster.ac.uk
T: 028 90366538

RECALL

Appendix I - Systematic review supplementary materials

Table A: Outcomes measured and results of each included study (*n*= 18)

STUDY DETAILS (AUTHOR, YEAR) & INTERVENTION APPROACH	PRIMARY OUTCOME				SECONDARY OUTCOMES			MAIN FINDINGS
	WM outcomes measured				Near-transfer effects (untrained WM)	Far-transfer effects	Durability (follow-up period)	
	Verbal STM	Verbal ELWM	Visuo Spatial STM	Visuo Spatial ELWM				
Elliott *et al.* (2010) **Adapting the environment**	Digit recall Word recall Non-word recall	Backward digit recall Listening recall counting recall	Dot matrix Mazes memory Block recall	Odd one out Mr X Spatial recall	_	5-6yr olds– vocabulary 9-10 yr. olds – reading and maths	_	WM measures: no significant gains on any WM measures except for dot matrix (VSSTM) with one cohort of the study. Far-transfer: no gains found.
Banales *et al.(*2015) **Direct WM training without strategy instruction**	_	Verbal N-back Listening recall	_	_	_	Reading: sight word recognition and word decoding	8 weeks	Trained ELWM tasks: 2 children demonstrated improvement on listening recall but not on N-back task. Far-transfer: no effect of WM training. Durability outcomes measured 8 weeks' post-intervention. One child who had improved on the listening recall task had maintained progress. None showed any delayed gains on reading skills.
Henry *et al.* (2014) **Direct WM training without strategy instruction**	Digit recall Word recall	Listening recall Counting recall	Block recall	Odd one out	Digit recall (VSTM) Word recall (VSTM) Block recall (VSSTM) Counting recall (VELWM)	Number skills Spelling Reading comprehension	6 months post-intervention: all WM measures (trained tasks and near-transfer), word reading and number skills assessments. 12 months post-intervention: 2	Trained VELWM and VSELWM tasks: significant post-training differences between intervention and control groups in favour of experimental group. Baseline to post-intervention change was greater for experimental group. Near-transfer: mixed results on untrained STM skills- intervention group showed no advantage on block recall (VSSTM) or digit recall (VSTM) but on word recall (VSTM) they performed significantly better than the control group. Untrained VELWM

							further far-transfer measures included (spelling, reading comprehension).	measure (counting recall) - trained group out-performed control group. Far-transfer: no significant effects of the intervention were found. Durability: 6-month follow-up- gains on trained WM and near-transfer measures were maintained; 12 month follow-up - intervention group scored significantly higher than control group on reading comprehension.
Passolunghi & Costa (2016) **Direct WM training without strategy instruction**	Word recall	Verbal dual task	Pathway recall (spatial)	Visuospatial dual task	_	Numeracy	_	Trained tasks: no significant effect on verbal or visuospatial STM measures. On ELWM tasks - WM training group made greater gains than the control and numeracy groups. Far-transfer: WM training group and numeracy group made greater gains than the control group. No difference between the 2 intervention groups.
Caviola *et al.*(2009) **Direct WM training with strategy instruction**	Forward digit span	Backward digit	Visual patterns test (visual) Corsi block tapping (spatial)	Backward Corsi	Forward digit (VSTM) Backward digit (VELWM) Visual patterns test (VSSTM) Backward Corsi (VSELWM)	_	_	Trained VSSTM task: experimental and control groups improved. No post-intervention difference between groups. Near-transfer: post intervention gains found on backward Corsi task. No benefit of training found on other near-transfer measures. No assessment of children's strategy-use.
Comblain (1994) **Direct WM training with strategy instruction**	Digit span, Letter span and Word span	_	_	_	_	_	6 weeks 6 months	Trained VSTM tasks: significant improvements on three immediate post-intervention measures. No clear comparison with control group reported. Durability: performance decreased between 6 week and 6-month assessment points but remained significantly higher than pre-intervention level.

