Working memory training and explicit teaching : A transdisciplinary approach to reading intervention

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WORKING MEMORY TRAINING AND EXPLICIT TEACHING: A TRANSDISCIPLINARY APPROACH TO READING INTERVENTION

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Declaration of Authorship and Sources

This thesis contains no material that has been extracted in whole or in part from a thesis that I have submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgment in the main text of the thesis.

All research procedures reported in the thesis received the approval of the Human Research Ethics Committee. Register Number: 2017 – 287H (Approval Form included in Appendices)

Abstract

This multiple case study investigates the use of adaptive, cognitive working memory training in tandem with a literacy intervention program in the address of learning difficulties in reading as well as working memory difficulties. The study was completed with middle primary aged students in a large Australian primary school. The study adds to research in this area through indication a transfer of trained improvement in working memory to improvement in reading skills with a high level of inter-relationship with working memory may be evidenced when both working memory training and reading intervention are delivered within the school setting. The study indicated the importance of considering cognitive load when structuring the delivery and timing of these intervention programs. Several suggestions for future research are offered to both challenge and extend the findings of this study.

*Keywords: w*orking memory, literacy intervention program, reading disability, multiple case study, transdisciplinary approach.

Dedication

There comes a point in your life when you need to stop reading other people's books and write your own.
(Albert Einstein)

This work is dedicated in the first instance to the many students I have encountered within my professional life whose personal struggle in learning to read and in learning with working memory difficulties have been a continuous source of motivation for my own passion for learning and growth as an educator.

It is likewise dedicated to the wonderfully inspiring individuals I have met along my professional journey who have encouraged me to take intellectual risks, believe in my professional passions and push into the frontiers of the unknown in the quest for answers to troubling educational questions. Always risky to start naming individuals but two must be highlighted: Professor Juhani Tuovinen and Dr John Rose - thank you both.

Lastly and most importantly, it is dedicated to my longsuffering and extremely supportive husband, family and friends who have stood by me through countless years of study and professional growth. I would like to promise it is over now, but I suspect that may be a falsehood.

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Finally, heartfelt love and unmeasurable gratitude is showered upon my beautiful husband and family. This has most definitely been a family journey – a trip of a lifetime – one not plausible or achievable without them.

Table of Contents

List of Tables

List of Figures

Glossary

ACER: Australian Council for Educational Research

Analytical generalisation: Yin (2014) defines as "the logic whereby case study findings can extend to situations outside of the original case study, based on the relevance of similar theoretical concepts or principles" (p. 237).

APD: Auditory Processing Deficits

AWM: Auditory Working Memory

Case A Sim: Case A Simultaneous

Case B Sim: Case B Simultaneous

Case A Seq: Case B Sequential

Case B Seq: Case B Sequential

CCSS: Common Core State Standards

CE: Central Executive

DSM-5: Diagnostic and Statistical Manual of Mental Disorders: DSM-5

EAL: English as an Additional Language

EF: Executive Function

FA: Focused Attention

HREC: Human Research Ethics Committee

ID: Intellectual Disability

KBIT-2: Kaufmann Brief Intelligence Test – Second Edition

LDR: Learning Difficulty in Reading

LERD: Late Emergent Reading Disabilities

Literal Replication: Yin (2014) describes as "the selection of two (or more) cases within a multiple-case study because the cases are predicted to produce similar findings" (p. 239).

LTM: Long Term Memory

MacqLit: Macquarie Literacy Program for Small Group Instruction

MCEECDYA: Ministerial Council for Education, Early Childhood Development and Youth Affairs.

MultiLit: Making Up Lost Time in Literacy

NAPLAN: National Assessment Program for Literacy and Numeracy

NCCD: Nationally Consistent Collection of Data on school students with disability

NMB: Number Memory Backwards

NMF: Number Memory Forward

OARS: Online Assessment and Reporting System

OECD : Organisation for Economic, Cooperation and Development

PATR-4: Australian Council of Educational Research, Progressive Achievement Test in Reading Fourth Edition - Comprehension

PDE: Phonemic Decoding Efficacy

PIRLS: Progress in International Reading Literacy Study

PISA: Programme for International Student Assessment

Purposeful sampling: Creswell (2014) defines as "a qualitative sampling procedure in which researchers intentionally select individuals and sites to learn or understand the central phenomenon" (p. 10).

RA: Reading Accuracy

RAN: Rapid Automatised Naming

RSE: Reader Self Efficacy

RTI: Response to Intervention

SES: Socioeconomic Status

SLD: Specific Learning Disorder

STAM: Short Term Auditory Memory

STVM: Short Term Visual Memory

SWE: Sight Word Efficacy

TAPS-3: Test of Auditory Processing – Third Edition

Theoretical Replication: Yin (2014) defines as "the selection of two (or more) cases in a multiple-case study because the cases are predicted to have contrasting findings, but for anticipatable reasons" (p. 241).

Theory or Concept Sampling: Creswell (2014) defines as "purposeful sampling strategy in which individuals or sites are sampled because they can help the researcher generate or discover a theory or specific concept within a theory" (p. 13).

TOWRE 2: Test of Word Reading Efficiency (Second Edition)

VSTM: Visual Short-Term Memory

VWM: Visual Working Memory

WARP: Wheldall Assessment of Reading Passages

WM: Working Memory

WM-AI: Working Memory-Auditory Input

WM-VI: Working Memory-Visual Input

WRA: Word Reading Ability

YARC: York Assessment of Reading for Comprehension – Passage Reading

ZPD: Zone of Proximal Development

Chapter 1

Introduction

Learn from yesterday, live for today, hope for tomorrow.
The important thing is not to stop questioning.
(Albert Einstein, n.d.)

One of the fundamental aims of a primary classroom teacher is to facilitate every student within the class to acquire the necessary skills to enable them to read and write, and thus launch them on a pathway towards becoming a literate member of society (Potocki, Sanchez, Ecalle, & Magnan, 2017).

In this postmodern age of technological advancement, rapid change, and expansive, multi-modal access to information, the need to be literate remains necessary (Adams, 1994; Murnane, Sawhill, & Snow, 2012; Reschly, 2010). To be a fully functional, participatory, and contributing member of modern society, it is important to be able to read and write. Teachers need to be successful in their craft of teaching these literacy skills. Unfortunately for many students the acquisition of reading skills is difficult. This is particularly so for the students identified with dyslexia who are represented within the estimated 5 to 17% of school aged students identified as having a specific learning disability (dyslexia, dysgraphia, and dyscalculia) (Kar, 2014).

It might be argued there are many competing and interactive influences which can affect the level of achievement of students apart from the student themselves. Hattie (2003) cites six major sources for the variance in student achievement with students accounting for 50% of the variance in achievement, teachers 30%, and 20% other factors. Affective, cognitive, physical, and dispositional characteristics of students contributed to the student variation (Hattie, 1992). Hattie claims the major factor attributed to the variation in student achievement is student ability (see also Klauda & Guthrie, 2015). Hattie also states there is a

high correlation between ability and achievement. Students with higher ability have higher trajectories of learning and students with lower abilities have lower trajectories of learning.

This is particularly relevant to this study as students with a learning disability often display a low trajectory of achievement, particularly those struggling to acquire reading skills (Sikiö, Siekkinen, & Holopainen, 2015; Wei, Blackorby, & Schiller 2011). As it has been found that affective and dispositional factors such as student motivation and engagement can also influence student achievement (Cirino et al., 2013; Hattie, 1992), this research study also supports consideration of the influence of these factors in addition to student ability.

Whether you reference Specific Learning Disorder (SLD) as categorised in the Diagnostic and Statistical Manual of Mental Disorders: DSM-5 (American Psychiatric Association, 2013), dyslexia, or one of many other reading difficulty labels used throughout the historical and substantial body of research into learning difficulties, it is broadly acknowledged that a significant percentage of students with learning difficulties, struggle to learn to read. Whilst poor levels of reading ability can and have been linked to exogenous factors such as social or economic disadvantage (Hernandez, 2011) the impact of disadvantage can often be diminished with appropriate educational resourcing (Hallinan & Kubitschek, 2010; Kennedy & Shiel, 2010). A much more difficult educational problem exists when trying to address reading failure linked to specific endogenous factors such as phonological processing difficulties, rapid naming difficulties, orthographic difficulties or working memory (WM) deficits. This form of reading failure or disability is not significantly attributable to general endogenous factors such as developmental delay, neurological or sensory (vision or hearing) deficits, or motor disorders (American Psychiatric Association, 2013). Reading failure due to a SLD is a significant challenge in education as demonstrated by de Jong et al. (2009) who estimate the prevalence of dyslexia to be between 2% and 10% of the population.

Discovering the puzzling complexities underpinning reading difficulties and the development of effective educational interventions have motivated a historically expansive body of scientific and educational research. This has created a passing parade of theories and well-intentioned therapeutic and educational intervention programs (see the review of literature in these areas in Chapters 2 and 3). Despite huge investment of financial resources, time, and effort, the search goes on. To that end this current study aims to contribute to the journey towards achievement of greater effectiveness in reading interventions in our primary schools. The focus of this research is not so much on cognitive theories around reading disability nor an investigation into the pedagogical approaches employed within and in addition to mainstream education, to address this specific learning disability. This study is specifically purposed on investigating the effectiveness of interconnecting these bodies of research and theory into the trial of a transdisciplinary reading intervention pedagogy. This transdisciplinary pedagogy focuses on improving reading outcomes for students with deficits in WM ability as well as a specific learning difficulty in the development of word reading skills (refer Figure 1.1).

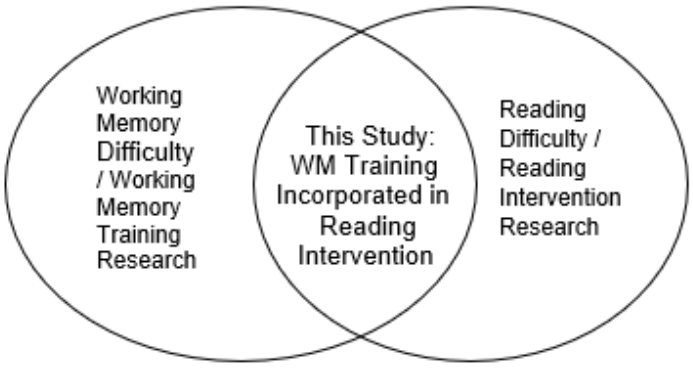

Figure 1.1. The transdisciplinary nature of this current study

Reflexive Statement

Having worked for over twenty-five years as a classroom and specialist teacher my personal experience has been that despite intensive, targeted, and repetitive, heavily phonic

based educational interventions, students with a phonologically linked learning difficulty in reading (LDR) often struggle to make even minimal progress (Kudo, Lussier, & Swanson, 2015). The reward for their enormous effort is slow, arduous, dependent decoding and word by word reading (Norton & Wolf, 2012). Similarly, whole language-based interventions with heavy reliance on visual processing skills are often extremely challenging for students presenting with deficits in visual processing ability (Kibby et al., 2015). Time spent in intervention often results in minimal phonological processing knowledge and a propensity to guess at words leaving reading highly inaccurate. Even in these times of more balanced approaches to intervention pedagogy, my experience has been that reading fluency and reading accuracy levels often show slow, laboured improvement and comprehension is often compromised.

Another personal and frequent observation throughout my career, particularly as I have annually assessed large numbers of students presenting with reading difficulties, is that a high percentage also have deficits in working memory (WM). This observation is supported in a substantial body of research (Gathercole et al., 2016; Peng et al., 2018). For the most comprehensive and widely accepted definition of WM, I refer to that of Baddeley (1986). Baddeley defines WM as the capacity to temporarily store information whilst using that information as part of a cognitive processing task. Malekpour, Aghababaei, and Abedi (2013) concur with this definition despite also pointing out that there is significant disagreement around the core components of WM and their nature.

Working memory was first conceptualised by Baddeley and Hitch (1974) as a three-component, working memory processing model. Baddeley, Hitch, and Allen, (2018) reference the theoretical framework for memory discussed in a paper by Atkinson and Shiffrin (1968) as a major influence on the development of their own model. Over 50 years ago, Atkinson and Shiffrin integrated recent major developments in cognitive psychology of

memory into a novel framework for memory. This framework postulated the existence of a modal memory structure comprised of a Long-Term Memory (LTM) as well as a limited capacity, Short Term Memory (STM) acting as a WM crucial to the performance of cognitive activities. In building on this framework, Baddeley and Hitch developed their own three component model of WM. This novel model comprised of a phonological loop, a visual-spatial sketchpad and a central executive which worked together to receive, integrate, and process auditory and visual input. In 2000, Baddeley introduced a fourth component named the Episodic Buffer. This introduced an integrative, temporary memory storage element into the system (Baddeley, 2000, 2006, 2017). Baddeley's model of WM has endured with little change over the years. This is despite a significant body of research across many scientific fields having contested and explored the exact nature, function, and location of WM. A comprehensive discussion of WM and WM research will be presented in Chapters 2 and 3.

Quite aside from the ongoing research exploring the theoretical construct and function of WM, the comorbidity of WM deficits with learning and behavioural difficulties continues to be endorsed and explored in an ever-expanding body of research (Graham, Harris, & Swanson, 2013; Hall, Jarrold, Towse, & Zarandi, 2015; Lubin, Regrin, Boulc`h, Pacton, & Lanoë, 2016; Maehler & Schuchardt, 2016; Malekpour et al., 2013; Troia, 2013). Of pertinence to this study is the research literature which explores the interconnections between learning disabilities and deficits in specific or generalised functions of WM – depending within which WM theoretical framework a research study is based. There is research interest in the interconnections with short-term visual memory (STVM), short-term auditory memory (STAM), auditory working memory (AWM,) visual working memory (VWM), and long-term memory (LTM) (Swanson, Zheng, & Jerman, 2009). There is also much research around the difficulties in aspects of executive function (EF) such as attention, concentration, and visual processing speed (Laasonen et al., 2012). My professional experience has been that student

with LDR often present with various combinations of memory and EF deficits which appear to impact their ability to learn to read (Potocki, Sanchez, Ecalle, & Magnan, 2017). For example, there are students who exhibit difficulty in their ability to hold and recall sequences of auditory information in their STAM. These students can struggle to sound out phonological sequences in unfamiliar words as the sequences often fade or jumble before they can be turned into words (Laasonen et al., 2012). There are students who have difficulty in simply holding and recalling sequences of visual information in their STVM (Michelle et al., 2015). This can impact correct letter sequence recognition which may lead to inaccurate decoding in reading or encoding in writing. There are students who in addition, or sometimes without either a STAM or STVM deficit, have deficits in their ability to cognitively manipulate auditory or visual information held in their short-term memory. This can lead to hesitancy in attempting unknown words when reading text, inaccurately decoding words or difficulties with comprehension (Oakhill, 2020). This is commonly referred to as a presentation of WM deficit (Alloway & Copello, 2013). WM deficit can present with or without evidence of deficits in EF such as attentional or focus difficulties or difficulties in ability to rapid automatic name (RAN) familiar words via retrieval from LTM (Cancer & Antonietti, 2018; Peng & Goodrich, 2020).

In my early career endeavours to support improvement in the ability of students with LDR to develop sight vocabulary, decode unknown words, read, understand, and enjoy texts, remedial education interventions were guided by the contemporary, theoretical understanding that the brain was basically hard wired by an early age (Merzenich, Van Vleet, & Nahum, 2014). If a physical component or function of the brain developed abnormally or suffered damage, it was believed the brain could not regenerate or rewire itself in response to medical or therapeutic interventions. As such many remedial education initiatives were based in the belief cognitive processing deficits, particularly those associated with storage and attentional

control, could not be neurologically repaired through remediation. Instead, strategies were taught to limit the impact of the neurological deficits so that learning could progress (Hock, Brasseur-Hock, Hock, & Duvel, 2017). Examples of typical strategies were encouraging and assisting students with STAM or STVM deficits to simply listen more effectively or to chunk small discreet units such as single letters or single sounds, into larger, unified wholes. These strategies aimed to reduce cognitive demand on short term memory processing and enhance cognitive storage capacity. Similarly, students were taught to develop personal mnemonics or memory aids so that retrieval from long term memory was enhanced by association. The employ of these compensatory strategies provided some recourse for learning to take place despite cognitive processing, memory, and attentional deficits. While these strategies were effective and are still widely used today to enhance learning potential, they did not remediate the underlying neurological basis for the cognitive processing and memory deficits contributing to the LDR. This observation is supported within research literature (Cirino et al., 2013; Scammacca et al., 2016).

As previously mentioned, it is also important to consider the affective factors which contribute to LDR. Within my own intervention teaching, I have often observed limited improvement in the reading self-efficacy (RSE) of the students with LDR during and post reading intervention programs. This is despite constant use of extrinsic rewards and reinforcement of small successes observed in the early reading skill abilities of students with LDR. Students with SLD often need to engage with intervention programs continually throughout their early years of schooling and while enthusiastic and bolstered by small successes initially, the constancy of their difficulties and their limited success, often results in continuing low RSE and limited improvements (Margolis, 2005).

Reading efficacy is discussed in McGeown, Norgate, and Warhurst (2012) as the judgement a person has about their own reading abilities. Schunk (2003) states that self -

efficacy is situated in the broader framework of social cognitive theory. This theory holds that human achievement is dependent on three interacting forces: personal behaviours, personal thoughts and beliefs, and external contextual conditions (Bandura, 1977, 1997). As early as 1977, Bandura suggested the activities a person chooses to engage in and the effort and persistence with which they do so is regulated by their self-efficacy. Data from international testing programs appears to support this contention. The report of the 2011Progress in International Reading Literacy Study (PIRLS) (Mullis, Martin, Foy, & Drucker, 2012) indicated there was evidence across multiple PIRLS studies from multiple countries that a student's attitude to reading is positively related to their achievement in reading. Students with greater RSE typically are better readers. As discussed above, I have certainly found evidence of this in my professional experience of students with LDR. I have also observed that students with LDR are very conscious of the progress of their peers which in turn also has a strong, negative influence on their RSE. This observation finds support in the research of Retelsdorf, Koller, & Moller (2011).

As described, there are many powerful internal and external forces working against natural success in reading for the student with LDR. The educationally based defence against these forces is the implementation of teaching and learning intervention strategies, techniques, and targeted reading programs. These teaching and learning interventions are quite variable but all similar in their purpose. Their aim is to address the educational impact of specific LDR rather than additionally and importantly, also addressing the neurological, developmental difficulties underlying the LDR. This is understandable given that scientific understanding has long held these neurological deficiencies to be immutable. That was until the discovery of neuroplasticity. The conceptual birth of neuroplasticity was quite pivotal and liberating for research and practice across many disciplines, not the least education (Hruby & Goswami, 2011). The doorway to the research-based development of effective reading

remediation programs aimed at the address of neurologically based deficits as well as cognitive processing deficits, seemed to be opening.

Research Context

Up until relatively recent times, mankind's knowledge of the physiology and function of the brain, particularly as it related to learning, was shallow and limited. Access to the internal functions of a living brain were ethically and scientifically problematic. Much of our early knowledge of living brain function was attained through mathematical and computational modelling (Friedman, Klivington, & Peterson, 1986). As previously discussed, the commonly held understanding of the brain being mostly hard wired by approximately six years of age, impacted the structure and purpose of educational intervention strategies and programs for students with LDR. The discovery of the brain's plasticity through developments in medical imaging and neurocognitive research has been revolutionary in scientific terms and certainly significant to education. Information about changes occurring in the brain as students learn, such as myelination, is increasingly shaping the way teachers operate within classrooms (Bailey & Pransky, 2014). In simple terms, myelin is a fatty substance that spirals around and protects the axons of a nerve cell or neuron. The axons are responsible for conducting impulses from one cell to the next. When we learn neurons get activated and myelination occurs. The myelin acts to speed up the impulses moving between neurons in the nervous system (Tomassy, Dershowitz, & Arlotta, 2016). It also prevents the brain from pruning or removing unused or infrequently used neural connections (Bailey & Pransky, 2014). Synaptic pruning is an important and highly necessary neurological process during critical periods of brain development (Neniskyte & Gross, 2017).

While there is an abundance of brain-based research of relevance to education, the enormous growth in research exploring the relationship of WM and EF to learning (de Jong et al., 2009) is of interest to educators in the field of special education and of relevance to this

study. Working Memory is one of the key cognitive functions which has attracted much research, particularly research into the training potential of WM as discussed in Morrison and Chein (2011).

Having earlier acknowledged strong research evidence of the connection of WM to learning and to reading success (Alloway & Copello, 2013), the research around the training potential of WM is highly relevant. There is growing body of research examining the training of WM and the relevance of this to education, particularly to reading intervention pedagogy. There have been very positive indications that WM function can be improved through training, and this can lead to gains in cognitive ability and educational attainment (Alloway, Bibile and Lau, 2013; Jausovec & Jausovec, 2012; Klingberg, 2010; Olesen, Westerberg, & Klingberg, 2003). There has been very little research evidence, however, of a significant and lasting transfer effect to reading improvement, more particularly improvement at the word reading level (Dahlin, 2011, 2013; Roberts et. al., 2016). This transfer of the gains made in trained WM to gains seen in WM dependent cognitive skills is referred to as a far transfer effect in research literature (Alloway et al., 2013; Hovik, Saunes, Aarlien, & Egeland, 2013). There is a continuing need for ongoing research around this problem of a lack of far transfer effect to academic improvement, particularly to the development of early reading ability.

Research Problem

As discussed above, the research problem explored in this current study is based in the knowledge that deficits in WM capacities and functions do impact reading skill development and research is indicating WM efficiency and capacities seem to be reactive to cognitive WM training. The specific problem being explored in this study is the lack of consistent, research-based evidence that trained improvement in WM functions can lead to or transfer through to enduring improvement in reading skills which rely on WM functions.

In Chapter 2, literature related to reading failure in the separate but inter-related areas of reading disability, WM theory, and reader self-efficacy will be reviewed.

In Chapter 3, research literature relating to reading and reading intervention pedagogy, cognitive WM training, and transfer of WM training effects to academic improvements, particularly reading improvements, will be reviewed. The chapter also reviews literature using or recommending WM training alongside educational interventions to improve reading improvement (Rabipour & Raz, 2012; Roberts et al., 2016).

The remainder of this chapter will establish the historical and contemporary relevance of this research problem, signpost the research questions, and the methodology employed within this current study before concluding with a discussion of the significance of engaging with this research problem.