Cornoldi *et al.*(2015) **Direct WM training with strategy instruction**	_	Word list recall tasks with updating	_	_	_	Arithmetical problem solving skills	Training group 1 - 3 months post training). No follow up for training group 2 due to cross-over study design.	Trained ELWM tasks: both groups improved from baseline scores when tested immediately after intervention period. No gains observed during untrained periods. Far-transfer: both groups improved during trained periods and not during untrained periods. Regression analyses indicated the only significant predictor of problem solving was WM updating. Durability: training group 1 maintained gains 8 weeks later. No further improvement in WM skills. Meta-cognitive questionnaire used to investigate effects of training on strategy use: significant increases during training periods which were maintained by gp 1.
Peng & Fuchs (2015) **Direct WM training with strategy instruction**	Digit recall	Listening recall Counting recall (named counting figures in the intervention description)	Block recall	_	Digit recall (VSTM) Listening recall (VELWM) Block recall (VSSTM)	Listening comprehension and retell. Assessed using 2 scores from the Qualitative Reading Inventory (QRI) (Leslie and Caldwell, 2001)	_	Trained task all three groups (strategy instruction; no strategy instruction and no intervention) improved from pre- to post-intervention assessment. When compared to no-intervention control group, neither strategy instruction nor no-strategy instruction groups made significant gains. No difference between the strategy and no-strategy groups. Near-transfer: No significant group differences post-intervention except on listening recall task where strategy group outperformed the control group. Far-transfer: QRI Retell measure- strategy group significantly outperformed the control group. No-strategy group did not QRI listening comprehension measure, both intervention groups out-performed control condition. Strategy use: children in the strategy instruction group were observed using rehearsal on 89% of trials compared to 17% for the no-strategy group.

Witt (2011) **Direct WM training with strategy instruction**	_	Backward digit recall	Visual patterns test	_	Visual patterns (VSSTM)	Maths: addition accuracy and time	_	Trained VELWM task: intervention group showed greater improvements on post-intervention assessment than the matched-pair control group. Near-transfer: intervention group showed greater improvements on post-intervention assessment than the control group. Far-transfer: intervention group showed greater improvements on post-intervention assessment than the control group on addition accuracy but there was no change on children's addition time. No objective measurement of children's strategy use but the study author reported that some children used the strategies whereas others appeared to be resistant to them.
Alesi *et al.*(2016) **Training skills that may indirectly impact on WM: physical activity**	Digit span	Backward digit	Corsi block tapping	_	_	_	_	Trained tasks (motor skills): pre-post intervention assessments on an agility test (Alesi *et al.,* 2014) indicated significant improvements for the football group whereas there was no effect for the control group. WM measures: Mixed results Significant pre- to post- intervention improvements for the football group on the visuospatial STM task but no effect on the verbal STM and ELWM tasks. The control group did not improve on any WM measures
Davis *et al.*(2007) **Training skills that may indirectly impact on WM: physical activity**	_	Successive scale of the Cognitive Assessment System (CAS) (Naglieri & Das, 1997)	_	_	_	_	_	Trained tasks (effects on weight and fitness): Body Mass Index score (BMI) - no group differences post-intervention. Treadmill performance- both intervention groups improved compared to control group. No difference between the intervention groups. WM measures: No significant group differences on post-intervention assessment.

Kamijo *et al.*(2011) **Training skills that may indirectly impact on WM: physical activity**	–	Modified Sternberg (Sternberg, 1966). Children had to encode a memory set of one, three or five letters	–	–	–	–	–	Trained task (fitness): Fitness measured by oxygen consumption during treadmill task- Significant pre-post intervention effect for the trained group. No effect for the control group. WM measures: results dependent on task demands. One letter condition - no differences in pre-to post-intervention for intervention or control group. Three letter condition –intervention group's response accuracy improved. Control group did not. Five letter condition - no improvement in accuracy for either group.
Koutsandréou *et al.*(2016) **Training skills that may indirectly impact on WM: physical activity**	–	Letter digit span**	–	–	–	–	–	Trained tasks (physical fitness and motor performance): fitness level of cardiovascular exercise (CE) group significantly improved. Motor demanding exercise (ME) and control groups did not. Motor performance- all 3 groups improved. ME group significantly better than control group on post-test. CE group were not. WM measures: CE and ME groups improved. Control group did not. Between group comparisons indicated ME group significantly better than controls but not significantly better than the CE group. Supplementary analysis indicated pre-post intervention difference was significantly larger in ME group compared to CE group. CE improved more than controls. WM benefited from both cardiovascular and motor exercise programs, but to a larger degree from the motor exercise intervention.
Van der Niet *et al.*(2016) **Training skills that may**	–	Backward digit	–	Visual memory span	–	–	–	Trained task (physical fitness): No effects found on any physical fitness variables. Motor skills not assessed. WM measures: the intervention group achieved significantly higher post-

indirectly impact on WM: physical activity								intervention scores than the no intervention control group on post-intervention assessment of backward digit span (VELWM) but not on visual memory span (VSELWM).
Melby-Lervåg & Hulme (2010) **Training skills that may indirectly impact on WM: phonological awareness**	Word span	_	_	_	_	_	_	Trained tasks: phoneme and rhyme groups improved on trained and untrained words. Vocab group improved on trained words only. WM measures: VSTM measures -results differed between serial recall and free recall tasks and between trained and untrained words. Serial recall with trained words - all three intervention groups improved. Phoneme group significantly outperformed the other conditions. Vocabulary group improved more than control group but rhyme group did not. Free recall with trained words - vocabulary group showed greater gains than all other groups. Phoneme group outperformed the control group, the rhyme group did not. Serial and free recall with untrained words - no significant differences between groups. Results suggest phoneme awareness training impacted on trained skill, had a transfer effect to serial recall and a smaller effect on free recall. Rhyme training improved rhyme generation skills but had no impact on VSTM. Vocabulary training improved free recall and had a smaller effect on serial recall, but only on trained words.

van Kleeck *et al.*(2006) (relating to van Kleeck *et al.* 1998) Training skills that may indirectly impact on WM: phonological awareness	Word span Non-word span	–	–	–	–	–	–	Trained tasks (van Kleeck *et al.,* 1998): Intervention group made significantly improved on rhyme and phoneme awareness skills. Gains on rhyme not attributed to intervention as control group also improved. WM measures (van Kleeck *et al.,* 2006): Report significant pre- to post-intervention improvements for the trained children. No comparison with control group.
Thibodeau *et al.*(2016) **Training skills that may indirectly impact on WM: fantastical play**	Digit span	–	–	–	–	–	–	Trained task (fantastical play): fantastical play group engaged in more pretending behaviours than the non-imaginative play and control groups. No differences observed on 4 other constructs of fantasy orientation. Baseline to post-intervention differences observed in fantastical play group. No change in the other 2 groups. WM measures: Fantastical play group improved from pre- to post-intervention. The other 2 groups did not.
Volckaert & Noël (2015) **Training skills that may indirectly impact on WM: inhibition**	Word span	Categospan	Corsi block tapping	–	–	Measures of children's externalising behaviours: Unfair Card Game (UCG) (Roskam *et al.,* 2016); Conners Rating Scale (Goyette *et al.,* 1978).	–	Trained task (inhibition): experimental group significantly improved from pre- to post-intervention. Control group did not. WM measures: 3 tasks combined into factorial analysis. Experimental group improved from pre- to post- intervention. Control group did not. Far- transfer: UCG - experimental group showed significantly less negative behaviours after training. Control group showed more. Conners scale - parents reported no effects on conduct or impulsivity scale but significant effects on hyperactivity. Teachers (blinded to the children's group) did not report improvements on conduct or hyperactivity scales. Significant improvement on inattention scale for the experimental group but not for the control group.