The Contextual Relevance of this Research Problem

As stated above, the presentation of students who struggle to learn to read is not a modern phenomenon but a problem with a long and well researched history. It is also a problem which presents in classrooms worldwide and attracts political, public, educational, and scientific attention (Murnane et al., 2012; Reschly, 2010; Scammacca et al., 2016).

Reading Failure as a Political Concern

Whilst there is much debate around what constitutes effective 21st century learning, literacy and numeracy remain essential and much valued educational outcomes as recognised by Masters (2016). Within the contemporary, globalised world, literacy has taken on an important role as a performance indicator. It is viewed as a measurement of the quality and equity of education provided by the schools of any developed nation. This performance is measured through international, high stakes tests such as the Programme for International Student Assessment, (PISA). PISA is a triennial assessment of the performance of fifteen-year-old students in science, mathematics and reading conducted by the Organisation for

Economic Cooperation and Development (OECD). Australia's performance on these tests is highly visible to the world, not just to the 65 member and non-member nations of the OECD that make up 90% of the world's economies who participate in this study. This creates a high level of international transparency and makes national educational achievement, particularly achievement in literacy, a political concern, and media focus.

As public education in Australia is primarily the economic and political responsibility of the individual states and territories, it has been difficult for the Federal Government historically to impact national literacy and numeracy results to any significant degree. In the past 20 years we have seen three major federal government initiatives instigated to mollify this predicament.

In 2008 the Federal Government commenced a national literacy and numeracy testing program in the form of the National Assessment Program for Literacy and Numeracy (NAPLAN). The Australian federal, state, and territory governments annually scrutinise and compare the results of these tests of literacy and numeracy to guide and structure policy development and economic decision making. Since 2010, the NAPLAN results for Australia's ten thousand or so schools have been highly visible to all Australians and the rest of the world through the My School website. This has raised the importance and stakes of national results from a national level right through to the individual student level.

The second recent initiative has been the development and implementation of the Australian National Curriculum. With compliance to this curriculum strongly tied to ongoing, additional Federal Government funding for state and territory funded education, the Federal Government has created a pathway for impacting literacy and educational attainment standards. This also provides some perceived control over the future PISA and commensurate high stakes testing results for Australia.

A third significant development has been the move towards an inclusive model of education for students with disability and learning difficulty. In the contemporary educational setting, particularly within Australia, disability has a very broad definition as defined in the Disability Discrimination Act of 1992. This definition covers disorders or malfunctions that cause a person to learn differently to a person without that disorder or malfunction. Whilst the move to an inclusive model of education certainly addresses the important issues of educational discrimination and equity, it also addresses the statistical evidence that students with disabilities often have lower levels of reading ability than students without disabilities (Hock, Brasseur-Hock, Hock, & Duvel, 2017). The lower reading abilities of students with disability impacts the results of national testing programs and provides increased motivation for governments around the world to influence the educational outcomes of all students. This can and has been observed in Australia. Legislative and policy documents of successive Australian federal, state and territory governments provide evidence of government interest and investment in the educational outcomes of all students, including those with disability. The Disability Discrimination Act of 1992, the Education Standards of 2005, the Melbourne Declaration on Educational Goals for Young Australians, 2008 (Ministerial Council for Education, Early Childhood Development and Youth Affairs, 2008), and the recent review by the Victorian Government of their Program for Students with Disabilities (Victoria State Government, Department of Education and Training, 2016) exemplify this move to greater control over the educational outcomes of all Australian children.

Political intervention in education through policy and legislation for raising literacy standards, is not peculiar to Australia but observed globally. Silliman and Wilkinson (2013) discuss the educational implications of American legislation and policy such as the No Child Left Behind Act 2001 and the Common Core State Standards (CCSS) 2010. This discussion references performance on PISA and the importance of literacy skills for keeping the U.S.

workforce competitive in the world arena. The economic benefits of a literate society are obviously one of the prime motivators for political intervention in literacy education and as such provide validation for continued research such as this study, aiming to improve the effectiveness of school-based reading intervention pedagogy. Similarly, the social issues proven to be connected to low literacy achievement provide equally important support for this and similar research.

Reading Failure as a Social Concern

Ever since Gutenberg's fifteenth century invention of the printing press enabled the rapid and accessible spread of the written word throughout society (Faktorovich, 2019), mankind has needed to be able to read, understand, and utilise printed text. Education of the masses have become a necessity, not just a privilege.

Whilst Australia does have relatively high levels of literacy compared to many other countries as measured by the OECD; we also have low levels of literacy achievement in certain sectors. Low level literacy skill has a significant impact on a person's social standing and life's progression (Hernandez, 2011).

Based on the 2012 PISA results, the OECD estimated that 14% of 15-year-old Australian students lacked the reading skills required to participate adequately in the workforce (Masters, 2016). Low literacy levels feature strongly in the profile of 10 to 14-year-old juvenile offenders (Snow & Powell, 2012). Golding and Thompson (2014) report we have significant numbers of adults with low levels of functional literacy and "one in three Australians (30 per cent) have literacy skills at levels that make them vulnerable to unemployment and social exclusion in a modern knowledge-based economy and society" (p. 7). Whilst there can be negative impact on academic outcomes for students exposed to factors such as low socioeconomic status (SES) (Gerhardstein, Dickerson, Miller, & Hipp, 2012), the distraction of adolescent peer culture (Lynch, Lerner, & Leventhal, 2013), and the impact of

learning when English is an additional language (EAL) (Ardasheva, Tretter, & Kinny, 2012) many of these influences have been present in Australian social and educational settings for over fifty years. The continuity of these influences does provide strong argument for Australia's somewhat stagnating performance in international tests such as the PISA.

The acquisition of basic, functional literacy skills is highly desirable and necessary for purposeful and productive engagement in the complex social and economic interactions of the 21st century. In this context, the social relevance of this study for students with LDR is high as these students are certainly represented in the statistics around graduate students with low literacy levels.

Reading Failure as an Educational Concern

As stated above, the PISA result in reading in 2012, estimated that 14% of 15-year-old Australians tested, had inadequate reading skills. The NAPLAN results for Year 9 in 2012, appear to verify the PISA results. In 2012, 8.6% of Year 9 students who sat the tests, fell below the national minimum standard, (this percentage included students who were exempt due to low level intellectual function or newly arrived in Australia). An additional 8.2% of Year 9 students were not represented in this statistic due to withdrawal by parents on philosophical grounds (1.4%) or absenteeism (6.6%). There is no 2012 NAPLAN reading assessment data on these students and no indication of their achievement against minimum standards. Dempsey and Davies (2013) support the view that a portion of this percentage may have fallen below national minimum standard if they had taken the test. If this were so, the below minimum standard percentage could be higher than reported. This aside, the 2012 PISA results for Australia certainly raise concern around Australia's performance on these tests in comparison to some of the other top performing countries (Masters, 2016). This concern has not abated as subsequent performance on PISA has continued to see Australia's global rankings in reading and science fall (OECD, 2019).

The NAPLAN longitudinal data also provides evidence for concern re the address of reading failure within our Australian schools. It would appear from the collated NAPLAN data in Table 1.1., that seven years spent within Australian schools between Years 3 and 9 does little to lower the number of students falling below minimum reading standard by Year 9.

Table 1.1.

Comparison of the Year 3 and Year 9 Percentage of Students At or Above Minimum Standard and the Mean Scale Score Achieved by Six Cohorts of Students 2008 – 2019, in the Australian NAPLAN Reading Test.

Calendar Year of Year 3 Student Reading NAPLAN Test	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Percentage of Year 3 Students At or Above National Minimum Standard in NAPLAN Reading Test	92.10%	93.70%	93.90%	93.80%	93.60%	95.30%
Year 3 Mean Scale Score (NAPLAN Reading)	400.5	410.8	414.3	415.7	419.6	419.1
Calendar Year of Year 9 Student Reading NAPLAN Test	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Percentage of Year 9 Students At or Above National Minimum Standard in NAPLAN Reading Test	92.10%	92.30%	92.80%	91.70%	93.40%	91.80%
Year 9 Mean Scale Score (NAPLAN Reading)	580.4	580.2	580.8	580.9	584.1	581.3

Note: The statistics for each cohort as tested in Year 3 and Year 9 are presented vertically.
Compiled from data sets: http://www.nap.edu.au/results-and-reports/national-reports.html

The percentage of students below the minimum standard in reading in Year 9 is consistently greater than the percentage of students below the minimum standard for reading, for the same cohort when they were in Year 3. The mean scaled scores for the six cohorts shown in Table 1.1., also validate this concern. Each successive cohort in Year 3 achieved a slightly higher mean scaled score than the previous Year 3 cohort, indicating there was

growth in the successful teaching of reading and possibly, the address of LDR. The concern arises however when you look at the mean scaled scores for the same cohorts when tested in Year 9. The mean scaled scores show very little variability and very little growth. Although Year 3 and Year 9 obviously have different minimum standards and year level cohorts do vary in their ability as indicated by the high achieving cohort 2012-2018, the overall relative consistency in the mean scaled score of reading at Year 9 does raise educational concerns of relevance to this study.

While there has been some growth in national achievement in reading as noted in the Year 3 results above, the statistics relating to the achievement levels of Australian students indicate the need for greater growth and consistent improvement. Given the need to focus on the student to improve achievement, as discussed previously, it is noteworthy that the Australian Government in 2018 began channelling increased resources to the support of students with disability. The distribution of funding is based on annual data collected in a new, compulsory census completed by all Australian schools in August. The census references the definition of disability set out in the Disability Discrimination Act 1992, as discussed previously. The nationally consistent collection of data on school students with disability (NCCD) is an authentic attempt by the Australian government to channel funding to where needs have been identified and are being catered to by schools (Australian Government, 2020). With increased resourcing in reading intervention, the need for research informed practice is critical. Reading intervention programs need to be informed by the latest research in literacy intervention pedagogy if they are to effectively target the academic and developmental characteristics of students with LDR.

Reading Failure as a Concern within Reading Pedagogical Discourse and Practice

Reading pedagogy worldwide, has been historically buffeted between what are heralded as philosophically opposed arguments regarding best practice in teaching reading.

On one side there are those who advocate a bottom up, skill-based approach. Reading is taught through a progressive build of core reading skills - phonics being central- which can be used by the reader to unlock the code of the language. On the opposing side sit the reading pedagogies which approach the teaching of reading through the making of meaning. The Whole Language Approach (Hempenstall, 1996) and the Language Experience Approach (Thorn, 1969) are two approaches within this philosophical framework which advocate that reading is best taught from the starting point of experience and meaning. Through repeated exposure to oral language and written texts the young reader's interest in reading is captured and reading skills developed through timely skill instruction.

There is merit in both approaches which have the same purpose and components, however their delivery processes are quite opposed. Ironically, much valuable time has been expended in debate rather than design of effective, eclectic reading instruction (Baumann, Hoffman, Moon, & Duffy-Hester, 1998). The importance of both skill acquisition and meaning making within the actual function of reading was first recognised by Gough and Tunmer (1986) when they proposed the Simple View of Reading. This view held that reading consisted of two essential and equally important components: decoding and linguistic comprehension. This simplified model of reading did not deny that reading is a complex, cognitive process nor did it advocate for any one approach, rather simply, that effective reading instruction should incorporate both decoding and linguistic comprehension. While both the Simple View of Reading (Gough & Tunmer, 1986; Hoover & Gough, 1990) and the report of the National Reading Panel (2000) might have been considered landmark studies for the clarity and evidence base they brought to this historical pedagogical discourse, subsequent literature addressing the shortcomings of both, suggests otherwise (Garan, 2001; Otaiba, Allor, Werfel, & Clemens, 2016). A review of the literature around this ongoing debate will be discussed in Chapter 2.

What has been encouraging and pertinent to this study, has been the swing in recent times to a more balanced approach to the teaching of reading incorporating phonological, visual, orthographic, and semantic skill development. While this approach is successful for most students, those with perceptual, memory or attentional deficits often continue to struggle. This can be bewildering and frustrating for teachers who often feel under-resourced to identify or address the underlying learning issues. In the light of growing understanding of neuroplasticity and the ability of cognitive training programs to improve processing capacities, there may be potential for the inclusion of such programs within classroom reading pedagogies, as an additional resource for teachers (Elosúa, García-Madruga, Vila, Gómez-Veiga, & Gil, 2013).

While it remains important for educational research into learning difficulties to explore the impact of environmental factors such as teacher effectiveness and educational resourcing (O'Mara, 2014) and behavioural concepts such as metacognition (Knight & Galletly, 2005) and self-efficacy (Lee & Jonson-Reid, 2016), there is growing research interest in transdisciplinary research to inform pedagogical change and development in our schools. A review of current research around the address of learning difficulties will be addressed in Chapters 2 and 3,

Reading Failure as a Concern for Inclusive Education

How best to address the instructional needs of young students with learning difficulties is an educational research question which historically has attracted worldwide debate and led to the implementation of a parade of research-based, pedagogical initiatives (Vaughn, Wanzek, & Denton, 2014).

At an institutional level, there has been a definite trend away from a segregated model of special education. Previously, students with disability or severe learning difficulty were placed in special schools or classes specifically designed and resourced to meet the

exceptional learning needs of the cohort. We are now in the age of Inclusive Education. Students with disability and learning difficulties are encouraged to integrate into general education as it is held that with appropriate identification and effective instruction students with significant deficits can be taught to read (Johnston, 2011; Pullen & Cash, 2011; Scanlon & Vellutino, 1997). Classroom teachers are required to cater to the individual needs of students without marginalising those with needs outside of the norm (Florian, 2014). In some countries, additional non-teaching staff are placed within classrooms to provide support for teachers working within this highly intensive and demanding model of educational delivery. This is an effective resource strategy but one which lacks uniformity in funding across education sectors and between states and territories in Australia.

The Response to Intervention (RTI) model for improving the learning outcomes of students who present with difficulties in keeping pace with expected benchmarks in learning, is a framework which has progressively been adopted by governments and education departments in many countries including Australia. The three-tiered RTI model is built on the classroom teacher at Tier 1 being resourced to identify and provide classroom-based interventions to address any early indications of learning difficulty (Vaughn et al., 2014). For this model to be effective it is necessary that classroom teachers have:

- confident understandings of how students learn,
- research-based understandings of the presentation of a range of learning difficulties,
- competent ability to implement effective methodologies for teaching cognitive based skills such as reading to students with LDR.

Can we be confident that teachers are being pre-service trained and continually, professionally upskilled to undertake these professional expectations and exhibit this level of specialised competency? Skues and Cunningham (2011) argue that this is not happening. There is a

need for more research and review of the RTI model such as that provided by O'Connor, Sanchez, & Kim (2017). Equally important and of relevance to this study, is the need for research informed reading intervention programs utilised in schools. These intervention programs need to be informed by current research relating to the cognitive processes involved in reading such as WM and other executive functions.

Reading Failure as a Concern Within Cognitive Research

For students with learning difficulties, particularly those with a LDR, who continue to fail or struggle to learn to read despite having been provided with repeated, targeted, educational interventions, one might suspect insight into their learning difficulty may be revealed through cognitive research.

There is certainly a rapidly growing body of evidence linking deficits in cognitive processing areas to deficits in literacy skills. This is not surprising given cognitive processing is involved in the development of reading skills in beginner readers right through to those of the skilled, independent reader (Hruby & Goswami, 2011). In beginner readers, it has been proven that individual differences in phonological awareness are linked to individual differences in word – level reading (Wagner et al., 1997). Phonological awareness relates to one's ability to identify sound structures in oral language (Wagner et al., 1997). Phonological processing deficits have been closely linked to literacy learning difficulties (Siddaiah & Venkatesh, 2014) but as Troia, (2013) rightly states they are not always the sole deficit. Deficits in rapid automatised naming (RAN), can impact word naming ability (Georgiou, Parrila, Cui, & Papadopoulos, 2013; Wolf, Bowers, & Biddle, 2000), word reading fluency (Jones, Snowling, & Moll, 2016; Norton & Wolf, 2012) and reading comprehension (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Araujo, Reis, Petersson, & Faisca, 2015). Rapid automatised naming (RAN) relates to the ability to name visual items which are familiar, as rapidly as possible (Georgiou & Parrila, 2020; Norton & Wolf, 2012). Working memory

(WM) has been identified as a critical cognitive process in learning, particularly in learning to read (Brandenburg et al., 2015) and specifically in learning to decode and comprehend (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014). Given decoding and linguistic comprehension are the two core skills in reading comprehension according to Hoover and Gough's (1990) *Simple View of Reading*, it is not surprising that Gathercole, Alloway, Willis, and Adams (2006) found that the severity of difficulties children encountered in both reading and mathematics was closely associated with their level of working memory function.

As will be discussed in chapters 2 and 3, research is providing very strong support for links between deficits in WM and difficulties in the acquisition of reading skills and abilities. There is likewise, an increasing quantity and confidence in transdisciplinary research around neural plasticity and the brain's ability to form new connections and reorganise itself for learning. In what could be viewed as a progressive linking of these two research areas, there has been an emergence and growth in research interest into the possibilities of prompting academic improvement via cognitive training of WM.

Reading Failure as a Concern to Cognitive Working Memory Training Research

There has been quite specific neurobiological evidence linked to adaptive cognitive training of WM. In 2004, Olesen, Westerberg and Klingberg identified that after WM training, there was increased brain activity in the prefrontal cortex, the area associated with WM activity. McNab et al. (2009) identified that dopamine, a neural substance with a central role in working memory function, was more abundant after 14 hours of WM training. Likewise, the body of research-based evidence supporting the efficacy of adaptive computer-based training in expanding the capacity and function of WM is also substantial and expanding (Dahlin, 2011; Klingberg 2010; Loo, Bamiou, Campbell, & Luxon, 2010; Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2016).

Contrarily, the evidence of significant transfer of trained working memory function to gains in cognitive WM based learning processes has not been as significant. In a review of this research landscape, Morrison and Chein (2011) concluded that core training of WM is associated with improvements in a variety of areas of cognition, including reading comprehension but also cautioned the need for much more research in this area. In a recent review study and meta-analysis, Peijnenborgh et al., (2016) identified evidence WM training produced a small, significant improvement on tasks involving decoding when subjects were tested immediately after training. The conclusions out of this review encouraged continued engagement with this research problem as there was promise of significant and lasting performance improvement in students with learning difficulties. They also made many suggestions for change in the research design so that greater clarity about effect could be drawn for different subsets of learners such as those with non-verbal learning difficulties or those with verbal learning difficulties.

Several research studies reviewed in preparation for this study were critical of a research design where adaptive cognitive training was the only intervention employed. Recommendations were made for an eclectic intervention where intensive instruction was provided in addition to cognitive training. To that end this study was designed as a transdisciplinary study involving the combined use of cognitive WM training and reading intervention pedagogy. It is designed to add to this wider field of research and contribute to the quest for greater effectiveness in reading intervention pedagogy.

Reading Failure as a Transdisciplinary Research Problem

While it is essential that both scientific research and studies in education continue to nurture and explore discipline specific and specialised research-based knowledge and practice, there may be benefit in collaboration and sharing of knowledge (Goswami, 2014). Collaboration is recognised as a highly valued 21st century teaching and learning skill. It also

appears to be increasingly utilised in research as a means of growing discipline-based knowledge as well as interdisciplinary understandings. This is aptly reflected in Friedman, Klivington and Peterson (1986) in their assembly of cross-disciplinary writings from the fields of neuroscience, cognitive psychology, and education.

The benefits of a closer alignment between cognitive psychology and the study of education in research endeavour was discussed by Baddeley (2006). He noted that both fields of knowledge often pondered mutual problems, sharing a similar focus in their individual research pursuits and yet the two fields of research were largely dichotomised. The divide between discipline-based research endeavour as well as the distinct possibility of mutual benefit for education and cognitive neuroscience is clearly evidenced in de Jong et al. (2009) who conclude their work with the prediction that the future may witness the birth of a new, unified research trajectory.

In a review of evidence for computer-based training in children with language and reading related learning difficulties, Loo et al. (2010) made the following conclusion. They suggested that while computer based auditory training may remediate auditory processing and phonological deficits, computer-based training may need to be followed by subsequent explicit training in reading and spoken language skills to achieve remediation of academic skills such as reading. A recent longitudinal study of the effect of working memory training in children with low working memory by Roberts et al. (2016) indicated little evidence of improved academic outcomes. The report did go on to suggest there may be benefit in pairing cognitive training programs such as the Pearson owned and distributed working memory training program, Cogmed (http://www.cogmed.com.au/) with educational interventions. Contemporary research advocates for transdisciplinary research in this area. This is yet to be realised (Nevo & Breznitz, 2014).

In terms of the educational intervention which could be coupled with adaptive cognitive training, certain teaching approaches have been found to be more effective than others for students who have difficulty in learning to read. Ritchey (2011) lists three central features of effective evidence-based reading interventions: explicit instruction, systematic development, and intensive instruction. Research evidence outlined in the discussion to this point, indicates the need for development of phonemic awareness, phonological decoding skills, rapid word recognition and basic comprehension strategies within this recommended instructional framework.

With respect to the type of adaptive cognitive WM training program which could be coupled with a reading intervention program it would be necessary to identify programs which are informed by the latest understandings of WM. They would also need to be an accessible and practical resource for use within an educational setting.

One final major consideration for future transdisciplinary research would be around how the two types of intervention (WM training and reading intervention) can be provided to students to achieve maximum transfer effect to improved academic outcomes.

Research Purpose

This research study has been informed by the latest research literature around reading difficulties, the provision of educational reading intervention, and the effectiveness of using adaptive, cognitive working memory training to assist in the educational address of LDR. It is specifically guided by the research informed understanding that cognitively trained WM gains and reading skills acquisition are both developmental, incremental processes which can result from intensive, repetitious exposure to carefully sequenced, incremental, contingent training. The study is purposed on contributing to both theoretical understanding and pragmatic, interdisciplinary, reading intervention program development.

Research Aims

The primary aim of this research is to identify if there will be any significant differences in the reading skills, working memory capacities and reader self-efficacy of students with both LDR and WM deficit if WM training and school-based reading intervention is received simultaneously as opposed to sequentially. One half of the research participants will participate in a simultaneously delivered program of cognitive WM training and reading intervention. The second half will complete a cognitive WM training program prior to a reading intervention program. This will constitute a sequential format of delivery.

The secondary research aim is to contribute to the closing of a research gap observed within literature where WM training and intensive reading instruction have rarely been provided simultaneously within a targeted, primary school setting. It has been conjectured that simultaneous training may contribute to observable difference in the impact of WM training on academic outcomes in reading.

Research Questions

As will be discussed in Chapters 2 and 3, research interest in the interrelationship of LDR, WM and WM training appears to be expanding. Available research literature is varied in terms of philosophical and theoretical framework, as well as research purpose, context, and methodology. To address these considerations, this transdisciplinary study was designed to be comparable to a sector of LDR research as well as a sector of adaptive, cognitive WM training research relevant to LDR. As discussed in Chapter 4, this study was also designed as a manageable study set within a functioning primary school.

The research questions deliberately narrow the foci of the research to three main variables: word reading ability (WRA), working memory (WM) abilities and reader self-efficacy (RSE).

Research question one addresses a sector of research indicating WRA to be less responsive to WM training than other reading skills such as comprehension. (Refer discussion in Chapter 3).

Q1. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence word reading ability outcomes?

Research question two addresses the effect of WM training on a range of WM abilities and aspects of EF reflective of Baddeley and Hitch's (1974) multimodal construct of WM. Baddeley's model of WM is the preferred theoretical framework for WM, used to frame this study and is discussed in Chapter 2.

Q2. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence measures of working memory abilities?

Research question three acknowledges the powerful influence RSE can have on the effectiveness of reading intervention programs. The act of reading is not simply a learned, psychomotor skill but is also a human behaviour. Reading success is influenced by behavioural attributes such as motivation, confidence, anxiety which can all be regulated by a student's RSE (Refer to discussion in Chapter 2).

Q3. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence reader self-efficacy?

Research Design

Methodological Framework

The research questions for this study have been framed by a positivist ontological worldview and objectivist epistemological preference. The study also sits very comfortably

in a pragmatic paradigm due to its strong focus on identifying possibilities for improved effectiveness in reading intervention pedagogy.

Due to the time and resource limitations of this doctoral research study, and the significant ethical concerns involved in planning for research actively involving young children, it was decided to avoid the somewhat logical choice of an experimental methodology. In reviewing various alternative research methodologies, the choice of methodology was influenced by the researcher's preference to utilise both qualitative and quantitative data. The previous professional experience of the researcher repeatedly revealed an over reliance on quantitative assessments to be problematic when assessing children. The results might not always reflect a student's true ability and potential due to the student's presentation at time of testing. Consequently, a balanced approach to the assessment of students using both quantitative measurements and qualitative data was preferred. The methodology selected for this study enabled this approach to data collection and analysis. The selected methodology was Case Study as defined by Yin (2014). The method employed was also one defined by Yin: Multiple Case Study with Embedded Units of analysis.

Research Method

The multiple case study with embedded units of analysis (Yin, 2014) is a research method which allows for research to be carried out within the real life setting of a classroom. It involves the collection and analysis of both quantitative and qualitative data and is an explanatory form of case study focused on the examination of cause and effect. Yin (2014) describes it as a design which is useful for program evaluation. As this research is aimed at examining the effectiveness of a transdisciplinary approach to reading intervention it did present as a perfect choice of research method.

An appealing aspect of this method is the robust research design which is structured to produce two forms of replication in the data results. The design is aimed at the observation of

literal replication in the results for both groups of students undertaking each of the two intervention formats. The study also aims to identify theoretical replication. Based on theoretical prediction, the reading improvement results of the two case studies receiving one intervention format will be similar to each other but different to the other two case studies receiving the different intervention format. While the results of this research will not be statistically generalisable, Yin contends that theoretical replication can contribute to the formation of analytical generalisations or the ability to generalise to other situations based on theoretical similarities. This adds a high level of validity to this research design which is detailed and discussed in depth in Chapter 4.

Significance of this Research

Reading difficulty and low levels of national literacy are of significant concern not just at the level of the individual learner but at all levels of society and across the globe. The identifiable and significant body of research addressing this learning difficulty, over many decades, speaks to the level of significance any additional theoretical understandings and practicum advances would add to the landscape.

Political Significance

As outlined earlier there is strong statistical evidence that a significant percentage of school aged students in Australia have difficulty in learning to read. Australian literacy levels are strong, although not growing at rates comparable to other top-ranking OECD countries (Masters, 2016). If research such as this study can identify more effective educational reading intervention methodologies, this may work to mitigate against the persistent level of below minimum standard achievement in reading observed in NAPLAN reports over many years. This could have flow on consequences politically and socio-economically.

Socio-Economic Significance

Students with difficulty in the acquisition of literacy find learning very difficult and often unrewarding. Over time this can impact their motivation to engage in learning and school. Students with LDR and a WM deficit feature persistently amongst the percentage of students in most cohorts who begin to show signs of learning difficulty quite early. These students continue to struggle through primary school and into lower secondary school. They feature highly amongst early school leavers, the unskilled workforce, and amongst the unemployed (Child Family Community Australia, 2013). The psychological and emotional impact of continued academic failure and resultant restricted life choices is significant and far reaching. Low and ineffectual literacy abilities can lead to mental health issues and often significant misbehaviour which in time can lead to criminal activity (Saldanha, Siddaiah, Veerappa, Ramachandra, & Padakannaya, 2014).

Even in this age of computer assisted learning, and technology driven employment opportunities, these students can be restricted in their level of engagement and success either because of their limited skill set, poor self-esteem, weak self-efficacy, or the frustrations generated by the very technology designed to assist them (Florian, 2014). Through no fault of their own they can become a substantial drain on the resources of the community and the nation, possessing very little power or personal resources for self-help (Buckingham, Wheldall, & Beaman-Wheldall, 2013).

It is anticipated this research will add to the theoretical understanding of effective reading remediation and the contribution working memory training might play in improving the effectiveness of reading intervention programs. To that end, it is hoped that this research will contribute to limiting the cycle of failure sparked at an early age through reading failure.

Educational Significance

Without a systematic and concerted effort to provide initial training, ongoing support for implementation, and social policy support at the state and district level, the evidence generated from quantitative research in special education will lie fallow in the journals in which it is published. (Odom & Lane, 2014, p385)

The current trend towards inclusive models of special education necessitates that classroom teachers are equipped to successfully work within this model to achieve world class results for all students, according to student potential. Teachers require the knowledge, skills, and resources to execute this at an effective and manageable level (Vaughn et al., 2014). Students with working memory deficits and or reading difficulties are very time, effort, and resource intensive. They require frequent instructions, pacing of work tasks, task and behaviour regulation, reassurance and social/emotional support, completion of individual plan documentation, and continual follow up with families and support professionals.

The provision of additional specialised teachers, specialised equipment, program resources and professional training for staff are just some of the additional financial and planning constraints placed on schools required to meet the additional learning needs of students with learning difficulties and achieve highly on national testing programs. Research and development are required to provide teachers with effective ways to identify the needs of individual students and to provide appropriate interventions. This research forms part of this process as it seeks to identify an effective way of addressing reading difficulty in students with deficits in WM.

Transdisciplinary Research Significance

This research was deliberately designed as a transdisciplinary study because it aims to draw together and contribute to research in cognitive science and education around reading intervention pedagogy and adaptive, cognitive WM training. In pursuing this aim it is hoped

this study contributes to the quest for increasing effectiveness in reading intervention in schools whilst contributing to ongoing research in both cognitive science and education as well as highlighting the unique advantages to be accessed through transdisciplinary research.

Summary

Teachers for centuries have acknowledged and responded in various ways to students who encounter difficulty in their learning. Whilst it is important for students to acknowledge and work towards overcoming learning challenges, it is the teacher's role to assist students to do so by manipulating the learning and teaching environments to facilitate success and growth in learning.

Difficulty in learning to read is a significant problem for many students and often it is accompanied by deficits in WM which impact across many aspects of their learning and daily functionality. There has been promising research in recent years into the potential of cognitive WM training but to date there is very little evidence that this training can effect change in learning outcomes.

The purpose of this research is to identify if there would be increased evidence of a transfer of trained WM improvements to reading improvements if WM training were undertaken at the same time as a reading intervention program, within a school environment.

Chapter 2

Reading Disability and Working Memory

The more that you read, the more things you will know
The more that you learn, the more places you'll go.
(Seuss, 1978)

Reading disability is a pervasive and debilitating phenomenon not just for students learning to read but for society (Paul & Clarke, 2016; Reynolds, Wheldall, & Madelaine, 2010; Yates, 2012). This learning disability can contribute to low student self-esteem (Holopainen, Taipale, & Savolainen, 2017), classroom inattentiveness and disengagement associated with antisocial behaviours (Turunen, Poskiparta, & Salmivalli, 2017) and broad based, minimal, laboured academic progress (Cunningham & Stanovich, 1997). The impact on students and the school setting can be wide-ranging but there is also a flow on effect on society. This is highlighted in Daniel et al. (2006) where a higher incidence of suicidal ideation, suicide attempts, and school dropout rate was identified in 15-year-old American students with poor reading ability than in similar aged students with normal reading ability. Similarly, Reschly (2010) identified a strong connection between poor reading ability and high school dropout rates. Pape, Bjorngaard, Westin, Holmen, and Krokstad (2011) identified a strong association between adolescent students with reading and writing difficulties, and welfare dependency later in life.

The persistent and prevalent presentation of reading disability has attracted a long history of research interest. Shaywitz (1998) indicated dyslexia or specific reading disability was one of the most commonly and carefully researched learning disorders, citing its prevalence as ranging from 5 to 17.5 %. These statistics remained unchanged in 2014 (Kar, 2014); however, there is some variability noted in literature from specific countries. In 2014, 22% of secondary school entry level students in the United Kingdom had less than age-appropriate reading skill (Middlemas & Easby, 2014). Based on the 2012 Programme for

International Student Assessment (PISA) results, the Organisation for Economic Co-operation and Development (OECD) estimated 14% of 15-year-old Australian students lacked the reading skills required to participate adequately in the workforce (Masters, 2016). In the United States of America, less than a third of 14-15-year-old students met the required grade level of reading proficiency (Institute of Education Sciences, 2013). An additional observation from the research literature is the indication this learning difficulty is not specific to any language; however, there is variance in incidence statistics according to the level of transparency of the orthography of a language (Ziegler & Goswami, 2005). The transparency of an orthography is explained by Landerl et al. (2013) as the level of consistency in how the orthographic symbols of a language represent the sounds of that language. For the purposes of this study, the focus of this review is solely on students learning to read English.

Establishing the Theoretical Framework of This Review

The ensuing discussion is provided to scope and encapsulate the areas of research pertinent to and implicit within this current study and literature review.

As discussed in Chapter 1, there are many underlying and contributory reasons why a student may struggle to learn to read at an expected rate of progress. These reasons can persist despite expenditure of reasonable levels of effort by all stake holders in the process: teacher, student, parent, or caregiver. There may be deficiencies in intellectual capacity, sensory deficits, physical disabilities, developmental delay, motor difficulty, socio-economic, or cultural disadvantage. Students with these additional and oft causative presentations are certainly represented strongly amongst students with a learning difficulty in reading (LDR) however these cohorts of students are not the central focus in this study. The address of reading difficulty in these student cohorts, within schools and society in general, is largely transparent, accessible, targeted and within realistic parameters set by the presenting comorbidity, potentially attainable. Given targeted and intensive educational and behavioural

management interventions, significant gains can be made in ameliorating reading deficits. On the other hand, in the absence of obvious socio-economic, behavioural, cognitive, or sensory deficits, students with LDR and a working memory (WM) deficit, are not so easily addressed and hence are the focus of this study.

The presentation of LDR in addition to WM deficits is often typified by, but not always uniquely matched to, a diagnosis of Specific Learning Disorder (SLD) in reading (American Psychiatric Association, 2013). This learning disorder is a neurodevelopmental disorder which hinders a student's ability to learn basic foundational academic skills such as those required in reading, writing and mathematics. Furthermore, it cannot be attributable to specified disorders or deficiency conditions and must have persisted for over six months during which time there has been minimal response to targeted intervention (Tannock, 2014). The examination of literature around WM and its relationship to LDR, highlights the need to broaden the research lens wider than students with a diagnosis of SLD, as WM deficit is a comorbidity in many learning disabilities where reading difficulty is manifested. One of the more universally reported findings within this field of research is that WM deficits are implicit in reading difficulties (Nevo & Breznitz, 2014; Peng et al., 2018; Swanson & Kong, 2018).

The researcher's motivation for this specific interest in WM is based on professional experience within the field of special education where the address of LDR has been thwarted or frustrated at best by the omnipotence and omnipresence of WM deficits. As the literature reviewed within this chapter will attest, there is a broad, cross disciplinary research interest in WM as it is a critical cognitive process involved in many aspects of human function, including learning (Cowan, 2014).

One of the central reasons for this intense research scrutiny within and around the WM theoretical framework has been the identification and growth in understanding of the

malleability of the physical structures and cognitive functions of the brain (Dahlin, Nyberg, Bäckman, & Neely, 2008; Holman & de Villers-Sidani, 2014; Klingberg, 2012). The improvement potential postulated by neuroplasticity has ignited research imagination and motivation. This has resulted in a plethora of research of varying credibility, worth, and educational relevance (Hulme & Melby-Lervåg, 2012). As a critique of this literature in Chapter 3 will indicate, this field of research is complex, diverse, rapidly expanding, and contentious. However, there is one quite significant and pertinent debate within this research spectrum, which has contributed significantly to the conceptualisation of this research study. This is the debate around the efficacy of WM training in improving academic performance, particularly in addressing LDR. The literature in this area is currently quite divided and thus presents opportunity to contribute through educational research to the theoretical and practical understanding of best practice in reading intervention pedagogy involving WM training.

One further phenomenon which is noticeable in the literature pertinent to the use of cognitive training of WM to improve academic performance, is that to date much of the research has been isolated within various discipline based, theoretical silos: Neuroscience, Cognitive Science, Behavioural Science, and Social Science (Wener & Archibald, 2011). There appears to be limited studies which have been designed and implemented by transdisciplinary teams, particularly teams inclusive of teachers with practical experience in special education. Whilst it is important for all schools of theory to continue to develop theoretical understanding within pure disciplines, I would argue that this research problem is a transdisciplinary problem. For truly effective educational outcomes which will inform and change educational practice, it is one which should be explored in a transdisciplinary manner.

This transdisciplinary focus will also extend within this study to consideration of the mediating influence of self-efficacy on the impact of either educational or cognitive training programs designed to address LDR and deficits in WM. A brief review of research literature

exploring the relationship of self-efficacy and LDR will be presented in the final section of this chapter.

Literature Review Structure

As signposted, the literature review for this current study was by necessity broad and extensive, requiring the discussion to be divided into two chapters. In this chapter there is a review of:

- theoretical understandings around LDR,
- theoretical understandings of WM,
- the relationship of WM to LDR and
- the relationship of self-efficacy to the success of reading intervention initiatives.

In Chapter 3 there is a review of:

- contemporary theories of educationally based reading intervention pedagogy,
- literature around cognitive training of WM,
- literature investigating training WM for improvement in reading skills,
- literature which supports a need for transdisciplinary research to close gaps and progress the development of a transdisciplinary, theoretical framework, and
- literature which establishes the theoretical significance of the proposed research study and signpost implications for improved practice in reading intervention programs.

Literature Review Process

Due to the transdisciplinary nature of the proposed study, it was pertinent to conduct a review of literature across several disciplines. In working through this process, it was necessary to commence the acquisition of an evolving science-based vocabulary, and to establish bedrock understandings of various scientific theories and concepts discussed within many of the studies investigating the structure, function, and training of WM.

The literature searches completed for this review were undertaken between March 2016 and March 2020. The data bases used for this search were ERIC, EBSCO, Science Direct, ProQuest Central, ProQuest Education, Sage, SpringerLink.

Search terms employed across the disciplines of Neuroscience, Cognitive Science, Psychology, and Education were:

- Working Memory Definition or Structure or Theory
- Working Memory Deficit
- Training Working Memory
- Executive Function
- Cognitive Load Theory
- Reading Difficulty
- Reading Comprehension Difficulty
- Word Reading Difficulty
- Reading Intervention
- Teacher Effectiveness
- Self-Efficacy and Reading Difficulty

Searches were restricted to peer reviewed articles written in English or at least accessible in English. Searches were refined using various filters such as:

- children not intellectual difficulties,
- children and reading difficulties,
- children and reading difficulties and working memory,
- peer reviewed journal articles published within the past 10 years, and
- peer reviewed journal articles published in the past 5 years.

The refinement in publication date was necessary in the searches into WM training as any form of research into the structure and function of the brain has become extremely

dynamic. The development of non-invasive techniques such as functional magnetic resonance imaging (fMRI) has allowed science to map and measure brain activity. For the purposes of this research, it was extremely critical and necessary to keep abreast of latest findings and developments in theoretical understandings of both neural form and function.

There were two main limitations within this literature review. Firstly, the wide variation in vocabulary used in different sciences to discuss the concept of WM may have resulted in articles of relevance not having been identified within the searches completed to date. Secondly, restricting the search to articles accessible in English may also have limited access to pertinent research.

Theoretical Understandings Around Reading Difficulties

The citation of statistical evidence of reading disability amongst adolescents in the introduction of this chapter, raises the question of whether most adolescents presenting with poor reading skills have carried this difficulty with them throughout their school journey? There is a body of research into a phenomenon referred to by Leach, Scarborough, and Rescorla (2003) as late emergent reading disabilities (LERD) where reading difficulties appear to manifest themselves around Grade 4. A study of this phenomenon by Etmanskie, Partanen, and Siegel (2016) concluded that most students appear to recover from this slump, in terms of their reading comprehension skill. Of relevance to this discussion, was the finding that participants with poor word and pseudoword decoding abilities did not experience a similar improvement. There was indication within this specific cohort of the study participants, that their word reading deficits were often traced back to poor working memory evident from an early age. This early emergence of word reading difficulty is echoed across much of the LDR literature thus validating the need for early identification and intervention (Reynolds, Wheldall, & Madelaine, 2010). It also provides strong support for ongoing

research into why students continue to encounter these early reading difficulties and more particularly, the relevance of WM deficits to this discussion.

As will be highlighted directly, the literature search around LDR clearly discusses several alternative, key causal factors for this learning difficulty. In my review of these factors, WM deficits constantly surface as a contributory element. The apparent pervasiveness of WM arises from the reality that there are several recognised and contested theoretical models presented in literature for the construct of WM. The studies of LDR reflect this diversity in current understanding of WM and how it impacts learning and learning to read. I will examine the specific theoretical landscape around WM after initially focusing on the key causal factors for reading difficulties observed within literature on LDR.

Causal Factors of Reading Difficulty

While Hoover and Gough (1990) distilled the act of reading to two core component skills of decoding and linguistic comprehension, the cognitive function associated with both skills is quite multifaceted. Reading is recognised as a complex cognitive activity which in an alphabetical, opaque orthography such as English, has long been discussed as involving an interplay of subsets of highly interdependent skills (refer Moats & Lyon, 1997). In a very minimalistic representation of the cognitive processes involved, reading requires an ability to:

- Discern and differentiate between the sounds of the language (phonological awareness- a subskill in phonological processing).
- Learn and recognise the symbols used to represent the sounds of a language (orthographic awareness).
- Map the symbols of the language to the sounds of the language (phonological decoding skills – involving several subskills in phonological processing).
- Associate meaning to words (comprehension skills).

- Develop automaticity in a multi-tier, multi-faceted process to generate enough fluency for the reader to build understanding of the text and retain interest in the overall process (commonly associated with rapid automatised naming (RAN)).

As the following analysis of research literature in LDR will attest, these cognitive processes are often the sole or selectively combined areas of interest in most of the research into LDR. Inevitably, within most of these discussions, there is mention of the influence of some or several subsidiary WM components.

Phonological awareness deficits. Throughout decades of research into LDR, phonological awareness has continued to be identified as a very strong predictor of reading success (Adams, 1994; Kudo, Lussier, & Swanson, 2015; Savage & Frederickson, 2006; Wagner et al., 1997). A significant subset of research in this area has examined the impact of auditory processing deficits (APD). There has been interest in identifying if phonological processing deficits are the primary cause of reading difficulty or secondary to deficits in the processing of acoustic input from either verbal or nonverbal sources such as in the process of sub-vocalisation. A recent study of 21 adolescent and young adults with dyslexia in Germany identified that while one fifth of the participants did not show APD, a strong majority did (Christmann, Lachmann, & Steinbrink, 2015). The overall results of the study indicated that auditory processing difficulties may be implicit in the phonological processing difficulties in a subset of people with dyslexia. Whilst this study did not involve young English-speaking students in their developmental years of reading skill acquisition, the results are important and contributory; they exemplify the complexity of the relationship between phonological processing and auditory processing. A systematic review of literature addressing auditory processing disorders by de Wit et al. (2016) supports a multimodality deficit theory but also the need for ongoing research in this area.

In reviewing the literature around the implication of phonological deficits in reading difficulties this suggestion of complicit modalities is frequently raised. WM or theoretically related cognitive capacities such as short-term auditory memory (STAM) or central executive (CE) function are often the most frequently discussed modalities. In the specific area of APD research, STAM has historically been a consideration as is exemplified in a study by Maerlender (2010). In this study of 36 English speaking students aged 7 to 14, with 22 participants diagnosed with APD, it was concluded that STAM deficits in students with APD was possibly ubiquitous. Likewise, in studies of LDR with a focus on the area of phonological awareness deficits, there is again frequent mention of the involvement of WM. This is exemplified in the comparative study of elementary school aged readers in Greece by Polychroni, Economou, Printezi, and Koutlidi (2011) which indicated that students with reading disabilities have deficiencies in short term memory and WM for phonological information.

Visuospatial processing deficits. A second area of research interest with respect to LDR is that of orthographic difficulties often associated with visuospatial processing deficits. This is a cognitive capacity which has fallen into and out of dyslexia research favour and focus over time (Kibby et al., 2015) but appears to be attracting renewed interest in the past ten years (Bellocchi, Muneaux, Bastien-Toniazzo, & Ducrot, 2013; Gori & Facoetti, 2015). Whilst recent research in this area in relation to LDR is limited, the findings of Boros et al. (2016) tend to encapsulate the developing theory that students with deficits in their ability to recognise letter strings and words may have functional impairment in certain neural areas known to be involved in visuospatial processing. As the ensuing discussion of WM theories will reveal, visuospatial processing is a key component of one of the most established theoretical frameworks for WM first postulated by Baddeley and Hitch (1974). As such,

within this consideration of visuospatial processing deficits as a contributory causal factor in reading difficulties, WM is seen to be intimately linked.