Appendix I - Systematic review supplementary materials. Table B1: Synthesised results - verbal STM

INTERVENTION TYPE	STUDY AUTHOR AND YEAR	POPULATION	INTERVENTION		COMPARISON		OUTCOMES		
		Status and age	Trained Skill	Executive-loaded?	Study design and comparison	No of partici-pants	Effect on trained skill	VSTM outcome(s) measured	Reported effect on VSTM
Adapting the environment	**Elliott *et al.* (2010)**	TD 5- 6 yr. olds; 9- 10 yr. olds.	None	N/A	QE Behavioural teaching; No intervention	256	No evidence of enhance strategy-use by teachers.	Digit span Word span Non-word span	No significant pre-post intervention differences or group differences observed (*p*>.05).
Direct WM training with strategy instruction	**Caviola *et al.* (2009)**	TD 8-9 yr. olds	Corsi block tapping	✗	QE General cognitive strategies	46	No	Digit span•	No significant difference found on post-intervention group comparison (*p*=.62).
	Comblain (1994)	DS 8 yr. olds	Digit, letter and word span	✗	QE No intervention	8*	Directly trained VSTM.	Digit span, Letter span Word span	Significant improvement for intervention group (*p*<.05). No clear comparison made with control group.
	Peng & Fuchs (2015)	LD 7 yr. olds	4 tasks described as verbal	✓	RCT Without strategy No intervention	58	No	Digit span	Neither the strategy instruction group (*p*= .29) nor the no-strategy instruction group (*p*=.46) made significant gains when compared to the control group.
Direct WM training without strategy instruction	**Henry *et al.* (2014)**	TD 7 yr. olds	Listening recall Odd one out	✓	RCT Active control	36	Yes	Digit span• word span•	Significant post-intervention group differences on word span (*p*<.01). On digit span both groups improved to the same extent.
	Passolunghi & Costa (2016)	TD 5yr olds	All 4 aspects of WM	✓	RCT Numeracy training No intervention	48	Significant effects on EWLWM but not on STM tasks.	Word span	No significant difference between groups (*p*=.51)
Training skills which may indirectly impact on	**Alesi *et al.*(2016)**	TD 8-9 yr. olds	Football	✓	RCT Sedentary children	44	Yes. Football group improved on agility test	Digit span	Control group did not improve n football test. No significant post-intervention difference between the groups (p>.05).

WM: physical activity							(Alesi *et al.*, 2014) (p< .05)..		
Training skills which may indirectly impact on WM: phonological awareness	**Melby-Lervåg & Hulme (2010)**	TD 4 yr. olds	Rhyme and phoneme awareness and vocabulary	✘	QE 3 exp. groups and one untrained control	160	Significant effects on on trained words	Word span (Serial recall Free recall)	Significant effects on trained words. Phoneme awareness group significantly better than other conditions. Phoneme group significantly outperformed the other conditions. Free recall with the trained words - the vocabulary group showed greater gains than all other groups. The phoneme group also outperformed the control group but the rhyme group did not. No significant effects on untrained words.
	van Kleeck *et al.*(2006)	SLI 4 yr. olds	Rhyme and phoneme awareness	✘	QE No control for WM outcomes	24	Gains in phoneme awareness. Gains in rhyme skills were not attributed to the intervention.	Word span Non-word span	Significant improvement for intervention group (*p*<.001)**
Training skills which may indirectly impact on WM: fantastical play	**Thibodeau *et al.* (2016)**	TD 4 yr. olds	Fantastical play	✓	RCT Non-imaginative play No-intervention control	110	Yes. On one measure of fantasy orientation Not significant on 3 other measures.	Digit span	Significant improvements for fantastical play group: (*p*=.003). No-significant gains for: non-imaginative play group (*p*=.801) or control group (*p*=.522)
Training skills which may indirectly impact on WM: inhibition	**Volckaert & Noël (2015)**	TD	Inhibition	✓	RCT Handicraft lessons	47	Yes	Word span	*WM measure: significant pre-post intervention gains for exp. group (*p*<.001). No significant gains for control group – (*p*=.215).