Phonological decoding deficits. One of the most significantly researched areas in literature relevant to LDR is that of phonological processing as evidenced in a meta-analysis by Kudo, Lussier and Swanson (2015). Phonological processing disorders are evidenced in all languages, across orthographic complexity but are more pronounced in what are termed opaque or deep orthographies such as the English language. In opaque orthographies there is not always a one-to-one correspondence of symbol to sound. For example, in English a single letter such as [a] can make several different sounds as in fat, fate and what. A letter pattern such as [ough] can make different single sounds such as in plough, though, thorough, through, and ought. That same letter pattern can also make different sound sequences such as in tough, cough, and hiccough. The lack of transparency in the orthography of English certainly increases the complexity of learning to read written English and significantly contributes to the incidence of LDR in English reading populations.

In reviewing literature in this area, the research studies which provided the most clarity around the link between phonological deficits and reading difficulties in elementary school children, were those completed in countries with transparent orthographies. One such study was completed by Brandenburg et al. (2015) involving 204, third grade German students. This study attempted to identify the cognitive causes of isolated or combined literacy difficulties in spelling and reading. The study concluded that spelling and reading disabilities appear to have quite different cognitive origins and that phonological deficits are more strongly implicated in spelling difficulty than reading difficulty. Of more specific relevance to this literature review, this study also concluded that spelling and reading disabilities have different WM profiles. In the discussion of that study, as in many other studies with a focus on phonological processing (refer to Kudo et al., 2015), there is evidence

of discussion around the implication of various WM components in the phonological processing processes being investigated.

Deficits in the ability to understand or associate meaning to text. Difficulties in learning to read can manifest themselves at different points in the continuum of cognitive processing and skill acquisition required by a reader to successfully decode text and make meaning. These difficulties can occur at the lowest level of cognitive processing such as at the word reading level right through to the higher order processing of text which is required for making meaning of the text or comprehending it. Students can have trouble in one area but not in the other, however students with isolated comprehension difficulties are often quite elusive to detect in the early years of schooling as discussed in the study of LERD by Etmanskie et al. (2016). The causal factors in reading comprehension difficulty have been the subject of significant amounts of research for decades. Amongst the many factors studied, WM is well presented. There is dissention as to the degree of influence WM has on comprehension, however, much of the variability can be attributed to variance in the tasks used to measure WM, the structure of tests used to measure comprehension, but even more significantly, to the theoretical construct of WM used in the design or interpretation of the study. For example, in studies such as Arrington, Kulesz, Francis, Fletcher, and Barnes (2014) and Segers, Damhuis, van de Sande, and Verhoeven (2016), a strong emphasis is placed on the attentional control role of executive function (EF) with WM presented as a factor of EF. On the other hand, in studies such as that by Goff, Pratt, and Ong (2005), the original, multicomponent WM theoretical framework is very evident. Despite this variability in WM theoretical framework, it is evident that WM is implicated in reading comprehension difficulty. It is professionally affirming that research literature is producing evidence of the involvement of WM in the task of comprehending text as this supports anecdotal observations of classroom teachers over a long period of time. It is not uncommon for teachers to have

students in their classes who struggle cognitively to understand a sentence or a paragraph not because they are known to have an intellectual, language or sensory deficit, but simply because the words or sentences fade from memory before meaning connections can be made.

Rapid automatised naming deficits. RAN deficits are observed in students who have difficulty developing automaticity in their word recognition and thus in achieving fluency in their reading. RAN has been a consideration in LDR research for over 40 years (Denckla, 1972; Yeung, 2016) and the review of literature in this area reveals that it continues to attract a significant level of interest across the globe in different orthographies and studies with participants of varying ages. According to Wolff (2014), Yeung (2016) and Georgiou, Parrila, Papadopoulos, and Cui (2013) the exact reason why RAN is related to reading continues to be unclear. However, a study by Georgiou et al. (2013) in Greece involving 65 children in Grade 2 and 65 children in Grade 6, concluded that both reading and RAN rely on serial processing and oral production of the stimulus names. Serial processing is a memory reliant cognitive activity. This connection to components of the WM model was discussed in a more deliberate manner in many studies such that of Aguilar-Vafaie, Safarpour, Khosrojavid, and Afruz (2012), involving 39 reading able and 39 dyslexic children. This study concluded that the impact of RAN deficits was much less significant than phonological factors and that RAN is a lower level of processing which enhances working memory performance in word reading and comprehension.

The Significance of Working Memory Deficits in Reading Difficulty

It would appear from the literature reviewed in the previous section that WM is a key player in the incremental development of cognitive skills known to be involved in the development of reading ability (Preßler, Könen, Hasselhorn, & Krajewski, 2014). As such, deficits in WM are a very valid contributor to reading difficulties. Exactly how impairments

in WM contribute to difficulties in the function of the cognitive and processing capacities involved in the development of reading skills continues to be the focus of much research.

In the discussion of their study into the association between WM, and reading and mathematics abilities, Gathercole, Alloway, Willis, and Adams (2006) favoured the view that deficiencies in WM present a bottleneck for learning within the individual learning episodes required to progressively and incrementally, build knowledge (Gathercole, 2004). This view is contrary to another theory which suggests that WM provides a facility for the learner to combine information retrieved from long term memory (LTM) with current input (Swanson & Beebe-Frankenberger, 2004). As I will discuss shortly, both explanations emanate from differing theoretical models of WM. These models continue to be explored in and of themselves, but also shape ongoing research into the role WM deficits play in contributing to the difficulties experienced by students with LDR. These WM theoretical models are shaping thinking and research into educationally based compensatory strategies for WM deficits and as well as influencing research into the efficacy of cognitive training to improve WM deficits.

The Evolving Working Memory Theoretical Framework

WM is generally defined as a cognitive construct or process which facilitates temporary storage and manipulation of information while executing a complex cognitive task (Wen, 2014). The evolution in understanding of WM is being shaped by intense research interest in its neural location and its neural function (Barak & Tsodyks, 2014; Christophel, Klink, Spitzer, Roelfsema, & Haynes, 2017). While it is widely recognised as being essential to the execution of a vast array of everyday functions, of greater relevance to this study, is its importance within and to the process of cognition and learning (Alloway & Alloway, 2010; Hill, Foster, Sofko, Elliott, & Shelton, 2016; Shelton, Elliott, Matthews, Hill, & Gouvier, 2010).

Over forty years ago, Alan Baddeley and Graham Hitch initially proposed a three-part model of working memory (Baddeley and Hitch, 1974). In an overview of the development of this initial model and subsequent elaboration and refinement by Baddeley and many others, Baddeley (2006) records that his interest in memory was initially stimulated by earlier research in the late 1950s out of both England (Brown, 1958) and the United States of America (Peterson & Peterson, 1959). This earlier research raised a unique suggestion that memory, which had long been held to be a unitary construct, should actually be viewed as a differentiated construct of a short-term memory (STM) and LTM. It was observed that small amounts of cognitive information were prone to fade from memory unless there was opportunity for rehearsal. According to Baddeley, it was this provocative view which led to substantial and cumulative research which by the late 1960s had already developed evidence for this clear distinction between the STM and LTM. From this basis, Baddeley and Hitch launched a three-year study into the relationship between the two constructs. This study resulted in the proposal of a tripartite model of working memory as an elaboration on STM and as a way of conceptualising the interconnection between STM and LTM. This model, while rudimentary in its inception and certainly one which has continued to be refined by Baddeley and reworked by others, has essentially stood the test of time. There have been over 10,000 citations of the 1974 chapter in scientific literature. It has provided a theoretical framework for WM and stimulated ongoing research in the fields of cognitive psychology, neuroscience, applied sciences, and education. This ongoing research has taken place in countries around the world, as each of these specialised bodies of knowledge and related practice, have conceptualised and theorised the relevance of WM within their domain (Logie & Cowan, 2015).

The Multimodal Model of Working Memory - Baddeley and Hitch

The early, multimodal model of WM theorised by Baddeley and Hitch (1974) comprised of a limited capacity, attentional control system which they named the central executive (CE). This area was assisted by two subsidiary temporary memory systems or *slave systems*. There was the phonological loop which was responsible for the temporary store of verbal information. It was comprised of two parts: a temporary store and an active rehearsal system involving sub-vocal speech. The second slave system, the visuo-spatial sketchpad, acted in the same way as the phonological loop however with visual and spatial information.

For over forty years Baddeley has continued to research and refine his model (Baddeley, 2008). In the late 1990's he included a fourth component which he named the episodic buffer (EB), (Baddeley, 2000). This area was conceptualised out of two successive promptings. Baddeley was aware of increased research into attention and the parts of the brain which control the focus, division and switching of attention. His original multimodal model located attentional focus and division of attention as separate functions within the CE however switching of attention was a more complex function to place. Having conceived of the CE as being purely focused on attentional control without storage capacity, Baddeley's model now lacked a structure in which domain specific information could interface with attentional control as well as with LTM (Baddeley, 2008). The EB was conceived in response as a multidimensional, limited capacity system, however this construct continues to be reviewed and refined by Baddeley and is now considered as a passive store area reflecting activity happening elsewhere. Baddeley's work in this area continues to evolve (Baddeley, 2012).

Since the advent of brain imaging techniques which have obviously provided a window into brain structure and function, some of the simplicity in the functional aspects of Baddeley's theory have been challenged. Fundamentally though, his multimodal

conceptualisation remains as a viable theoretical framework. There are other theoretical models of WM which have developed alongside and interconnected with Baddeley's multi-modal theory. As he states, these alternative frameworks are broadly consistent with his own varying mostly in the terminology used or the emphasis they place on different components of his model (Baddeley, 2012); a view shared by García-madruga et al. (2013).

Alternate Theoretical Constructs of Working Memory

Alloway, Gathercole, and Pickering (2006) observed variability in theoretical postulation around WM. This view was prompted by over three decades of research interest in this area. These three researchers have contributed significantly to the growth in understandings around the theoretical framework of WM (Alloway, 2006, 2011; Alloway & Copello, 2013; Gathercole, 2004; Gathercole, Alloway, Willis, & Adams, 2006; Gathercole, Pickering, Ambridge, & Wearing, 2004; Pickering, 2006; Wang & Gathercole, 2013) and yet they represent only a sector of the broader research interest in the theoretical construct of WM. In 2012. Baddeley identified four different theoretical frameworks:

- computational models of WM such as the model proposed by Barnard (1985);
- individual difference-based theories developed principally through the work of Engle and colleagues (Engle, Kane, & Tuholski, 1999; Kane & Engle, 2002; Evans & Stanovich, 2013) and to some extent, Miyake and Friedman (2012);
- a framework exploring the interplay of mind and brain in memory (Jonides et al., 2008) and the
- theory of embedded processes developed over many years by Nelson Cowan and which, along with Baddeley's model, is discussed in Gruszka and Orzechowski (2016), as being a significant contributor to the developing WM theoretical framework.

Cowan has exhibited a keen interest in the development of a theoretical understand of WM arising from his background interest in human consciousness (Logie & Cowan, 2015). Cowan postulates an embedded processes theory of WM in which there is a single memory repository (LTM) but within which WM is temporarily activated through attentional processes activated at different levels (Gruszka & Orzechowski, 2016). It is largely a domain general rather than domain specific conceptualisation of WM with a greater focus on process and function than structural specificity.

The capacity and function of WM would appear to provide distinct areas of research interest in the evolving theoretical framework of WM. This is quite notable in the variability in WM theory found in literature exploring the relationship of WM to learning and to reading particularly. There is continuing interest in the capacity of WM as seen for example in literature exploring the theory of cognitive load (Squires, 2018; Sweller, 2011; Sweller, Merriënboer & Paas, 2019). There is a distinction in literature based on the theory of WM as either a generalised or domain specific cognitive function (Swanson, 2011). There is an identifiable body of literature built out of interest in the attention regulating mechanisms of WM and how those mechanisms are involved in language learning and processing (Arrington et al., 2014; Miyake & Friedman, 2012). A recent meta-analysis of the relation between reading and WM by Peng et al. (2018) highlighted this variability in literature based on WM theory. This analysis was contextualised within the framework of three major theories of WM: the domain specific theory, the intrinsic cognitive load theory, and the dual process theory of higher cognition. This variability will again be highlighted in Chapter 3, in the review of literature around the concept of cognitive training of WM and how that relates to improving reading outcomes. For now, this review of alternative conceptualisations of WM concludes with the declaration this current study aligns with Baddeley's model of WM.

Baddeley's multi-modal model provides a theoretical understanding of how WM is related to the phonological and visual processing demands of reading from the lower level of word reading and development of vocabulary, to the more complex, higher order level of processing involved in the comprehension of text. This multimodal model also allows for consideration of attentional and CE deficits which are often seen within students with reading difficulties. For these reasons Baddeley's model continues to provide the greatest relevance to research into LDR; a view endorsed in Swanson, Zheng, and Jerman (2009).

Of course, theories are organic and while Baddeley himself likes to consider himself more an explorer of initial stage concepts than the architect of a detailed theoretical model (Baddeley, 2012), he acknowledges the importance of both tasks in the development of a complete theory. He continues to explore and build his model and theory based on rigorous debates around his theoretical model and those of others. To that end the theoretical basis of this research will also draw on elements from some of the other WM theoretical frameworks discussed above, where they are seen to complement the multimodal theory and the proposed research purpose.

Reading Difficulty, Working Memory and Self Efficacy

As discussed in Chapter 1 and earlier in this chapter, the pragmatic focus of this research has prompted the purposeful consideration of social cognitive theory as a third, interconnecting theoretical framework. While the literature discussed thus far addresses how reading happens cognitively and neurologically, it has not yet acknowledged that reading is a behaviour. Bandura (1997) argues that for the mechanics of how something happens to be actioned, there needs to be human agency or human determination (Deci & Ryan, 2000) to power the mechanics into action. The actions taken by people are based in the understanding humans have the power to do something and in their belief in their ability to complete the action. This belief in ability is described by Bandura as self-efficacy. In the context of

learning to read, students struggling with cognitive and neurological WM functional deficits find themselves perpetually required to action inadequate mechanics. This requires significant effort and yields minimal reward. Research indicates that over time this impacts the self-efficacy of struggling readers despite the efforts of teachers to commend and praise effortful gains (Schiefele, Schaffner, Möller, & Wigfield, 2012). There is frequent mention of lower reading self-efficacy in struggling readers than in reading able students (Margolis, 2005). Similarly, the literature supports the observation struggling readers are more likely to be extremely self-conscious of their lower ability (Bong & Skaalvik, 2003). These students often seek ways to avoid reading in front of peers or employ other behaviours to shift attention away from their reading ability (Martin, 2008).

Historically, self-efficacy has received minimal mention in LDR research within educational and scientific research silos. This has changed in recent decades with growth in understanding of the neurology and cognitive functioning of the brain and mind. For example, there has been growing acknowledgement of the role of metacognition in influencing educational outcomes (Afflerbach, Cho, Kim, Crassas, & Doyle, 2013; Usher, Li, Butz, & Rojas, 2019) and more particularly, the role of self-efficacy in achieving success in reading (Lee & Jonson-Reid, 2016). Whilst not widely considered a primary causal factor in LDR, self-efficacy does emerge within the research silo of social cognitive theory as a powerful player not just in the reading success of students with LDR but the educational success of adolescents (Caprara et al., 2008; Lee & Jonson-Reid, 2016; Klassen, 2010). In my review of literature in this theoretical space, three studies stood out as particularly relevant to this current study.

Yang, Badri, Al Rashedi, and Almazroui (2018) completed a study focussed on students in grade 4 in Abu Dhabi which indicated the strongest predicator of reading success for these students was self-efficacy. This was also identified through a meta-analysis of literature

addressing the relationship between attitude to reading and reading achievement in students at different stages in school completed by Petscher (2010). This analysis revealed a moderate strength in the relationship between attitude to reading and reading achievement with the strongest relationship found in elementary students. Both studies were relevant to this current study with its focus on primary school aged student participants.

In a meta-analysis by Unrau et al., (2018) it was recommended that future research-based development of reading interventions would be advantaged in utilising and building on strong correlations identified between reading self-efficacy and reading comprehension. This endorsed the aim of this current research to contribute to research-based improvements in the effectiveness of reading interventions for students with LDR and WM deficits.

Summary

Despite the highly technologically dependent structure and function of 21st century life, the skill of reading continues to be highly valued and critical for individual and corporate development and wellbeing. Unfortunately, the development of reading skill can be problematic for many students but none more so than for those students with a LDR. These students struggle to acquire reading skills commensurate to their cognitive and social-emotional potential. A common presentation amongst this sector of students, is the presentation of low WM. A review of the skills of reading has highlighted the strong relationship of WM to reading skill development: an observation not seemingly influenced by the wide variability in theoretical understanding of the capacity and function of WM.

Reading difficulties are increasingly identified early in a student's educational journey but despite exposure to various educational and para-educational interventions, there still exists frustratingly high rates of reading difficulty at adolescence. This directs our review of research literature in chapter 3 to an examination of the educational landscape of reading

intervention, the research around the plasticity of the brain and the potential for training WM to improve reading outcomes.

Chapter 3

Reading Intervention Pedagogy and Working Memory Training

Until such time as knowledgeable literacy education scholars prepare themselves to engage in such a conversation, the full promise of the biological sciences for analyzing educational issues will remain obscure. (Hruby & Goswami, 2011, p. 169)

In this highly literate world of the 21st century, the ability to read is almost quintessential for success and fulfilment: a reality which has fuelled the quest for continual improvement in reading intervention pedagogy. Parents of students with learning difficulty in reading (LDR) perpetually journey to locate effective remediations for their child. Schools, as partners in this journey, must continue to locate and provide the most effective, research based educational interventions available.

This chapter begins with a review of the literature around reading intervention pedagogy. Based on the strong connection of WM to reading discussed in chapter 2, the literature review moves forward to focus on the cognitive training potential of working memory (WM) and the relevance of this to improving reading outcomes for students with deficits in both WM and reading skills. The chapter concludes with a review of literature highlighting the need for a transdisciplinary approach to ongoing research in the reading intervention pedagogy space. The discussion highlights the possibilities transdisciplinary research may offer for the development of effective, transdisciplinary reading intervention programs.

Reading Pedagogy and Reading Intervention Pedagogy

As mentioned previously, the address of the LDR has been a perennial challenge for teachers around the world, but particularly in English speaking countries due to the complexity of the orthography of English. This very complexity may be one of the contributory drivers behind the continual pendulum swing observed in popular reading pedagogy in our primary schools. According to Walczyk, Tcholakian, Igou, and Dixon

(2014), the debate around which method is most effective has simmered since the 1800s. The pendulum has swung between skills-based or phonics approaches and whole language, meaning based pedagogy (Baumann, Hoffman, Moon, & Duffy-Hester, 1998; Fox, 1986; Manning & Kamii, 2000).

In phonics-based pedagogy, students learn to read by initially learning the sounds of the language and mapping these to the orthographic symbols. It is a part to whole methodology. Sound and letter knowledge enable decoding of the written code: single words, phrases, and sentences. This primary emphasis on phonic decoding is partnered with the memorisation of irregularly coded words, known as sight words. These words consist of letters and letter strings with unusual sound to letter correspondences such as the words: who, said, what, because. Students are progressively taught how to make meaning from the increasingly larger units of decoded text. This pedagogy is principally criticised as being too focused on teaching and drilling fundamental disparate, decoding skills at the expense of teaching reading for meaning (Manning & Kamii, 2000).

Whole language-based pedagogy places prime importance on students learning to read through exposure to meaningful, whole language activities (Ryan & Goodman, 2016). Students are exposed to natural written and oral language from the outset. From the beginning of reading instruction, they are immersed in literature and exposed to written text. The process of reading is modelled to students as books are read to them out loud or as the students themselves engage with the process of reading through guided and instructional reading processes. During these frequent exposures to whole and real language, opportunity for instruction in skills of decoding and comprehension are pursued as they arise. It is a whole to part methodology. This pedagogy finds its largest criticism in the argument that it does not provide sufficient and systematic instruction in the phonological processing skills required to independently decode unfamiliar or novel text (Cook, Rodes, & Lipsitz, 2017).

In reviewing this pedagogical debate, it is not unusual to observe similar and aligned swings in the underlying philosophical framework underpinning reading intervention programs. For example, in the phonic era of the early 20th century, any type of reading intervention was in the form of additional skill and drill activities. In the whole language era of the 1980s and 1990s, the whole language aligned Reading Recovery program became very popular and widely implemented across the globe (Holliman, Hurry & Bodman, 2016; Lipp & Helfrich, 2016, Munn & Ellis, 2005, Wade, 1992). Of greater relevance to this study is the indisputable evidence that no matter which pedagogy and intervention has prevailed, the incidence of reading difficulties persisting into adolescence, has been consistent over time as discussed in Chapter 2. This is not surprising given that both pedagogical approaches teach decoding skills and comprehension strategies, albeit with differing emphasis and sequence. Decoding skills and comprehension processes are widely recognised as being core components of reading.

Paul and Clarke (2016) provide a snapshot of current understandings around the process of reading. They draw on the Simple View of Reading (Gough & Tunmer, 1986) and the Construction-Integration model (Kintsch & Rawson, 2008). Paul and Clarke present reading as being purposed on making meaning from text but dependent on the mastery and integration of component skills. These are skills such as decoding, oral language, and the process of connecting novel, or activating stored meaning from experience and perspective to words or text. Recognition and endorsement of these core components were also echoed in the report of the National Reading Panel (2000).

At this point in time, the reading debate is leaning towards a phonics-based approach with primary emphasis on skills based or phonologically based reading instruction. This is viewed as the most appropriate, evidence-based pedagogy for the teaching reading. What is slightly different in the current debate is the call for whole language instruction as well as

phonics instruction. This is illustrated in a study by Snyder and Golightly (2017). They investigated the effect of partnering a phonics-based reading intervention with a whole language intervention with a student with LDR. The positive results achieved in that study, albeit a single subject study, supported a growing body of evidence that a balanced intervention approach can effectively improve core skills such as phonological processing skills, sight word recognition, and comprehension (Castles, Rastle, & Nation, 2018). This advocacy and other emerging research situate the reading pedagogical debate pendulum in a more central or balanced position. What is still missing from the concomitant reading intervention debate but certainly beginning to enter the discourse is the impact of deficits in WM and other cognitive capacities associated with WM, such as short-term auditory memory (STAM), visual short-term memory (VSTM), sustained attention, and task switching (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014). This was highlighted by Snyder and Golightly when they acknowledged that the attentional difficulties of the participant had not been addressed or monitored during the study and could possibly have impacted the results. While this discussion was noteworthy to read, it still reflected a siloed approach to addressing LDR. Working memory is now recognised as being intricately involved in the process of reading yet the educational address of LDR continues to be through a focus on reading intervention programs and separate, extraneous management of WM deficits (Sweller, Merriënboer, & Paas, 2019). The literature reflecting this dichotomous educational intervention landscape will now be reviewed.

The Educational Response to Working Memory and Reading Difficulties

As discussed in Chapter 2, there is strong evidence of the involvement of WM in all skills and processes involved in learning to read. The address of WM functional deficits within the educational setting have been largely limited to the use of specific teaching strategies and classroom management strategies aimed at reducing the load on these cognitive

capacities, particularly on WM (Berninger, Lee, Abbott, & Breznitz, 2013). This includes strategies such as controlling the difficulty, pacing and length of a task; giving direct, cued, short instruction supported by visuals; using memory aids or mnemonics; reducing classroom noise and distractions; using assistive technology; providing frequent breaks (refer Pesova, Sivevska, & Runceva, 2014) or in the case of the Snyder and Golightly (2017) study, providing a reward system for on task behaviours. These management strategies have also been used alongside reading intervention programs which, as discussed above, have been reflective of the prevailing reading pedagogy. Historically, intervention has been delivered apart from the normal classroom. With a shift to a more inclusive educational philosophy in recent times, there has been a change in this landscape.

The Response to Intervention Model

The current provision of targeted interventions for students with specific learning difficulties in reading is initially delivered within the classroom. This integrated model of servicing learning difficulties is founded in the Response to Intervention (RTI) model (Kavale, 2005; Vaughn & Fuchs, 2003; Vaughn et al., 2014). This has developed out of an inclusive theory of education and according to Vaughn and Fuchs (2003), is a pragmatic address of soaring costs of special education. As reading achievement expectations continue to expand so too do the number of students being identified with learning difficulties (Ashby, Burns, & Royle, 2014; Chong, 2018) along with the costs incurred in resourcing their intervention. The intensity and specialisation required to service special needs education means these growing costs are exceptional to the resourcing of general education (Chambers, Parrish, & Harr, 2002).

The three tiered, RTI model encompassing both early identification and strategic intervention, is premised on the theory that a student's response to intervention will be more receptive and successful if they do not feel different or targeted in view of their peers.

Consequently, the educational intervention needs of students with learning difficulties are initially addressed at tier one within their peer setting and within normal educational programs. This is elevated to tier two if the students are perceived to not be making sufficient progress. In tier two, specific, targeted intervention programs are provided to students in small groups. These programs can occur within the classroom or in a withdrawal setting. Should tier two interventions also appear to be insufficient then the student is elevated to tier three intervention. In this tier the student is often referred to external health professionals for professional diagnostic assessment, guidance and support which is then integrated with intensive, individualised interventions provided within the school setting.

The debate around the efficacy of RTI model in meeting the learning needs of students with learning difficulties and particularly LDR, is for another review however some of the issues arising from this model add weight to the argument for this research. Firstly, there are concerns as reported by Fielding-Barnsley (2010) around the level of pre-service training teachers receive to equip them to teach reading in the first instance but even more importantly, the proficiency of mainstream teachers to identify LDR (Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2016). There are also concerns related to the lack of rigor and uniformity in the training of special education teachers critical to the success of tier 2 and 3 interventions (Brownell, Sindelar, Kiely, & Danielson, 2010). Aside from the perceived inadequacies of the RTI model, the issue of how to effectively address WM deficits in students with LDR, remains, particularly if reading interventions are to be holistically beneficial to the student with LDR.

The practice of employing classroom management strategies to compensate for limitations in WM capacity is constrained by the WM capacity limitations the strategies aim to assist. Complicating these well-intentioned attempts to address WM deficits within the classroom, has been the rush of educational publications, training programs, and often

sparingly researched, brain-based learning theories and classroom advice which have flooded the educational stage in the past decade. Teacher training does little to assist teachers in screening the neuro-myths from the neuro-realities as discussed in Dekker, Lee, Howard-Jones, and Jolles (2012); Karakus, Howard-Jones, and Jay (2015); Pei, Howard-Jones, Zhang, Liu, and Jin (2015), leaving them exposed to the winds of commercially driven initiatives in this undeniably exciting frontier of human knowledge. It is essential that education and scientific research unite in a common purpose to develop evidence-based understanding and practice: a conclusion echoed by Hruby and Goswami (2011) in a review of neuroscience research and literacy education research.

Having examined reading intervention pedagogy and its difficulties in addressing the omnipresent and significant impact of WM deficits, this discussion will now move focus to a review of research literature addressing the malleability of WM and the potential of utilising cognitive WM training within the reading intervention arena.

Working Memory Deficits and Cognitive Training

It is not surprising given the strong association of WM to an expansive range of cognitive processes that there has been growing and broad research interest in WM deficits. Of relevance to this current study has been research investigating whether WM can be compensated to improve efficiency, or in fact ameliorated through improvement in capacity with consequential gains in efficiency. Both research trajectories are relevant to the pursuit of successful educational outcomes for students with WM deficits.

Improving Working Memory Efficiency Through Cognitive Training

An instructional design theory of pertinence to this discussion is cognitive load theory (Sweller, 2011; Sweller, Merriënboer, & Paas, 2019). This theory holds that the cognitive load placed on WM cannot exceed WM resources. The theory also differentiates cognitive load into three subtypes: intrinsic, extraneous, and germane cognitive loads (Sweller, 2010).

In simple terms, intrinsic cognitive load relates to the complexity of the material being learned. The extraneous cognitive load relates to the cognitive demands of the instructional process. The germane cognitive load relates to the cognitive resources the learner can or does commit to dealing with the intrinsic cognitive load. Each subtype can be manipulated through instructional design to reduce cognitive load on WM so that WM can work efficiently within its given capacity or situation (Paas, Renkl, & Sweller, 2003).

There seems to be a degree of alignment with cognitive load theory in another area of WM research of relevance to this review. This is the research around a mind-brain based WM model. This research explores the manipulation of WM efficiency through management of unnecessary or functionally impairing thoughts or emotions. An example of this research trajectory is observed in a study completed in France with 111 children in 6th grade by Autin and Croizet (2012). In this research the focus was on examining the effectiveness of psychologically changing or reframing the meta-cognitive interpretation of the perceived difficulty of a task. The research questions lay around whether this would reduce stress limiting effects on WM capacity and lead to enhanced achievement potential. The study concluded that reframing can improve WM efficiency rather than capacity and this did have a positive result on complex cognitive processing, in this case, comprehension. It was noteworthy that Autin and Croizet also suggested combining metacognitive reframing with cognitive training so that not only efficiency, but capacity of WM be enhanced.

Improving Working Memory Capacity and Efficiency Through Cognitive Training

There appears to be growing acknowledgement in research literature that WM capacity can be altered through cognitive training. WM training research has certainly become more prolific since the discovery of neuroplasticity and has been greatly facilitated by advances in computer technology and medical imaging. Research by McNab et al. (2009) provides an example of the insight gained through these technologies. They were able to

identify that dopamine, a neural substance with a central role in working memory function, was more abundant after 14 hours of WM training. Other research examples exemplifying the powerful benefit of insight provided by advances in neurological scanning technology can be found in Olesen, Westerberg, & Klingberg (2003); Klingberg (2010); Jausovec and Jausovec, (2012); Salmi, Nyberg, and Laine (2018). Within this literature there is evidence of changes in neural activity post WM training in areas of the brain associated with WM and control of attention. These findings must be viewed with the understanding that advanced technology is being used to provide evidence of change from training when there is still dissention within the theoretical framework of WM regarding its actual neural architecture and neural function. That discussion is beyond the scope of this study however for the purposes of this research there is sufficient indication that the training of WM does effect change in neural structures in the brain and cognitive WM function. What does need to be explored are the questions around the longevity, transferability, and impact on learning of the observed changes after training of WM.

Just prior to examining the literature around the transfer of WM training effect, it is important to note the impact of commercial interest in this area of WM training. This is not unexpected and certainly required at some stage, however there is evidence in academic literature suggesting this is somewhat premature. WM training research has given rise to various commercial WM training programs which have in turn attracted critics in scientific and academic research literature. Some of the criticism is around the programs having insufficient and non-rigorous research basis or being potentially open to research bias due to the result of conflict of interest (Kirk, Gray, Riby, & Cornish, 2015). These are not arguments to be pursued in this literature review, as it is not the training programs under inspection in this current study but the theory of WM training. As far as this current study is concerned, these adaptive, cognitive training programs provide an accessible format for

training WM. The literature relating to contemporary WM training programs has guided the selection of a suitable training program for use in the study.

The Transfer of Working Memory Training to Non-Trained Tasks

The issue of whether improvements seen in WM after training, are transferrable to other non-trained tasks is a contested field of research and debate. There appears to be very clearly juxtaposed groups of researchers which is not unexpected in a developing theoretical framework, however the research on either side aligns closely with the main theoretical models of WM outlined within this review. The discussions in and between research studies have been lively. For the large part, the research is objective and balanced, evidence based, and often concludes with an acknowledgement that research in this area is embryonic but certainly worthy of further exploration (refer Morrison & Chein, 2011, 2012).

The body of literature relating to the efficacy of WM training in terms of its benefit to learning is certainly expansive. Narrowing the focus to studies involving primary school aged children with reading difficulties but not intellectual delay, in English speaking schools, was problematic with very few examples identified. In filtering down to these highly relevant studies, numerous studies based in various, often non-English speaking countries were identified. There were studies which involved pre-school students (Drigas, Kokkalia, & Lytras, 2015); school aged children with learning difficulties (Alloway, 2012; Alloway, Bibile, & Lau, 2013; Peijnenborgh et al., 2016); school aged students without learning difficulties (St Clair-Thompson, Stevens, Hunt, & Bolder, 2010); students with ADHD (Hovik, Saunes, Aarlien, & Egeland, 2013); young adults and older adults (Redick et al., 2013).The conclusions regarding training effect are quite varied within literature.

There are studies which conclude there is only evidence of training effect on trained WM tasks such as in the studies by Thompson et al. (2013) and Owen et al. (2010). Often, as was the case in both these studies, there are features of the study design which limit the

relevance of the results to the question of whether training effects can be seen in children with WM deficits. In both studies, the participants were adults. The first study involved adults between the ages of 18 and 45 and in the second study the participants were aged between 18 and 60. While it is important that research into WM training for adult populations occurs, with respect to this current study, it needs to be noted that WM is developmental and hence markedly different between childhood and adult presentations. WM as a construct is known to progressively develop in capacity in early childhood, stabilise in early adolescence, and is prone to decline throughout adulthood. Students with WM deficits often do not experience this normal developmental journey and consequently, their development in certain WM dependent academic skills such as reading can be compromised. Consequently, it is important for research into WM training with children to continue with the hope that transfer of trained WM gains may be used to facilitate improvement in academic performance, particularly in reading.

Of assistance to this quest for ongoing research is the continual refinement in the research process being used with children. Redick, Shipstead, Wiemers, Melby-Lervag, and Hulme (2015) provide a clear example of this. They concluded that WM training produces limited gains in STM and WM related tasks and there appeared to be no advantage for academic outcomes in reading and arithmetic. They did highlight some limitations in their research. Similar limitations were identified across several related studies in this area. For example, Peijnenborgh et al. (2016) highlighted certain methodological issues plaguing this research. There is high variation in participant age, sample sizes too small, variation in the component of WM being measured, high variation in the tests used to measure WM and academic progress, and lack of follow up assessments. These are all very valid criticisms useful in guiding future research.

As indicated above, it is possible to identify studies involving the training of WM in children which do provide some evidence of a transfer effect to untrained tasks, post training of WM. A study by St Clair-Thompson et al. (2010) involving 254 children between the ages of 5 and 8 years in the north of England provided evidence that computer-based memory strategy training produced improvement in performance on tasks of WM and performance in the classroom, albeit specific WM tasks. Similar supportive evidence was found in Alloway et. al. (2013); Karbach, Strobach, and Schubert (2015); Dahlin, Nyberg, Bäckman, and Neely (2008).

Working Memory Training and Transfer to Academic Achievement

The issue of whether trained improvements in WM can transfer to gains in academic performance is probably now the most central question driving educationally relevant WM training research and debate. Whilst this current study has a specific focus on the relevance of WM training as a method of improving reading performance in students with LDR, a sector of current WM training research is also focused on measuring growth in aspects of general intelligence. WM is considered within measures of general intelligence, so this sector of literature is also relevant to this review and current study.

There have been several meta-analyses completed to date with vigorous research-based responses exchanged between research groups from opposing WM model viewpoints. For example, a meta-analysis by Melby-Lervåg and Hulme (2013) concluded there was no evidence that WM training has efficacy for improvements in academic outcomes, however Au et al. (2015) concluded there was a degree of demonstrated efficacy of training in improving general intelligence. Both parties have continued this debate to date (Au, Buschkuehl, Duncan & Jaeggi, 2016; Melby-Lervåg & Hulme, 2016). Leaving this debate to one side, this discussion will now move to focus more specifically on literature addressing the efficacy of

WM training in remediating reading skills in primary school students. As will be evidenced, this literature often draws heavily on Baddeley's (2012) multi-modal model of WM.

There is increasing evidence of a possible transfer effect in studies which focus on measuring the effect of WM training on specific academic skills such as Word Reading Ability (WRA) or reading comprehension. Chein and Morrison (2010) identified improvements in reading comprehension after WM training in a study involving university students in Philadelphia, Pennsylvania. A study of cognitive training of WM by Dahlin (2011) involving 57 Swedish primary school students with general learning problems in an ordinary school setting found both WM and reading comprehension showed significant improvement. In this study there was not however any observed improvement in word decoding or WRA. In Switzerland, a study of 66 children aged between 9 and 11 years, identified not only improvement on trained tasks but more importantly in the students' ability to read single words and text (Loosli, Buschkuehl, Perrig, & Jaeggi, 2012). Likewise in Germany, a study of 28 elementary school students concluded there was evidence of transfer effect to untrained tasks, one of which was a reading task, and that there was evidence the gains were stable, as they were still significant after 3 months (Karbach et al., 2015). Similarly, longitudinal evidence was seen in a study by Söderqvist and Nutley (2015) where improvement in academic performance was seen immediately after training and two years post training in a study involving a group of 20, grade 4 students in Sweden. There does appear to be noteworthy indication in these recent, highly relevant studies of the potential in utilising adaptive cognitive WM training programs to improve reading skills when they are implemented within an educational setting. Further research of this transdisciplinary nature would no doubt be welcomed by classroom and intervention teachers in their professional endeavour to provide increasingly effective reading intervention programs for their students with LDR.

Developing a Transdisciplinary Approach to Reading Intervention

In moving on to review the need for a transdisciplinary approach to research into the far transfer of trained WM to academic gains, it must firstly be acknowledged that ongoing siloed research in various fields of neuroscience and psychology continues to be essential. It is particularly important to continue to grow neurological and psychological understandings around WM and the neurological and psychological changes which cognitive training can enact. There needs to be continued scientific studies around how memories are created, modified and updated (Eriksson, Vogel, Lansner, Bergström, & Nyberg, 2015; Herszage & Censor, 2018), which parts and processes of the brain are involved in WM (Bäckman et al., 2011; Christophel, Klink, Spitzer, Roelfsema, & Haynes, 2017; Doyle, Smeaton, Roche, & Boran, 2018) and which areas of the brain might be involved in the transfer of training effects to untrained tasks (Dahlin, Bäckman, Neely, & Nyberg, 2009; Zhang, Yao, Zhang, Long, & Zhao, 2013). This stated, it is also important that research focussed on the identification of a sustained, far transfer effect of trained WM improvement to novel WM dependent tasks, such as word reading skills, moves more consistently towards transdisciplinary research. This research would investigate the most effective structure and delivery format for utilising adaptive, cognitive WM training delivered in tandem with educational interventions. It would focus on the identification of statistically significant and durable transfer of training effect to academic improvement in reading. It would also need to be informed, designed, implemented, and critiqued within a transdisciplinary theoretical framework.

The desire to investigate the efficacy of a transdisciplinary approach to reading intervention for students with LDR and WM deficit, is a proposal to address perceived gaps in current WM training research. It is also a proposal capitalising on current educationally based, reading intervention strengths in the united purpose of achieving improved WM

capacity and efficiency, enhanced reading skills, and ultimately, sustained gains in academic achievement in reading.

There are several anticipated gains in utilising a transdisciplinary educational intervention:

- Training is provided to young students in their developmental years when WM deficits are initially identified.
- Working memory training is matched to and occurs with progressive academic skills tuition.
- Working memory training is targeted, individualised, adaptive, sustained, and administered by a teacher.
- Consistent and appropriate measurement and observation tools are used to continually monitor growth over time.
- There is ability to incorporate some of the mind-brain WM theory into the overall intervention plan.
- Student WM capacity and efficiency are improved thus assisting or reducing the need for externally applied, classroom WM management strategies.

Support for a transdisciplinary approach is identifiable in recent research literature. In a discussion of research around executive function (EF) and comprehension, Scheff, Hudson, Tarsha, and Cutting (2010) argue there is potential for improvement to intervention practices in future research combining education, neuroscience, and psychology. A recent Australian longitudinal study of children 6 to 7 years of age with low WM, investigated the relationship between cognitively trained WM and academic outcomes over time. The participants received 20 standard training sessions using a commercially available research-based, cognitive training program. They were taken out of their normal classrooms to complete the training which was supervised by research assistants. This study identified little evidence of improvement in academic outcomes (Roberts et al., 2016). Whilst this training regime is

efficient in improving measures of WM, the results of this study raise the question of whether sustained WM training within and as part of an ongoing, remedial reading program, would result in greater transfer effects to academic improvement. This suggestion finds support in Rabipour and Raz (2012) who advocate for an incorporation of adaptive, cognitive training into school curricula with benefits to be gained from sustained training over longer periods of time. There may also be greater benefit in the training being delivered within class under normal classroom conditions and supervised by the classroom teacher. This theory was investigated by Holmes and Gathercole (2014) who found that training transferred to improvement in National Curriculum assessments in English and Mathematics and led to the suggestion for the integration of WM training into normal classroom practice. There are numerous studies available highlighting the effectiveness of various aspects of teacher practice such as those reviewed in a meta-analysis by Seidel and Shavelson (2007) and in a study by Boonen, Van Damme, and Onghena (2014) which highlighted that the instructional practices of teachers had the largest effects on reading and spelling achievement. Having teachers deliver the cognitive training programs as well as the reading intervention programs would appear to be pertinent based on this research evidence.

The suggested transdisciplinary approach also provides a defence for WM training when it is criticised as a quick fix for language and learning disabilities (Kamhi, 2014). What is needed in a transdisciplinary approach to intervention for LDR is both best practice in the reading pedagogy implemented concurrently with WM training or through embedding WM training in reading intervention programs. This was trialled in a study with primary aged students completed by García-madruga et al. (2013) producing improvements in WM executive processes and reading comprehension.

A plausible argument for combining training of WM functions with carefully aligned and paced training of basic phonological processing skills and comprehension strategies to

achieve the elusive transfer of WM training effect to improvement in both reading components, is identified in Lachmann and van Leeuwen (2014). In this paper, a functional coordination model of reading is presented. This theory holds that reading is a secondary process resulting from the functional coordination or synthesis of primary pre-existing skills, drawn principally from the auditory and visual domains, into procedures for reading which, over time and with practice, become automated. The study suggests attempts to address deficits in basic processes once automatisation is advanced, may only produce limited success without a reorganisation and re-automatisation of skills. This theory is also highlighted in Christmann, Lachmann, & Steinbrink, (2015). In a discussion of the clinical implications for their finding that auditory processing skills are impaired in persons with developmental dyslexia, they discounted the effectiveness of using intervention based, isolated training of auditory processing skills to address dyslexia based on the expected lack of transfer effect from this training to reading once there is advanced automatisation of the functional coordination process involved in reading. They argued that a more effective approach might be to combine training of basic non-linguistic functions (auditory processing) with training of linguistic skills (phonological and orthographical processing) to embed improved processing skills into a reorganised functional coordination which with practice could become re-automatised.

Teachers of reading intervention programs similarly move through a reorganisation process. They return to re-teach and re-build basic, fundamental phonological awareness and processing skills along with sight word confidence and automaticity, with the purpose of improving reading fluency, understanding, and enjoyment. This pedagogy is premised on Vygotsky's concept of the Zone of Proximal Development (ZPD) as discussed in Gredler and Shields (2007). This concept is generally about working with a student on the edge of their ability with the goal of capitalising on the potential for growth. In a similar manner, the

adaptive, computer-based feature of many WM training programs greatly facilitate teachers in assisting students to work within their ZPD. As such, providing WM training hand in hand with reading intervention instruction, may provide optimum remediation opportunity (Resing, 2013).

St Clair-Thompson et al. (2010) comment that the use of WM training within the classroom may disrupt the pattern of learning failure often experienced by students with WM deficits and hence aid in improved confidence and motivation to learn. This thinking aligns with the mind and brain WM model discussed in Chapter 2 and lends support to a research investigation of a transdisciplinary approach to reading intervention incorporating WM training.

Support for training WM within the classroom, possibly in addition to utilising compensatory strategies to manage cognitive load as discussed above, can be found in a review study and meta-analysis of the efficacy of WM training in children and adolescents with learning difficulties by Peijnenborgh et al. (2016). Compensatory or *bypass* strategies employed by teachers to enable students with WM deficits to work efficiently within their WM capacity, were criticised on the basis that students do not internalise the WM strategies. It was suggested that possibly, these strategies may be internalised through training WM.

Summary

The review of literature in the research fields of reading intervention pedagogy and WM training has revealed that difficulty in learning to read remains a pervasive educational and social problem in countries worldwide. Working memory deficits are often manifest in students with reading difficulty and significantly contribute to difficulties in phonological processing, word recognition, fluency, and comprehension. Substantial research interest in the use of adaptive, cognitive training of WM has to date revealed minimal evidence that trained improvement in WM can transfer to improved academic performance and

achievement in reading however there have also been quite distinct and recognised limitations within the research. A review of these limitations along with evidence of the effectiveness of teacher led interventions, particularly in reading, generated the conceptualisation of the transdisciplinary reading intervention model. This model is explored within this current research study using two different formats of delivery. This intervention model explored in this current study is designed for use in a primary classroom, delivered by a teacher and characterised by regular, targeted, adaptive, cognitive training of WM and teacher directed reading instruction. The goals of this intervention model are to identify significant improvement in WM efficiency and capacity, along with improved academic achievement in reading. The aim of this current study is to contribute to ongoing research into the most effective pedagogies for the address of working memory related reading difficulties in young children, and in turn, contribute to the mitigation of reading failure amongst school leavers and in the wider society.