Key: TD = typically developing; DS= Down's syndrome; SLI = specific language impairment; O = overweight; LD = at risk of learning difficulties; QE= Quasi-experimental; RCT = Randomised Controlled Trial. ♦ these were untrained WM measures so are near-transfer * This study also included older participants. Only the child participants have been considered in this review. ** gains on rhyme were not attributed to the intervention (van Kleeck *et al.,* 1998) *** Results across WM measures were combined into a factor analysis so specific effects on VSTM cannot be distinguished

Appendix I - Systematic review supplementary materials. Table B2: Synthesised results - visuospatial STM

INTERVENTION TYPE	STUDY AUTHOR AND YEAR	POPULATION	INTERVENTION		COMPARISON		OUTCOMES		
		Status and age	**Trained Skill**	**Executive-loaded?**	**Study design and comparison**	**No of partici-pants**	**Effect on trained skill**	**VSSTM outcome(s) measured**	**Effect**
Adapting the environment	**Elliott *et al.*, (2010)**	TD 5- 6 yr. olds; 9- 10 yr. olds.	None	N/A	QE Behavioural teaching; No intervention	256	No evidence of enhanced strategy-use by teachers	Dot matrix	In 1 of the 2 cohorts: WM group significantly improved (p=.004). Other groups did not.
Direct WM training without strategy instruction	**Henry *et al.*, (2014)**	TD 7 yr. olds	Listening recall Odd one out	✓	RCT Active control	36	Yes	Block recall	Post-intervention group comparisons: not significant.
	Passolunghi & Costa (2016)	TD 5yr olds	All 4 aspects of WM	✓	RCT Numeracy training No intervention	48	Improved ELWM skills but not STM	Pathway recall	No significant difference between groups (*p*=.25).
Direct WM training with strategy instruction	**Caviola *et al.*, (2009)**	TD 8-9 yr. olds	Corsi block tapping	✗	QE General cognitive strategies	46	No.	Corsi block tapping Visual patterns test (VPT)	Corsi block tapping: no significant difference post-intervention group difference (p= .13). VPT: significant difference (*p*=.27).
	Peng & Fuchs (2015)	LD 7 yr. olds	4 tasks described as verbal	✓	RCT Without strategy No intervention	58	No	Block recall	Neither the strategy instruction group (*p*= .99) nor the no-strategy instruction group (*p*=.48) made significant gains when compared to the control group.
	Witt (2011)	TD 9 yr. olds	BDS; updating task; counting recall	✓	QE No intervention	38	Yes	Visual patterns test	Significant post-intervention group differences (p<.05)

Training skills which may indirectly impact on WM: physical activity	**Alesi *et al.*, (2016)**	TD 8-9 yr. olds	Football	✓	RCT Sedentary children	44	Yes	Corsi block tapping	Pre-post intervention gains for experimental group (*p*<.05) Not significant for control group
Training skills which may indirectly impact on WM: inhibition	**Volckaert & Noël (2015)**	TD	Inhibition	✓	RCT Handicraft lessons	47	Yes	Corsi block tapping	*WM measure: significant pre-post intervention gains for exp. group (*p*<.001). No gains for control group – (*p*=.215).