Chapter 4

Methodology

A goal without a plan is just a wish.
(Saint-Exupéry, 1943)

The review of literature presented within the previous two chapters identified the need for ongoing research into the effectiveness of using working memory (WM) training to improve reading skills for students with deficits in both reading skills and WM. This is based in evidence indicating WM development and reading skill acquisition are both multifaceted and complementary processes (Peng et al., 2018). Despite this strong interconnection of the two multifaceted cognitive capacities, there is minimal research evidence of a direct transfer of trained improvement in WM capacities to reading skill improvement.

To address this gap in literature, this study is designed to investigate if there might be greater transfer of trained WM improvement to reading skill development when WM and reading skills are trained simultaneously in time as opposed to disparately. To facilitate this research, it was pertinent to design and implement a transdisciplinary study.

Research Aims

This transdisciplinary study aimed to contribute to:

- scientific research into the structure, function, and malleability of WM, particularly research into the adaptive, cognitive training of WM for the improvement of early, developmental reading skills.
- educational research into effective and enduring reading intervention pedagogies for students with reading disabilities, particularly students with WM deficits.

This study also aimed to make a unique contribution to ongoing research investigating the potential of WM training administered within the school environment

contributing to improved reading skill development. It was undertaken as a case study, by an educator within the real-life setting of an elementary school in Australia. By design, the study aimed to reflect and analyse the organic interface and interplay of theory and practice within the Response to Intervention (RTI) model of integrated special education delivery.

Research Questions

As the literature review in Chapters 2 and 3 highlighted, there are multiple, interrelated subskills involved in the process of reading and likewise in the theoretical framework of WM. Students presenting with a learning difficulty in reading (LDR) may not have deficits across all subskills. Likewise, students presenting with WM deficit may not have deficits across the multiple components of the WM theoretical construct. While the participants in the study were selected based on both below average reading ability and WM deficits, it was beyond the scope of this study to collect and analyse data in relation to all reading subskills and WM functions. To that end, the focus of the data analysis was narrowed to the key reading skills associated with Word Reading Ability (WRA) and the key memory and executive functions associated with Baddeley's (2012) multimodal model of WM. A third area of focus for data collection was on reader self-efficacy as both the research literature and professional practice testifies to the powerful influence of self-efficacy on educational outcomes, especially for students with learning challenges (Schiefele, Schaffner, Möller, & Wigfield, 2012).

There were two independent variables and eight dependent variables within this study. The dependent variables comprised a selection of reading skills associated with WRA, a selection of modality specific WM functions, and reader self-efficacy (RSE). The independent variables were ACTIVATE, a cognitive training program produced by Wexler (2015) and MacqLit, a literacy intervention program published by MultiLit (2014). Details pertaining to these programs will be provided in the methodology section below.

The eight dependent variables were:

1. Sight word efficiency (SWE): the ability to accurately read single, phonically irregular words.
2. Phonemic decoding efficacy (PDE): the ability to accurately read single, phonically regular words.
3. Reading accuracy (RA): the ability to accurately read words in text.
4. Short term auditory sequential memory (STAM): the ability to remember a sequence of numbers presented auditorily.
5. Working memory measured via auditory input (WM-AI): the ability to recall and cognitively manipulate a sequence of numbers presented purely auditorily.
6. Working memory measured with visual input WM-VI): the ability to recall and cognitively manipulate the order of sequences of pictures presented purely visually.
7. Focussed Attention (FA): the ability to maintain attention and inhibit automatic responses that may interfere with achieving goals.
8. Reader self-efficacy (RSE): The demonstration of the reader's choice to read, persistence to read, effort to read, and confidence to read.

The dependent variables provided the basis for three research questions:

Q1. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence word reading ability outcomes?

Q2. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence measures of working memory abilities?

Q3. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence reader self-efficacy?

Philosophical Framework

The philosophical framework of this study was within a realist ontological space. The study was purposed on exploring research questions generated by theoretically informed understandings of the interdependence of WM and reading skills acquisition, theoretical models of WM, and research evidence of the receptiveness of WM to trained improvement. The literature review of research conducted globally in the past ten years investigating a causal relationship between WM training and improvement in academic outcomes, particularly fundamental reading skills, has principally been experimental.

Within this frame of reference, an experimental methodology might have been considered a logical choice for this study, however, there were several unavoidable limitations which did not make this methodological choice feasible:

- Given this study was to be undertaken within a single primary school setting, with a specific focus on students within Years three and four, there was a statistical likelihood of insufficient numbers of students with both a learning difficulty in reading (LDR) and WM deficits.
- If the research sample was too small, it could be considered of inadequate size for the results to be theoretically generalisable to a larger population and hence lack sufficient external validity.
- As a single, part time researcher constrained by time parameters, there were concerns around managing the internal validity of such a study with many independent variables foreseeably difficult to control within an operational school environment.

There were also foreseeable resource limitations such as:

- insufficient financial capacity to provide large scale access to a commercial cognitive, WM training program;

- inflexibility of school timetables limiting access to suitable participants in significant numbers, for required intervention time; and
- inevitable disruptions to the planned intervention schedule due to non-timetabled school community events.

In sourcing an alternative methodology, it was necessary to identify one which could:

- facilitate the investigation of a theoretically informed hypothesis;
- identify a causal relationship;
- utilise the collection and analysis of both quantitative and qualitative data;
- be feasible within and enhanced by the context of a functional school setting;
- facilitate investigation of the pragmatic aims and research questions underpinning the study.

Case study methodology presented itself as the ideal alternative to an experimental methodology, particularly the approach to case study expounded by Yin (2014).

Case Study as Methodology

As with other key case study methodologists or proponents such as Stake (1995) and Merriam (1998), Yin (2014) defines case study research as the exploration of a contemporary phenomenon within a real-life setting, drawing from multiple sources of data to develop in-depth understandings. This conceptualisation of case study as a methodology aligned perfectly with the aims of this research. It also presented an alternative to other forms of case study research where the case itself is the actual phenomenon of research interest as in Stake's intrinsic case study design (1995).

Within the various approaches to case study, case is generally defined as a bounded entity such as a person, group, place, process, or program: bound by time, place, circumstance, or purpose (Creswell, 2014). While Stake (1995) in his definition of an instrumental case and Yin (2014) with his various types of case and case study designs, both

enable the use of case study as a tool for investigating a phenomenon, it was the differing ontological position of these two methodologists, which made the choice of Yin appropriate.

As a methodologist, Yin is clearly positioned towards a realist ontological space and has greater alignment with positivist, objectivist epistemology although he is very reluctant to distinguish between qualitative and quantitative approaches arguing there is essential strength to be found in both (Yin, 2014). Yin's case study methodology requires a thorough literature review be completed in order to establish theoretical understandings from which the research questions and research design are formulated. This must be completed prior to any data collection and subsequent analysis. He insists that every step of the research process be tested for validity and reliability so that the resulting study is robust and rigorous. This approach would be complementary to previous experimental research into this research problem highlighted in Chapter 3.

Whilst Yin's case study methodology aligns strongly with the realist ontological framework of previous research, it also offers scope for the investigation of the very real-life struggles of students with LDR. In its quest to identify reading pedagogical improvement, this research also has quite pragmatic aims. The use of Yin's case study methodology enables the study to sit quite compatibly within this pragmatist space as it enables the research to occur within the context of a real-life classroom setting.

Yin's (2014) reluctance to draw distinctive boundaries between qualitative and quantitative approaches was also a feature of his case study methodology which aligned well with the purposes of the study. Yin argues that his case study conceptualisation allows researchers to answer the 'how' and 'why' questions within real life contexts, using both qualitative and quantitative data if necessary. The use of multiple methods to research real-life problems is an approach highly valued by Tashakkori and Teddlie (1998). It is one which Scoles, Huxham, and McArthur (2014) suggest is highly suited to educational research which

often focuses on a problem within the complex environment of a classroom. In navigating the education of students, teachers generally rely on both quantitative and qualitative data to chart progress and address difficulties. In this study where cognitive capacities and skills, as well as affective behaviours are under inspection, the use of both quantitative and qualitative approaches was ideal.

Whilst Yin (2014) describes three different types of case, it is his explanatory case, used to explain how or why some condition came to be, which provided the best fit for this research. This focus on cause and effect provided some consistency with the predominantly experimental nature of previous research into WM training and its effect on academic improvement. Yin also states that this type of case is well suited to program evaluation. In exploring and comparing the effectiveness of combining adaptive, cognitive WM training with a reading intervention program, this study was evaluating a novel, transdisciplinary approach to the provision of a reading intervention program.

Multiple Case Study with Embedded Units of Analysis

There are four different case study designs defined by Yin (2014). These designs are built around whether there are single or multiple cases studied and whether there are single or multiple units of analysis embedded within each case. For the purposes of this research Yin's multiple case–embedded design stood out as the most suitable design.

The logic underpinning Yin's (2014) multiple case design is that the replication made possible in studying multiple cases in the one study, makes the study design considerably more robust than a single case study. Yin describes two types of replications possible through careful selection of each case in the study. He describes a literal replication where similar results for each case are predicted. To achieve literal replication in this study each of the two different intervention formats needed to be undertaken by two groups (cases) of students.

Based on Yin's replication logic, the researcher anticipated replication in the results achieved by both groups of students undertaking the same intervention format (Figure 4.1).

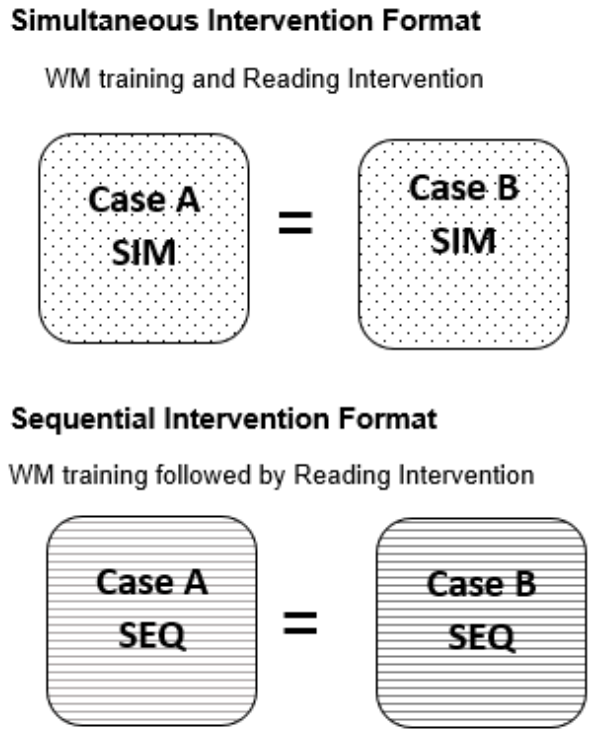

Figure 4.1. Literal replication using a multiple case design. Using literal replication logic, it would be expected that the results for Case A SIM and Case B SIM would be similar and the results for Case A SEQ and Case B SEQ would be similar.

Each group in this multiple case study was designed to contain four students or sub-units of analysis. Having four students in an intervention class is ideal as this small number allows the intervention to be delivered to multiple students at once whilst ensuring there remains a high level of individualised attention, instruction, and monitoring. Having multiple students in both cases receiving each intervention type also provided greater opportunity for literal replication and hence increased the rigor and validity of the study (see Figure 4.2).

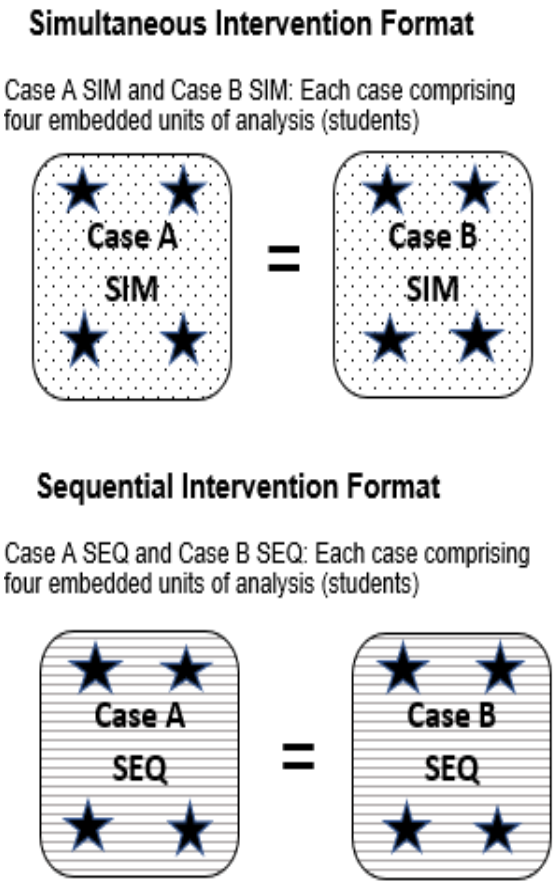

Figure 4.2 Multiple case study with embedded units of analysis. A schematic of Yin's (2014) Multiple case study with embedded units of analysis design used in this study. The four embedded units of analysis in this study were students in primary school Years three and four who exhibited WM deficits and LDR

The second form of replication described by Yin is a theoretical replication. Based on theoretically informed reasons, theoretical replication would be identified by contrasting results for the two different intervention formats (see Figure 4.3).

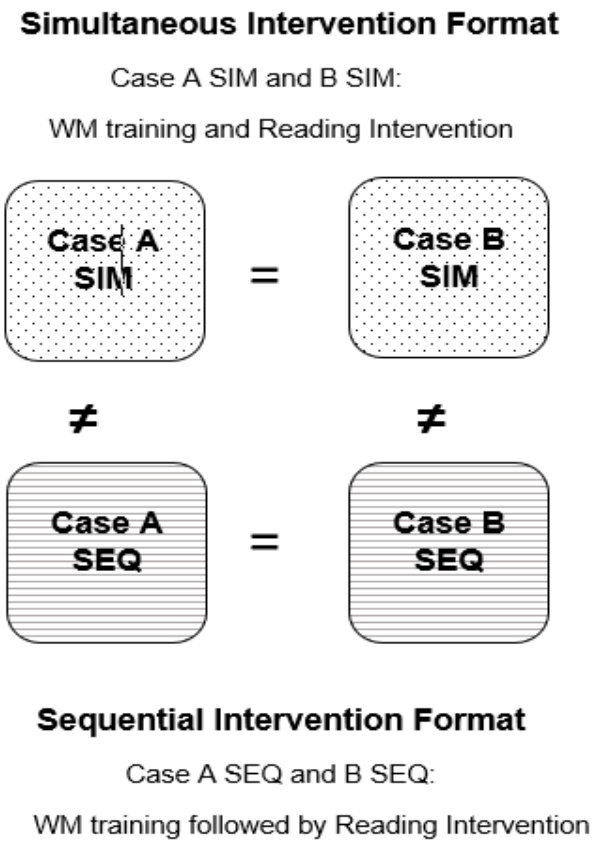

Figure 4.3 Theoretical replication using a multiple case study design. The use of theoretical replication logic to predict a difference in the results for the cases undertaking the simultaneous format to the cases undertaking the Sequential format. This prediction is based on theoretically informed reasons for administering different intervention formats to the two sets of cases.

To achieve theoretical replication and allow for literal replication the researcher needed to study four groups of students. Two groups undertook a Simultaneous intervention format, and two additional groups undertook a Sequential intervention format. Increased rigor and validity may have been achieved by the inclusion of groups receiving single treatment formats of either WM training or reading intervention, however, the study parameters did not allow for this. The deliberate choice of a single school setting with a focus on students in Years three and four with both LDR and WM deficits suggested there could be insufficient participant numbers and resources to facilitate these additional groups. This prediction was realised as highlighted in the ensuing discussion of the Method employed in this study.

One final note on the aspect of theoretical replication is that Yin (2014) contends as does Gagnon (2010), that it will contribute to the formation of analytical generalisations or the ability to generalise to situations beyond the case study findings based on theoretical similarities. This capacity of Yin's multiple case with embedded units of analysis design is well suited to this study purposed on contributing to theoretical understandings around the effectiveness of using cognitive WM training to enhance the educational pedagogical address of LDR.

Method

Whilst this study had a quasi-experimental nature involving pre- and post-quantitative and qualitative data collection, this approach to data collection sat within the stated research method of a multiple case study design. The focus of both the quantitative and qualitative data collection was the individual student participants in each case. While it was important to collect and analyse pre- and post-data for individual students within each case, Yin (2014) stresses the importance of maintaining a strong focus on the case and not the individual embedded units when completing the data analysis and discussion. Yin holds that it is the separate cases which are utilised to generate cross case conclusions necessary to address each of the research questions and potentially inform the development of analytical generalisations.

Context

The naturalistic setting selected for this research was within a multi-site, primary school in Australia. The socioeconomic status of most of the school community was typically Australian middle class (Australian Government, 2018) however in many instances both parents were working to support their educational choice. Whilst this school was becoming more multicultural with increasing enrolments of students with English as an additional language, the majority of enrolled students were of English-speaking origin.

All schools within Australia are mandated to follow the national curriculum either directly or in a format presented through state education departments. This school followed the national curriculum directly. Students were instructed in straight year level groups, with class sizes ranging between 15 to 24 students depending on the school site: one urban and one regional. Each class had one teacher and students either shared or had individual access to a laptop to assist their learning.

The support for students with additional learning needs in this school was provided through an RTI model of identification, assessment, and intervention instruction. This model was discussed in Chapter 2 of this dissertation. This model reflects inclusive educational practice and is widely utilised in many countries, including Australia. To suitably support the learning and development of a student with additional needs, students receive intervention in one of three different tiers of provision. These tiers progressively increase in the degree of specialisation and intensity of intervention provided as the tiers get higher in number. The participants within this study were students from tier one who had been identified as requiring tier two intervention in the form of small group intensive, targeted intervention in literacy.

The intervention programs administered within this study were delivered within purpose specific teaching spaces established for learning intervention at each of the two different school sites. The layout of the instructional space in these rooms had been manipulated to ensure optimum instructional advantage but also that the privacy of the students and their comfort was respected and accommodated. The rooms were well lit and ventilated, temperature regulated, and purpose resourced.

The classroom learning culture of this school was inclusive of student movement in and out of standard classes. Students regularly left classrooms to attend a variety of learning related activities. This culture reduced the risk of the participants in the study feeling embarrassed about leaving class to attend the intervention classes. It similarly reduced the

likelihood of non-participating students making comment about the participants leaving class to attend the non-timetabled classes. Depending on each participant's level of self-confidence and ability, participants were either collected from class by the intervention teacher or moved independently to the intervention classroom.

Participant Selection

According to Yin (2014), the selection of participants or embedded units of analysis within any case in multiple case studies, is based on a logic of replication and not sampling. Yin states that multiple case studies should be considered as multiple experiments and not multiple participants in an experiment. As discussed previously, this study aimed to identify both a literal and theoretical replication, so the participants were carefully selected according to their fit within the theoretical framework of this research. The participants had to exhibit below average reading ability and below average WM. Creswell (2014) refers to this as theory or concept sampling, a form of purposeful sampling which he states is the research term for qualitative sampling.

Participant selection criteria. As part of this purposeful sampling, the participants for this research were drawn from both Year 3 and Year 4 of the Australian Primary level of schooling. These students were in their fourth and fifth year of formal education due to a preparatory year of formal schooling preceding what is known as Year 1. The decision to focus on these year levels was due to consideration of several key features of students at this stage of their educational journey.

Normally developing students in Years 3 and 4 in Australia, would be expected to be moving towards a level of independence in their reading development. Teachers of students within this stage of education would be placing greater focus on teaching their students how to 'read to learn', rather than how to 'learn to read' (McKee & Carr, 2016). At this stage in their primary education, the average student would be expected to read with fluency, ease, and

understanding. They would have developed a level of automaticity in their reading. The demonstrated reading would now be at a rate and level of accuracy that was less effortful than in earlier, developmental years when reading was principally a decoding exercise: a process of deciphering the alphabetic code into units of meaning. The process of decoding or making meaning from words requires significant skill and effort. Texts written for younger students are often scaffolded with visual text to reduce the cognitive load and assist with both the breaking of the alphabetic code and the building of meaning. Young students who are encountering difficulties in their acquisition of early reading skills increasingly struggle as they move into the middle years of primary school (Wei, Spear-Swerling, & Mercurio, 2021). At this level of primary school, the age-appropriate reading materials progressively become more text dense, vocabulary becomes more complex and less familiar, and texts contain less visual scaffolding. As such, when students with LDR enter or move through the middle years of primary schooling, their reading difficulties become quite pronounced and identifiable through data collection. Classroom teachers can access quantitative data from standardised or diagnostic testing and qualitative data from classroom observations and running records. For these reasons it was anticipated there would be adequate numbers of students within this level of schooling who would meet the criteria of having below average reading difficulty and be readily identifiable through school wide testing processes.

In requiring student participants to have below average WM, the decision to select participants from Years three and four was also purposeful. Quite often students with WM deficit are identified in the early years of schooling. In cases where this has not occurred by Years three and four, there are often very recognisable behavioural indications that a WM deficit could be an underlying cause for a student's inattention, distractibility, inability to follow multiple instructions, or struggle to understand their reading. Once again, this level of

schooling was anticipated to be able to supply the required number of participants with below average WM.

The choice of research participants from Years three and four in preference to Years one and two, or Years five and six, was also based on a principle of optimal fit or what Hill, Bordes, Chopra, and Weston (2015) cite as the Goldilocks Principle. It was anticipated there would be adequate eligible participants identifiable in these middle years of primary school whereas the lower levels of primary school may have rendered insufficient eligible students and likewise the upper primary levels may have proffered participants whose presentations were too extreme for the purposes of the study.