Key: TD = typically developing; DS= Down's syndrome; SLI = specific language impairment; O = overweight; LD = at risk of learning difficulties; QE= Quasi-experimental; RCT = Randomised Controlled Trial. ♦ these were untrained WM measures so are near-transfer * This study also included older participants. Only the child participants have been considered in this review. ** gains on rhyme were not attributed to the intervention (van Kleeck *et al.,* 1998) *** Results across WM measures were combined into a factor analysis so specific effects on VSTM cannot be distinguished

Appendix I - Systematic review supplementary materials. Table B3: Synthesised results - verbal ELWM

INTERVENTION TYPE	**STUDY AUTHOR AND YEAR**	**POPULATION**	**INTERVENTION**		**COMPARISON**		**OUTCOMES**		
		Status and age	**Trained skill**	**Executive -loaded?**	**Study design and comparison**	**No of partici-pants**	**Effect on trained skill**	**VELWM outcome(s) measured**	**Effect**
Adapting the environment	**Elliott *et al.* (2010)**	TD 5- 6 yr. olds; 9- 10 yr. olds.	None	N/A	QE Behavioural teaching; No intervention	256	No evidence of enhance strategy-use by teachers.	Backward digit span, listening recall. counting recall	No significant pre-post intervention differences or group differences observed (*p*>.05).
Direct WM training without strategy instruction	**Banales *et al.* (2015)**	R+WM 9 yr. olds	N-back Listening recall	✓	Case series Each child own matched control	4	Directly trained VEWLM.	N-back Listening recall	2 children improved on listening recall. None on N-back.
	Henry *et al.* (2014)	TD 7 yr. olds	Listening recall Odd one out	✓	RCT Active control	36	Directly trained VEWLM.	Listening recall Counting recall	Significant difference between exp. and control (*p*<.001) Counting recall (*p*<.05)
	Passolunghi & Costa (2016)	TD 5yr olds	All 4 aspects of WM	✓	RCT Numeracy training No intervention	48	Significant effects on EWLWM but not on STM tasks.	Verbal dual task	Significant post-intervention group difference between exp. versus numeracy (*p*=.009); and exp. versus control (*p*=.002)
Direct WM training with strategy instruction	**Caviola *et al.* (2009)**	TD 8-9 yr. olds	Corsi block tapping	✗	QE General cognitive strategies	46	No	Backward digit span	Post-intervention group comparisons - not significant (*p*=.10)
	Cornoldi *et al.*(2015)	TD 9 yr. olds	Word list updating	✓	QE Cross over design- Usual maths lessons	135	Directly trained VEWLM.	Word list updating	Pre-post intervention comparisons. Both trained groups significant gains (*p*=.002; *p*<.001)
	Peng & Fuchs (2015)	LD 7 yr. olds	Counting recall	✓	RCT Without strategy No intervention	58	No significant group differences	Counting recall Listening recall	All 3 groups showed significant post-intervention improvement. Counting recall - neither the strategy instruction group (*p*= .45) nor the no-strategy instruction group (*p*=.17)

									made significant gains when compared to the control group. No difference between the strategy and the no-strategy groups (*p*=.52).
	Witt (2011)	TD 9 yr. olds	Backward digit span, Updating and counting recall	✓	QE No intervention	38	Significant post-intervention group difference (*p*<.05)	Backward digit span	Significant post-intervention group difference (*p*<.05)
Training skills which may indirectly impact on WM: physical activity	**Alesi *et al.*(2016)**	TD 8-9 yr. olds	Football	✓	RCT Sedentary children	44	Yes.	Backward digit span	No significant post-intervention difference between the groups (p>.05).
	Davis *et al.*(2007)	Overweight 9 yr. olds	Physical activity	✓	RCT Low dose; high dose; No intervention control.	94	No.	CAS successive scale	No significant post intervention group differences (p=.08)
	Kamijo *et al.* (2011)	TD	Physical activity	✓	RCT Waitlist	43	Yes	Modified Sternberg task	Effects on the 3 letter condition (not on 1 and 5 letter condition)
	Koutsandréou *et al.* (2016)	TD	Physical activity	✓	RCT Cardiovascular group; motor demanding group; No-exercise control.	71	Yes. Specific effects for each group	Letter digit span	Pre-post intervention gains observed for both intervention groups but not for the control gp: CE *p*<.001; ME *p*<.001 Control *p*=0.391
	Van der Niet *et al.* (2016)	TD	Physical activity	✓	QE Normal school routine	112	No	Backward digit span	Post-intervention group comparisons: significant differences between exp. and control (*p*=.02)
Training skills which may indirectly impact on WM: inhibition	**Volckaert & Noël (2015)**	TD	Inhibition	✓	RCT Handicraft lessons	47	Yes	Categospan	*WM measure: significant pre-post intervention gains for exp. group (*p*<.001). No significant gains for control group – (*p*=.215).