An additional and powerful reason for selection of participants from the middle primary levels of schooling was identified in the literature review (refer chapters 2 and 3). This level of the student population has been the target population in several recent studies into WM training and measured post training improvements in certain reading skills (Dahlin, 2011; García-Madruga et al., 2013; Karbach, Strobach, & Schubert, 2015; Loosli, Buschkuehl, Perrig, & Jaeggi, 2012; Söderqvist & Nutley, 2015). Whilst this research study was not aimed at statistical generalisation, as much of the current research in this area has been, it was anticipated that this study might contribute to the building of theory in this transdisciplinary research space via the process of analytical generalisation (Yin, 2014).

As this research was purposed on investigating the effectiveness of differing intervention formats for students with normal intelligence, LDR and WM deficits, all participants in the study had to meet the following four criteria:

1. A participant must have below average general reading ability;
2. A participant must not have an intellectual disability (ID) as measured by a full-scale IQ score at or below two standard deviations.
3. A participant must use English as their first language at home and for learning.

4. A participant must have a WM deficit.

As the scope of this study did not allow for gender or chronological age to be dependent variables, there was no necessity to ensure the cases were balanced for either. The important balance that needed to be achieved in the establishment of the cases was that they contained no more than four participants and there was a similar spread of reading and WM ability amongst participants in each of the cases.

Participant selection process. The specific process of participant selection involved a progressive filtering of available and attainable student data, for all students in Years three and four, against each of the four required criteria.

The filtering process began with an initial screen of the school's most current, annual standardised test data. These data are collected by the school in October each year, from students in Years one through to ten. New students entering the school at the start of each school year, sit these tests in February. Every student undertakes several standardised tests using an Australian Council for Educational Research (ACER) online assessment and reporting system (OARS). One of these tests is the Australian Council of Educational Research, Progressive Achievement Test in Reading Fourth Edition - Comprehension Test (PATR-4), (ACER, 2008). Using the most current, school standardised test data all students in Years three and four who scored Stanine 3 or below on the PATR-4 test, were identified as meeting the first of the participant criteria: below average reading ability.

The second filter applied was to remove any student with a diagnosed intellectual disability. If there were concerns that an identified eligible research participant might have had an undiagnosed intellectual deficit (ID), then school-based screening could have occurred using the Kaufman Brief Intelligence Test –Second Edition (KBIT-2), (Kaufman & Kaufman, 2004). This was not required. One eligible student was filtered out of the study based on the

fact their professional psychological cognitive assessment fell within eligibility for the diagnosis of ID, but the diagnosis was not made or stated within the report.

The third filter was to remove any student who was classified as being an English as an additional language (EAL) student. As discussed earlier, this school had very minimal EAL students enrolled however one student was filtered out of the study by this criterion.

The final filter applied was to check the refined list of below average readers for students who also had a diagnosis of a WM deficit and thus met the fourth criteria for participation. This screening process did not reveal adequate numbers of participants so further testing for WM deficit needed to occur. The list of eligible below average reading students was reviewed with classroom teachers to identify any student with a behavioural and reading behaviour presentation which was suggestive of a WM deficit. These students were screened using a simple digit span screener to remove any students who despite their behavioural presentation, did not present as having limited digit recall. This process revealed fourteen students in total. Permission for these students to be involved in the study was then obtained prior to all students being tested by the school's Speech Pathologist using the Test of Auditory Processing -Third Edition (TAPS-3), (Martin & Brownell, 2005). This test provided measurements of short-term auditory memory (STAM) and WM as measured by purely auditory input. For the purposes of this study data from two out of the four subtests given, were used in the data analysis.

The next task was to construct four balanced cases or intervention groups. Each school site required two groups: one for each intervention format. To assist with group selection, all participants were given two tests developed by Making Up Lost Time in Literacy (MultiLit). MultiLit is a research initiative of Macquarie University, the author and publisher of the literacy intervention program used in this research, namely the Macquarie Literacy Program for Small Group Instruction (MacqLit), (MultiLit, 2014). The students

were tested with the Wheldall Assessment of Reading Passages (WARP) (Wheldall & Madelaine, 2013) and the MacqLit Word Placement Test (MultiLit, 2014). The data from these tests guided the placement of students across the four groups so that each group comprised students with a similar range of reading abilities.

Intervention Programs

As the aim of this research was to ascertain if training working memory at the same time as providing intensive reading intervention would be more effective in improving reading skills than exposing the students to the interventions separately, it was necessary to have access to a research based, effective adaptive WM training program and a research based, effective reading intervention program. The WM training program selected for use in this research was ACTIVATE (Wexler, 2015) and the reading intervention program selected was as mentioned above, the Macquarie Literacy Program for Small Group Instruction (MacqLit) (MultiLit, 2014). Information about both intervention programs is presented below.

ACTIVATE: A cognitive training program. Whilst there are many commercial products competing in the burgeoning marketplace of cognitive training programs, ACTIVATE presented as a suitable product for use in this research.

ACTIVATE (Wexler, 2015) is a researched base initiative out of Yale University, Connecticut, USA. Compared to other research-based products, this relatively new product on the market had attracted limited research at the design stage of this study, however, the available research indicated positive support for its effectiveness in enhancing attention, memory, and executive function. The program provides training in eight core cognitive capacities (C8): sustained attention, working memory, speed of processing, response inhibition, cognitive flexibility, category formation, pattern recognition, and multiple simultaneous attention. As the review of the research literature around WM and WM training

highlighted (refer chapter 3), there are various evolving theoretical frameworks for the neurological composition, location, and function of WM. As the eight differing cognitive capacities trained by the ACTIVATE program are all very much a part of the varying theoretical, research-based conceptualisations of WM, this training program presented as an effective choice for exploring the research questions structuring this study.

The ACTIVATE program is delivered online. The program adapts to the student's achievement every ten seconds and works on the principle of game-based competition. Students are subconsciously trained into always functioning at their optimal level in any of the eight training areas. Training regularly, intensively, and at an optimal level has been proven to lead to neurological changes (McNab et al., 2009).

Each of the student participants undertaking ACTIVATE training were to engage with the program up to five days a week for 20 minutes each day for eight weeks. The teachers providing the interventions at both campuses were provided with two hours of initial ACTIVATE training via a Skype session with C8 Sciences at Yale University, additional access to the program for exploration and trialling of the training games, written support materials to reference, and online support as required throughout the intervention period.

MacqLit: A literacy intervention program. MacqLit is an explicit and systematic reading intervention program designed for use with small groups of low ability readers in Year 3 in primary school but can be utilised with students with LDR presenting in secondary school.

MacqLit is designed to provide instruction in all the key skill areas considered necessary for effective reading: phonemic awareness, phonics, fluency, vocabulary, and comprehension. The nature and importance of each of these skills was clearly expounded and supported in the review of literature around reading disability and the effectiveness of varying reading intervention programs in discussed in Chapter 3.

MacqLit is designed to be delivered to students up to five days a week, for an hour each time. Each session includes intensive instruction and training in all key components of the program. As MacqLit is an explicit, direct instruction program, there were inbuilt controls around the consistency with which the program would be delivered to students in the two cases at each of the two sites. The systematic, explicit, direct instruction model of delivery used within MacqLit was also highlighted as a successful instructional model for use in reading intervention in the literature reviewed, so again MacqLit presented as a suitable intervention for this research. Additionally, as MacqLit was already successfully being utilised within the school where this research occurred its use as the reading intervention program of choice provided many delimitations for this research study, all of which are highlighted in the relevant section below. The format with which the participants in each of the two cases at each school site were exposed to each of these two intervention programs is set out in the next section.

Intervention Program Exposure

In this study the participants in one case at each school site undertook both ACTIVATE training and MacqLit intervention lessons simultaneously for 8 weeks. These cases are referred to as Case A Simultaneous (Case A Sim) and Case B Simultaneous (Case B Sim). The participants in the other case at each school site commenced the study at the same time as the two cases undertaking the Simultaneous intervention format. These additional school cases commenced the study with exposure to ACTIVATE training as a single intervention program. These two cases are referred to as Case A Sequential (Case A Seq) and Case B Sequential (Case B Seq). Case A Seq and Case B Seq completed 8 weeks of ACTIVATE training and then undertook a further 8 weeks of MacqLit reading intervention as a single intervention program. The data sources which were employed within the study will now be outlined.

Data Sources

One of the prominent, distinguishing features of case study research is its ability to use multiple data sources. The integration of varying and multiple data sources assists in the construction of in-depth understandings of the complexities of the situationally based case/s being studied (Creswell, 2014). According to Creswell (2014) it can also enable the strength of one data form to offset the weakness of the other data form.

Case study also enables the collection of both qualitative and quantitative data. Miles, Huberman, and Saldaña (2014) suggest "qualitative data are useful when one needs to supplement, validate or illuminate quantitative data gathered from the same setting" (p.12). Given the naturalistic setting and pragmatic purpose of this study, the use of multiple data sources and a mixed method approach ensured the three research questions were sufficiently informed. The data sources used to address each of the research questions are presented in Table 4.1.

Equal importance was given to both quantitative and qualitative data as both forms of data were required to address the three different research questions, and ultimately, to enable any conclusions about the effectiveness of either intervention format to be drawn. The different and multiple data sources provided insight into any differences between the effectiveness of the two different intervention formats, on measures of WRA, WM and RSE. The data collection tools along with the nature of each type of datum collected are discussed in the next section.

Quantitative data sources. A range of tests were used to collect quantitative data on WRA and WM. A summary of the quantitative and qualitative data collection tools used at varying times prior to, within and post the intervention periods is provided in Appendix F presented as Table F.4.1. All tests, except for the PATR-4 were administered individually to every participant. As mentioned previously, the PATR-4 is administered online and

supervised by classroom teachers. The other tests used in this study were administered by the school intervention teachers and/or school speech pathologist.

All the tests utilised have published, research-based reliability and validity, and all have alternative test forms, providing test –retest reliability.

Table 4.1

Data Source Matched to Research Questions (RQ)

Data Source	RQ1	RQ2	RQ3
TOWRE 2 Test of word reading efficiency	**X**		
YARC York assessment of reading for comprehension, passage reading, and accuracy	**X**		
TAPS 3 Test of auditory processing skills (3rd ed.)		**X**	
National Institute of Health (NIH) Toolbox Flanker test and List Sorting Working Memory test		**X**	
Student Questionnaire	**X**	**X**	**X**
Parent Questionnaire	**X**	**X**	**X**
Classroom Teacher Questionnaire	**X**	**X**	**X**
Semi Structure Interviews with Intervention Teachers	**X**	**X**	**X**
Physical Artefacts	**X**	**X**	**X**

Quantitative data sources used in pre-selection of participants. As discussed in the participant selection section of this chapter, the PATR-4 was used to initially identify

students with below average reading ability. It is a standardised reading comprehension test comprised of several short passages with accompanying multiple-choice, comprehension questions developed and standardised by ACER.

The WARP (Wheldall & Madelaine, 2013) was used to assist with the placement of students within the two cases at each school site. The WARP was designed and marketed as an assessment tool for the identification of student eligibility for inclusion in a MacqLit Literacy Intervention Program. The WARP has three initial screening passages and ten progress monitoring passages. The average number of words a student reads correctly within the three initial screening passages in the WARP, indicates the current oral reading fluency of a student. Within the context of this study the results of the WARP provided an indication of the WRA of the participants at each school site and consequently enabled the balanced placement of participants in each case at each site.

Quantitative data sources used in pre- and post-intervention participant testing. Prior to the start of the intervention sequences, every participant was tested to gain two different measures of their single word reading ability, one measure of their reading accuracy and two measures of auditory WM.

Single word reading ability was measured using two different subtests of the Test of Word Reading Efficiency 2 (TOWRE 2) (Torgesen, Wagner, & Rashotte, 2012). The TOWRE 2 was normed in America and at that time, Australian norms were not available.

The TOWRE 2 has alternative test forms. Each test form provides two measures: a measure of the participant's ability to accurately read sight words and the ability to read phonemically regular non-words. The participant reads the two lists of words, each for 45 seconds, and the words read correctly on each are tallied and scored independently.

Reading accuracy was measured by the York Assessment of Reading for Comprehension -Passage Reading (YARC) (Snowling et al., 2009). The YARC has two

alternative, parallel tests of graded passages (A and B). These alternative test forms were used in pre- and post-testing. The passages are read aloud by the participant. Reading inaccuracies are noted and scored to provide a measure of reading accuracy. Reading inaccuracies are classified as:

- Mispronunciation: the reader attempts the word but reads it incorrectly.
- Substitution: the reader reads a different word to the one in the text.
- Refusal: the reader refuses to attempt to read a word.
- Addition: the reader reads a word which is not in the text.
- Omission: the reader leaves out a word which is in the text.
- Reversal: the reader reads a word incorrectly because they have reversed the order of the letters in the word.

Two of the memory subtests within the TAPS-3 were utilised to provide data relating to two different auditory memory functions: short term auditory memory (STAM) and auditory WM which for the purposes of this study have been labelled as working memory measured purely with auditory information (WM-AI). The Digit Forwards Subtest comprises progressively longer strings of isolated, single digit numbers delivered orally to the testee, which the testee must recall and repeat orally. This subtest provides an indication of STAM. The Digits Backwards Subtest comprises progressively longer strings of isolated, single digit numbers delivered orally, which the testee is required to repeat orally but in reverse order to the original sequence. For example, the tester might say 4,8,2,0 and the correct response would be 0, 2, 8,4. This subtest provides as indication of WM measured using purely auditory input.

Additionally, data were collected in relation WM measured using visual input referred to within this current study as WM-VI and in relation to the ability to focus attention (FA).

These data were collected from the ACTIVATE pre-post data for the WM test and the Flanker Test.

Qualitative data sources. Being a case study, the data used to address the research questions needed to reflect the data utilised within a primary school classroom to inform and guide practice. Qualitative data is a very rich source of data within this context as learning is behavioural, interactive, and fluid. While it can be measured quantitatively, these measurements are what educators refer to as a snapshot in time. This snapshot may look different depending on the presentation of the learner, the context of the assessment and many other variables which can influence human behaviour. To that end, within the classroom quantitative data is often balanced against descriptive input from qualitative data. This was also the case in this study where both forms of data were used to inform the address of the three research questions.

In selecting qualitative data sources, the researcher decided to use more than one source of description as Gillham (2005) highlights the discrepancy that often exists between what people know or say, and what they do. Gathering data from the participants themselves and from those who know them well in different capacities and contexts, allowed for a convergence of the data to build an explanation; an analytic technique detailed by Yin (2014). This data was collected pre- and post- intervention format, from participating students, their parents or principal caregivers, their classroom teacher, and their intervention teacher.

The students, parents and classroom teacher were asked to complete an open-ended questionnaire comprised of four questions (refer Appendix G). The questionnaire was designed to provide insight into the student's belief about their reading ability, how much they value reading, the time they spend reading, and how much effort it takes them to read text. To facilitate the data convergence for each of the three research questions the construct of the four questionnaire questions was kept simple and similar across the different

questionnaires compiled for the various respondents: student participant, parent, and teacher. The grammatical structure of the questions was essentially all that changed so as to make them more contextually appropriate.

The questionnaires were completed online, through a Microsoft Office 365 form. A link to the form was emailed to the parent and classroom teacher respondents. The students were not sent the link. The student link was sent to the intervention teacher who administered the questionnaire orally and individually with each student, scribing their responses into the form. This delivery format provided immediate access to digital, manipulatable data which greatly assisted in the ease of data collection, storage, and analysis. While these data were collected in specific reference to the third research question, the responses were also screened for qualitative data which could be triangulated with the quantitative data used to explore the first two research questions.

This also proved to be a worthwhile exercise in relation to the data collected through the semi structured interviews with the two intervention teachers. These semi structured interviews were conducted by the researcher, face to face, one on one with each of the two intervention teachers at the conclusion of the Sequential intervention format. This was the final stage of the data collection process for this study. One intervention teacher was interviewed over a single session and the other intervention teacher was interviewed over two sessions due to time constraints on that teacher. The sessions were broken into separate interviews relating to the individual student participants the intervention teacher had worked with as part of this study. Each interview was relatively short with no interview lasting longer than 10 minutes. As mentioned above the questions presented were the same as those presented to the student participants, parents, and classroom teachers. As these interviews were deliberately conducted as semi-structured interviews, the use of prompts allowed for additional information to be sought from the intervention teachers when the initial responses

indicated the opening to do so. This often provided very useful data relating to the first two research questions as well as research question three. Details relating to the actual prompts utilised are provided in Appendix H.

Gillham (2005) celebrates the validity of interview data and believes its value lies in what it adds to other data. The data from these interviews provided a different perspective on the effectiveness of the reading intervention for each participant and each case, and in triangulation with all available data, certainly assisted in the task of comparing the effectiveness of both intervention formats. These data were also very useful in understanding the limitations of conducting a case study of this nature in a real-life school setting. The teachers mentioned many limitations they encountered as they endeavoured to deliver the two different intervention formats as designed within the ever-changing landscape of a primary school. While many of these limitations were predictable and discussed below, others arose purely due to the fact this study was actioned in the organic, dynamic environment of a primary school. The impact of predicated and unexpected limitations on the execution of the study, the data collection and analysis will be discussed in Chapters 5 and 6.

One final source of qualitative data used in the data analysis was physical artefacts from the ACTIVATE training data and the MacqLit intervention classrooms. The ACTIVATE training data provided progressive and summative records of student engagement and progress through the program and within individual games aimed at training different cognitive capacities. The artefacts from the MacqLit classroom came in the manner of attendance records, written notes and oral conversations between the researcher and the intervention teachers about session behaviours of individual students, student workbooks and the progress data from the WARP.

Data Analysis

The analysis of the various data sets pursued a multi-levelled, multi-staged, convergent analysis format. According to Yin (2014), the value of two data types and multiple sources within one study is only realised if there is convergence in the data analysis process. Yin contends that separate analyses with no convergence is akin to the comparison of results from separate studies, yielding separate conclusions. Yin also holds that the construct validity of a case study can be strengthened through the convergence or triangulation of multiple sources of evidence.

To prepare for case level analysis an initial step in both the qualitative and quantitative data analyses was to assemble the data of each individual participant -the embedded unit of analysis (Yin, 2014). As it is important in case study methodology for the focus to be on the case rather than the individual (Yin, 2014) the analysis of the individual participant data within each case was by case rather than by individual. This analysis step is a deliberate design strategy to protect against selectivity and unintended analysis bias.

As Table 4.1 indicates the data which was used to inform each of the three research questions were both quantitative and qualitative. Given the different nature of these two types of data, different tools were used in their analysis. This separate, yet parallel analysis of the two different data types for each participant constituted the first stage of the data analysis.

For the powerful nature of this mixed method type approach to be realised, it was important the data analysis move to a second stage where there was convergence and integration of data. This type of data analysis is presented in Creswell (2014) as a convergent, parallel mixed method design. In this study it was necessary to converge the two types of data at three levels: the individual, within the case, and multiple cases (see Figure 4.4). Yin (2014) emphasises the necessity of this convergence at critical stages to address research

questions and to build an explanation: in the case of this study, to explain any difference in effectiveness of the two different *intervention* formats.

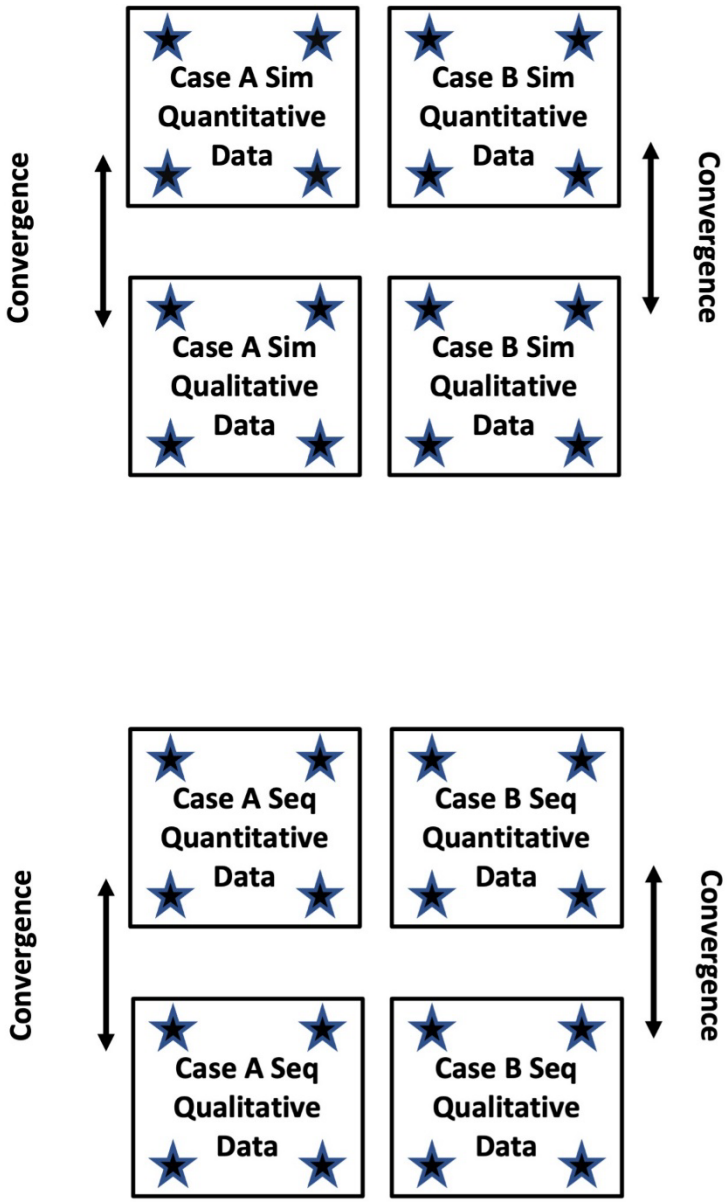

Figure 4.4. Three tiers of data analysis using the convergent parallel mixed method design. Convergence occurs at the level of the individual unit of analysis each case, at case level and multiple case level within each intervention format: Simultaneous (Sim) vs Sequential (Seq).

A second important aspect to the data analysis was how the data were analysed within the multiple case-embedded design to identify any literal replication (refer Figure 4.1) and to identify any theoretical replication enabling the formulation of analytical generalisations

(refer Figure 4.3). As discussed above, Yin (2014) stipulates the importance of moving on from analysis of data at the level of each individual unit of analysis in each case, to analysis of the whole case. Case level data within each intervention format needed to be examined to establish any level of literal replication. The multiple case data from each of the two different intervention formats needed to be analysed and compared in order to identify evidence of theoretical replication. In this study this would be identified if the Simultaneous intervention format proved more effective than the Sequential intervention format (refer discussion of the theoretical basis for this prediction in chapter 3). This would enable the formulation of analytical generalisations.