Key: C= control group (s); E = experimental group; TD = typically developing; LD = at risk of learning difficulties; R+WM=reading and WM difficulties. QE= Quasi-experimental; RCT = Randomised Controlled Trial. BDS= backward digit span * Results across WM measures combined into a factor analysis so specific effects on VELWM cannot be distinguished.

Appendix I - Systematic review supplementary materials. Table B4: Synthesised results - visuospatial ELWM

INTERVENTION TYPE	STUDY AUTHOR AND YEAR	POPULATION	INTERVENTION		COMPARISON		OUTCOMES		
		Status and age	**Trained skill**	**Executive-loaded?**	**Study design and comparison**	**No of partici-pants**	**Effect on trained skill**	**VSELWM outcome(s) measured**	**Effect**
Adapting the environment	**Elliott *et al.*(2010)**	TD 5- 6 yr. olds; 9- 10 yr. olds.	None	N/A	QE Behavioural teaching; No intervention	256	No evidence of enhance strategy-use by teachers.	Odd one out Mr X Spatial recall	No significant pre-post intervention differences or group differences observed (p>.05).
Direct WM training without strategy instruction	**Henry *et al.* (2014)**	TD 7 yr. olds	Listening recall Odd one out	✓	RCT Active control	36	Yes	Odd one out Counting recall	Post-intervention group comparisons: Significant differences between exp. and control on both tasks Odd one out (p<.001)
	Passolunghi & Costa (2016)	TD 5yr olds	All 4 aspects of WM	✓	RCT Numeracy training No intervention	48	Significant effects on EWLWM but not on STM tasks.	Visuospatial dual task	Significant post-intervention group difference between exp. versus numeracy (p=.03); and exp. versus control (p<.001)
Direct WM training with strategy instruction	**Caviola *et al.*(2009)**	TD 8-9 yr. olds	Corsi block tapping	✗	QE General cognitive strategies	46	No effect on VSSTM trained task.	Backward Corsi A near-transfer measure	Post-intervention group comparisons – non significant (p=.03)
Training skills which may indirectly impact on WM: physical activity	**Van der Niet *et al.* (2016)**	TD	Physical activity	✓	QE Normal school routine	112	No	Visual memory span	Post-intervention group comparisons - not significant (p=.115)

Appendix I - Systematic review supplementary materials. Table B5: Synthesised results - near- and far-transfer effects

INTERVENTION TYPE	STUDY AUTHOR AND YEAR	POPULATION	INTERVENTION		COMPARISON		NEAR-TRANSFER EFFECTS		FAR-TRANSFER EFFECTS	
		Status and age	**Trained skill**	**Executive-loaded?**	**Study design and comparison**	**Total sample**	**Outcome(s) measured**	**Effect**	**Outcome(s) measured**	**Effect**
Adapting the environment	**Elliott *et al.* (2010)**	5- 6 year olds 9-10 year olds	No directly trained task	✗	QE Behavioural teaching; No intervention	256	N/A due to nature of the intervention	-	5- 6yr olds cohort – vocabulary 9- 10 yr. old cohort – reading and maths	No significant effects found
Direct WM training without strategy instruction	**Henry *et al.* (2014)**	TD 7 yr. olds	Listening recall (VELWM) Odd one out (VSELWM)	✓	RCT Active control	36	Digit recall (VSTM)	Group comparisons on post intervention - No	Number skills Spelling Reading comprehension	No significant effects found except on reading comprehension task which was introduced at 12 month follow-up (p<.01).
							Word recall (VSTM)	Group comparisons on post intervention - Yes. p<.01		
							Counting recall (VELWM)	Group comparisons on post intervention - Yes. p,.05		
							Block recall (VSSTM)	Group comparisons on post intervention - No.		
	Banales *et al.*(2015)	R+WM 9 year olds	N-back Listening recall	✓	Case series Each child own	4	Not measured	-	Reading: sight word recognition	No effect

					matched control				and word decoding	
	Passolunghi & Costa (2016)	TD 5yr olds	All 4 aspects of WM	✓	RCT Numeracy training No intervention	48	Not measured	-	Numeracy	WM training group and numeracy groups made greater gains than the control group but there was no difference between the 2 intervention groups.
Direct WM training with strategy instruction	**Caviola *et al.* (2009)**	TD 8-9 yr. olds	Corsi block tapping (VSSTM)	✗	QE General cognitive strategies	46	Forward digit span	No. p=.62	Not measured	-
							Backward digit	No. p=.10		
							Visual patterns	No. p= .27		
							Backward Corsi	Yes. P=.03		
	Cornoldi *et al.*(2015)	TD 9 yr. olds	Word list updating	✓	QE Cross over design- Usual maths lessons	135	Not measured	-	Arithmetical problem solving	both groups improved during trained periods and not during the untrained periods. Regression analyses indicated that the only significant predictor of problem solving was a gain in WM updating.
	Peng & Fuchs (2015)	LD 7 yr. olds	Counting recall (VELWM)	✓	RCT Without strategy No intervention	58	Digit recall (VSTM)	No effect	Listening comprehension and retell.	On the QRI Retell measure the strategy group significantly outperformed the control group whereas the no-strategy group did not On the QRI listening comprehension measure, both intervention groups outperformed the control condition.
							Block recall (VSSTM)	No effect		
							Listening recall (VELWM)	No effect		

										Strategy use: children in the strategy instruction group were observed using rehearsal on 89% of trials compared to 17% for the no-strategy group.
	Witt (2011)	TD 9 yr. olds	Backward digit span, updating and counting recall (VELWM)	✓	QE No intervention	38	Visual patterns (VSSTM)	Significant post-intervention group difference (*p*<.05)	Maths addition time and accuracy	Significant effects on addition time. No change on children's addition time.
Training skills which may indirectly impact on WM: inhibition	**Volckaert & Noël (2015)**	TD	Inhibition	? ✓	RCT Handicraft lessons	47	N/A due to nature of the intervention	-		UCG - experimental group showed significantly less negative behaviours after training. Control group showed more. Conners scale - parents reported no effects on conduct or impulsivity scale but significant effects on hyperactivity. Teachers (blinded to the children's group) did not report improvements on conduct or hyperactivity scales. Significant improvement on inattention scale for the experimental group but not for the control group.

Appendix J - TIDIER checklist (Hoffman *et al.* 2014)

TIDieR
Template for Intervention Description and Replication

The TIDieR (Template for Intervention Description and Replication) Checklist*:
Information to include when describing an intervention and the location of the information

Item number		Where located ** Primary paper (page or appendix number)	Other † (details)
	BRIEF NAME		
1.		______________	______________
	WHY		
2.	Describe any rationale, theory, or goal of the elements essential to the intervention.	______________	______________
	WHAT		
3.	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	______________	______________
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	______________	______________
	WHO PROVIDED		
5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	______________	______________
	HOW		

6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	_____________	_____________
	WHERE		
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	_____________	_____________
	WHEN and HOW MUCH		
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	_____________	_____________
	TAILORING		
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	_____________	_____________
	MODIFICATIONS		
10.‡	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	_____________	_____________
	HOW WELL		
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	_____________	_____________
12.‡	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	_____________	_____________

** **Authors -** use N/A if an item is not applicable for the intervention being described. **Reviewers** – use '?' if information about the element is not reported/not sufficiently reported.