Quantitative data analysis. As discussed earlier, it was necessary to look at data for individual participants to ascertain if there was any difference in WRA and WM abilities due to exposure to differing intervention formats. Note there was no quantitative data collected in relation to RSE. As traditional approaches to the analysis of quantitative data tend to be more aggregate or nomothetic, it was necessary to adopt an idiographic approach to enable analysis of the impact of an intervention format on the WRA and WM capacities of each student. Hitchcock, Johnson, and Schoonenboom (2018) provide support for this approach to quantitative data analysis within research in special education as it is often purposed on investigating causation and treatment effects.

At the level of individual participant, the pre- and post-intervention raw scores on each test type were converted to percentiles. The pre –post percentile ranking for each individual participant on each test instrument was analysed to identify any difference in the WRA or WM abilities of the individual, post exposure to an intervention format. The results for all individuals in each case were then analysed as a whole case to identify difference in WRA and WM by case. Finally, the results for the two cases within an intervention format were discussed in relation to the pertinent research questions.

Qualitative data analysis. The data collected from the open-ended response questionnaires, the semi-structures interviews and the physical artefacts were likewise analysed at the individual and case levels. In preparing for this analysis, the data needed to be reduced through deductive processes drawn from the theoretical propositions which framed this study.

The approach taken in the analysis of the qualitative data was structured on the five phases of analysis featured in Figure 4.5 which Yin (2016) presents as being a complete cycle yet composed of movement back and forth between phases as the analysis occurs.

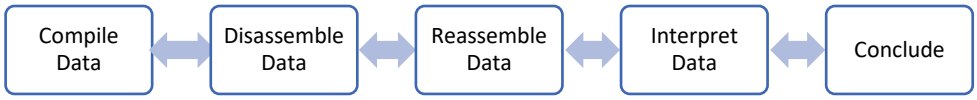

Figure 4.5 Five phases of qualitative analysis adapted from exhibit 5.8 in Yin (2016).

Yin argues these five phases are identifiable in most qualitative analysis no matter the specificity of the research design. Within this study, the qualitative data analysis process initially moved recursively through the first four phases. To reach conclusions around the research questions, it was necessary to converge quantitative data and qualitative data analyses while still within phase 4 as depicted in Figure 4.6.

The general analytic technique employed throughout this process was a special form of pattern matching referred to as Explanation Building by Yin (2014). This technique is particularly relevant to this study being an explanatory case study. It was purposed on identifying if simultaneous exposure rather than sequential exposure to a reading intervention program and a cognitive WM training program would result in greater gains in the WRA, WM and RSE of participants. This explanation would reflect and be linked to theoretical understandings around the strong interrelationship of WRA, WM and RSE (Peng et al.,

2018; Schiefele, Schaffner, Möller, & Wigfield, 2012). It would also contribute to ongoing research into the effectiveness of utiliisng WM training in WRA interventions in students with deficits in both WM and WRA (Loosli, Buschkuehl, Perrig, & Jaeggi, 2012).

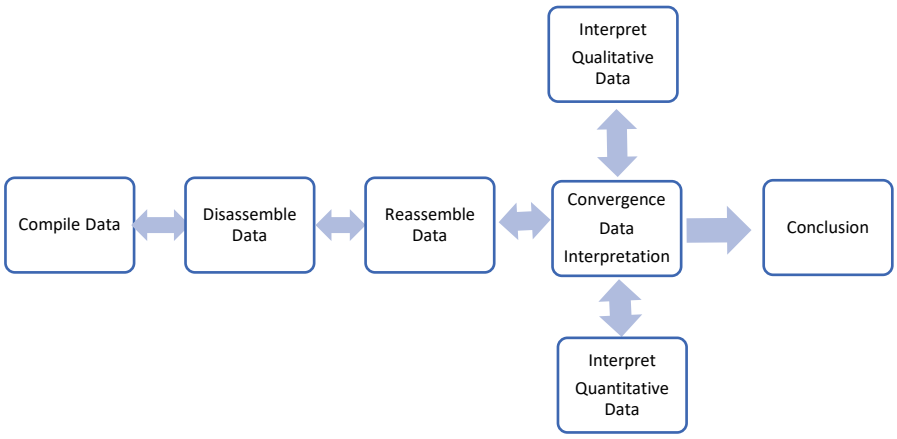

Figure 4.6. Convergence of quantitative and qualitative data analysis to reach conclusion.

Phase one: Qualitative data compilation. The initial treatment of the qualitative data was to compile it by data type according to the 13 participant students. The data from the pre-post online questionnaires were compiled into an Office 365, Excel workbook comprising separate worksheets for the student, parent, and classroom teacher responses to the pre – post questionnaires. As discussed earlier in this chapter, the questions on the pre-post questionnaire were all deliberately similar for student, parent, and classroom teacher. This assisted in both the compilation and subsequent coding phases.

The audio capture of the semi structured interviews conducted with the intervention teachers from both school sites were transcribed with the assistance of TRINT, a commercial, online transcription service. The post intervention ACTIVATE reports for each student participant were generated from the C8 Sciences ACTIVATE portal.

At this point in time the compiled qualitative data were raw and vast. The next step in the analysis was to make the ongoing analysis process not only manageable but relevant to the research questions. Each data format required disassembly for it to align with the research questions.

Phase two: Qualitative data disassembly. The first iteration of this process involved compilation of all the pre-post qualitative data relating to each individual student participant into a single Excel workbook for each student. For this process to achieve the goal of disassembling the data according to the research questions, the pre-post data were entered into a spreadsheet according to whether it related to two different WRA, two different WM capacities and thirdly to RSE. The two WRA were: Sight Word Efficacy (SWE) and Phonemic Decoding Efficacy (PDE). The two WM abilities: Focussed Attention (FA) and Working Memory measured with purely visual input (WM-VI). Data relating to RSE were identified as it related to the time and effort participants invested in reading, the confidence with which they approached reading and the value they placed on reading as a skill or pastime.

To enable this disassembly of the raw data relating to SWE, PDE and RSE, a form of NVivo coding (Saldaña, 2013) was utilised. It is a literal, verbatim, natural, or emic coding as discussed by Rogers (2018). Essentially this form of coding places prime importance on the voice of the individual participant. In this study where the researcher intentionally utilized qualitative data as well as quantitative data to gain greater insight into the context and story of each student's reading development, the voice of the participant and other characters in their story was very important. The use of the participant voice was also a deliberate action to reduce researcher bias and value laden interpretation.

To disassemble the FA and WM-VI qualitative data available in ACTIVATE, descriptive comments from the cognitive reports for each student was coded. The specific information utilized related to the entrance ability and degree of change in FA and WM-VI for each participant exhibited in the pre–post NIH assessments completed within the ACTIVATE training sessions.

On completion of this first level of coding, the data were informative and rich but still

extremely expansive and unmanageable with respect to the identification of emerging explanatory patterns relating to the research questions. It was therefore necessary to move into the third, Reassembly Phase.

Phase three: Qualitative data reassembly. To reassemble the data, a second level of coding was utilised. Saldaña, (2013) identifies this as pattern coding, whereas Yin (2016) calls it category coding. Yin's definition highlights the need to view and think about the data at a higher level of analysis: to categorise it conceptually.

The most relevant concepts for SWE and PDE related to the level of Skill Acquisition and Skill Application. With respect to identifying change in RSE, the researcher drew on research around the relationship of self-efficacy and academic outcomes (Bandura, 1977; Lee & Jonson-Reid, 2016; Schunk, 1995; Unrau et al., 2018). Within this research, there was strong indication that self-efficacy influences behaviours related to academic success. Schunk (2003) states that achievement behaviours such as choice of task, level of effort applied to a task and persistence in engaging in a task in the face of difficulty can all be influenced by self-efficacy. To that end it was decided to use the following concepts and related measurements to identify change in RSE:

- Task Persistence reflected in Time spent on task.
- Task Effort reflected in Effort required to engage in task.
- Task Confidence reflected in Belief in task ability.
- Task Choice reflected as the Value of task (reading) to the participant.

The second level codes applied to the SWE, PDE and RES data along with the descriptors used to identify evidence of these second level codes are displayed in Appendix I, Table I.4.1.

To identify patterns within the pre-intervention, ACTIVATE data concerning the FA and WM-VI abilities of participants, the data were coded as reflecting Weak, Moderate or

Strong ability. The post-intervention FA and WM-VI qualitative data were coded according to the level of described change in both capacities. Change in ability was coded as having shown Decline, Very Little Change, or Valuable Gains.

To avoid what Miles, Huberman, and Saldaña (2014) observe as a tradition in qualitative data analysis of dealing with the qualitative data in a quantitative manner and losing sight of some of the rich narrative provided by qualitative data, relevant quotations from the qualitative database related to the second level codes were compiled. The quotations from the participants in all cases were compiled and displayed in Appendix M, Tables M.5.1, M.5.2, M.5.3, M.5.4, M5.4, M5.5, M5.6. These quotations along with the Second Level Codes enabled the qualitative data analysis to progress to the fourth, interpretative phase of qualitative data analysis.

Phase four: Qualitative data interpretation. Having now assembled and sorted the qualitative data at the level of individual participant, it was important to analyse at the case and multiple case levels. This was completed according to the three research questions. Once this phase was completed it was possible to move to phase five where conclusions could be drawn for each of the research questions based on qualitative data alone. In order to reach conclusions for the whole study based on all of the data, it was extremely critical to converge the two separate data analyses. This process is represented in Figure 4.7 and is discussed in the next section.

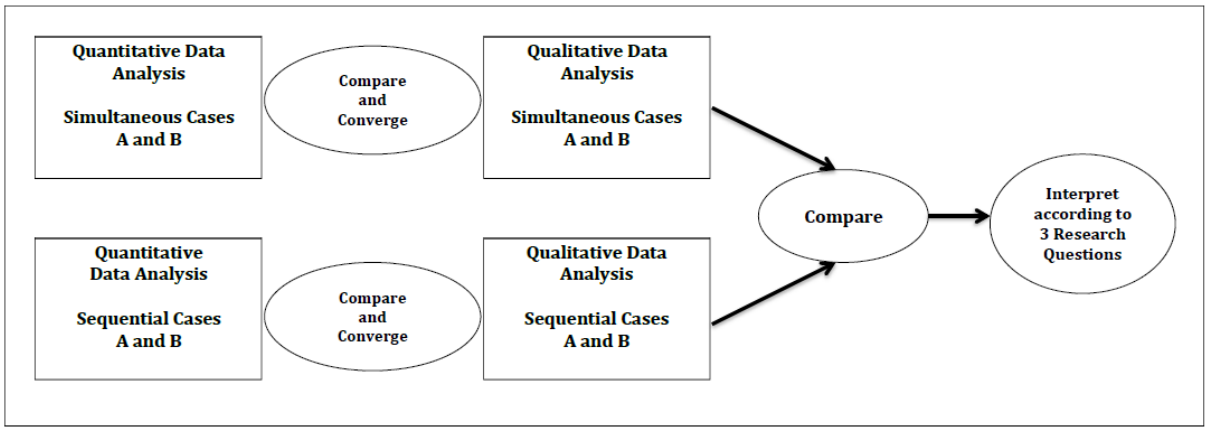

Figure 4.7. Convergence of parallel quantitative and qualitative data analyses.

Convergent comparative analysis. As discussed earlier in this chapter, this convergence of data allowed for the statistical quantitative data to be viewed within the affective context provided by the qualitative data. This is reflective of a balanced assessment approach often utilised within primary aged classrooms and hence provides a research-based capture of the effect of either intervention formats. The convergence also enabled the results of the two parallel data analysis processes (quantitative and qualitative) to provide a unified response to each of the three research questions.

The convergent process involved juxtaposing the results of the quantitative and qualitative data analyses for each case within each intervention format. As well as addressing the research questions, this discussion also facilitated a discussion around theoretical replication. Based on research discussed in Chapter 3 this current study investigated whether trained improvement in WM might lead to improvement in WRA if WM training and educational interventions were to be provided simultaneously within schools. The aim of this study was to contribute to this research focus of growing understanding of how WM training could be used within schools, to contribute to the improvement in reading ability of students with low WM and reading difficulties.

Limitations

As discussed earlier in the chapter, one of the principal reasons for utilising a case study methodology over an experimental methodology was the inability to control for all variables which could arise when conducting experimental research within a real life setting such as a classroom. Whilst the use of the multiple case-embedded design did allow for a quasi-experimental type of research study such as this one, the real-life classroom setting, did present some significant limitations as listed:

- The selection of eligible participants needed to sit within school-based quantitative assessment processes, the response to intervention (RTI) school-based processes and resourcing for intervention programs at each school site.
- The regular attendance of participants could not be guaranteed.
- Participants may have unenrolled from the school during the study or taken extended holidays.
- Intervention classes were highly susceptible to interruption or cancellation due to whole school events.
- Intervention teacher absenteeism.
- Intervention teacher may leave the school unexpectedly.
- The existence of a power relationship between researcher and intervention teacher.

The address of each limitation was as follows:

- The use of both quantitative and qualitative pre- and post-data, as reflective of normal classroom balanced assessment procedures, assured the researcher that all participants were selected as eligible candidates who required intervention for their below average reading and WM abilities.

- Both the WM and reading interventions were administered over an eight-week period to allow for any minor interruption due to student or teacher absenteeism, and program interruptions.
- Each case was to be comprised of four participants so if a participant withdrew for any reason, there were enough participants left for the study to have viability.
- There were to be two intervention teachers trained at both campuses so in the event of teacher absence, there was the possibility of a trained replacement teacher, so the class could proceed.
- Whilst the researcher normally works in a relationship of authority with the intervention teachers and the student participants, the researcher was to have minimal face-to-face involvement in the study. The researcher's involvement in the study was to be limited to the conduct of the semi-structured interviews with the intervention teachers where the focus of the questions was not related to teacher behaviour but student behaviour. This was a deliberate effort to diminish any effect due to this relationship of power. This was also an effort to mitigate against any bias in the data collection phase.

Delimitations

There are several deliberate actions listed below, which influenced the development of this study to achieve rigor and quality within the design:

- It was grounded in the theoretical frameworks of WM, WM training, reading skill development and reading intervention pedagogy identified through an extensive literature review.
- the development of theoretically based research questions;
- the selection of a contextually appropriate and achievable methodology;

- the development of a methodical and rigorous screening process for appropriate participants;
- the location of an accessible WM training program;
- the pre-existence of MacqLit as the reading intervention program of choice in the school selected for this research;
- the intervention teachers already trained in MacqLit;
- planning for multiple data sources and data triangulation;
- the inclusion of measures such as member checking, (Gillham 2005) put in place to limit researcher bias; and
- the employment of a research design that will facilitate a contribution to the build of the theoretical frameworks underpinning the study.

To that end, this research was designed to be credible, trustworthy, theoretically transferable, and confirmable.

Ethical Considerations

In planning for this study there were many ethical considerations to plan for and accommodate prior to commencing the research, throughout the course of the research study and through to the publication of the final research dissertation.

Within the research and design phase, there was a deliberate focus on ethical scholarship. Under this banner Yin (2014) would include the avoidance of plagiarism and the falsification of information, the maintenance of current research understandings, and the purposeful endeavour to maintain honesty and rigor in all aspects of the research preparations.

An application for ethical approval was submitted to the Human Research Ethics Committee (HREC) of the Australian Catholic University and approval was granted on the 14th of February 2018 (refer Appendix A), with the research risk being deemed as low.

The successful HREC application addressed the following concerns:

1. In the selection of participants there may have been concern that not all eligible students would be able to participate in the research, hence raising questions of equity. As most schools have limited resources for addressing the additional learning needs of students via intervention programs, it is not unusual for students to be placed on waiting lists to be provided with access once a program opening arises. The students not able to participate in this study would be offered places in subsequent programs.
2. A possible risk of harm to a student's academic progress due to loss of learning time while withdrawn for intervention classes was negated by the fact that the reading intervention program was currently being used successfully within the school with no evidence of such harm to the current participants.
    - There may be possible inconvenience to the students due to a loss of free time at lunch times, if WM training had taken place during lunch breaks. It was thought this could be minimised by only training at lunch time once a week and incorporating the remaining training sessions into alternative timeslots during the school day.
    - The possibility that one intervention format will be more effective than the another, resulting in two groups of students being provided with greater benefit than the other two, could be considered a risk. As there was no certainty there would be a difference in effect, and as all students were to receive both WM training and reading intervention, with only the delivery format changing, this was a low-level risk.
3. With respect to informed consent, the participants within this research were too young to be asked for consent. Informed consent was sought from their parents. In doing this, the parents were provided with complete details about the purpose of the research, the risks and benefits for their child and the implications of their

involvement. The parents were assured that all their child's data would be kept anonymous and confidential (Refer Appendices B and C).

4. Informed consent was also gained from participating school staff (Refer Appendices D and E).
5. The preparation of this dissertation for examination, has been careful to ensure the school, the participants and the intervention teachers are all non-identifiable. The research is reported in an academically rigorous, honest, timely, and scholarly manner.

Summary

The development of this research study was motivated by a research-based understanding of limited evidence pertaining to the transfer of trained improvement in WM through to improvement in reading ability, particularly at the word reading level, in young students with both WM and reading deficits.

This research study was designed to identify if there would be any difference in word reading ability if WM training were to be undertaken simultaneously with a reading intervention program rather than separately. The research was designed as a multiple case study with embedded units of analysis set within the context of real classroom settings. Through purposeful, rigorous, and methodical design construction, this study was intended to be highly credible and trustworthy, and to offer via the principle of theoretical replication, a contribution to theoretical understanding of how cognitive WM training may contribute to the improvement in word reading skills of students with WM and reading ability deficits.

Chapter 5

Results

In God we trust; all others must bring data.
(W. Edwards Deming, n.d.)

This study was set within research informed understandings of reading as a developmental and learned skill. The participants were students who had both a learning difficulty in reading (LDR) and a deficit in working memory (WM) abilities. The literature review in Chapters 2 and 3, highlighted the strong connection between LDR and WM abilities (Nevo & Breznitz, 2014; Peng et al., 2018; Swanson & Kong, 2018). This study was inspired by growing evidence in research literature that WM abilities can be trained and yet minimal evidence indicating trained improvement in WM contributes to improvement in academic outcomes (Dahlin, 2011; Loosli, Buschkuehl, Perrig, & Jaeggi, 2012).

This study aimed to contribute to ongoing research into the effectiveness of using WM training to contribute to improvement in academic outcomes for students with deficits in Word Reading Ability (WRA) and WM abilities. It was a unique study set within a multi-site Australian school, in the middle primary years. It investigated and compared the effectiveness of using WM training and literacy intervention at the same time (Simultaneous intervention format) as opposed to disparately in time (Sequential intervention format) within a school setting. The study also investigated and compared the impact of the two different intervention formats on Reader Self Efficacy (RSE). There were three research questions under investigation:

Q1. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence word reading ability outcomes?

Q2. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence measures of working memory abilities?

Q3. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence reader self-efficacy?

As the growth of reading ability involves the development of many reading subskills, the possible scope of the data collection in relation to reading ability was narrowed to data relating to WRA. Research indicates WRA is very important to early and ongoing success in the acquisition of reading (Reynolds, Wheldall, & Madelaine, 2010; Yeung, 2016). WRA is also associated with WM abilities (Etmanskie, Partanen, & Siegel, 2016; Polychroni, Economou, Printezi, & Koutlidi, 2011).

The data collected in relation to WM examined WM related abilities which align to the established multi-modal model of WM first postulated by Baddeley and Hitch (1974). Data were collected for visual and auditory memory abilities and focussed attention.

The data collected in relation to the self-efficacy of the participants as readers, aligned with research indicating that self-efficacy influences learning behaviours associated with achievement (Bandura, 1997; Schunk, 2003). Qualitative data were collected in relation to Task Choice, Task Effort, Task Persistence and Task Confidence with the task defined as reading.

Study Implementation

This study employed case study methodology with a multiple case with embedded units of analysis design (Yin, 2014). Two cases (groups) undertook each of the intervention formats (Simultaneous versus Sequential). Each case contained multiple units of analysis (students).

Due to the risk of confounding variables arising from small participant numbers and the naturalistic setting of a school, multiple quantitative and qualitative data were used to inform the research questions. To ensure a deliberate design focus on case rather than the individual within a case (Yin, 2014), the individual participant quantitative and qualitative data were collated by individual within each intervention group (case). The quantitative and qualitative data analyses occurred by case in a parallel process. The two data analyses were then converged in the discussion of how the mixed data addressed each of the research questions.

Participant Information and Case Composition

The study commenced with 14 participants located across two geographically separate sites of one primary school. There were 7 participants at Site A and 7 participants at site B. Site A had a group of three (Case A Sim) and a group of four (Case A Seq). Site B had a group of four (Case B Sim) and a group of three (Case B Seq). One participant in Case B Seq was withdrawn by their parents in the fifth week of the study. The reasons for withdrawal are elaborated in Appendix J. Data for 13 participants were used in the data analysis.

The distribution of students across cases and the intervention format undertaken by each case is depicted in Table 5.1.

Table 5.1

Participant's Demographics and Spread Across Cases

Site	Intervention Format	Participants	Gender - Age
A	A-Simultaneous	3	3 males aged 9 -10
A	A - Sequential	4	4 males aged 9 – 10
B	B – Simultaneous	4	1 male and 3 females aged 8 – 10
B	B - Sequential	2	1 male and 1 female aged 8 - 10

Seven participants undertook Simultaneous interventions, and six participants undertook Sequential interventions. The table also outlines the major demographics for each participant. There were four females and nine males with ages ranging between 8 and 10 years of age, although it must be noted that age and gender were not variables within the study.

Variability in Intervention Exposure by Case

As detailed in Chapter 4, the logic underpinning literal and theoretical replication guided the multiple case study design, participant selection and planned delivery of the two different intervention formats. As mentioned previously, a very real limitation for this study was the possibility of confounding variables due to the naturalistic setting of a functioning primary school.

Despite careful planning and research supervision, one such variable did arise in the form of exposure time to the two intervention programs received by one of the groups. Differences in intervention exposure became evident and non- circumnavigable as the study progressed. The interventions were being delivered in a functioning, busy primary school on two different sites, where absenteeism of both students and staff, along with unexpected interruptions to program delivery did differ slightly between the two sites. The most significant difference was felt in Case A Seq which had high participant absenteeism and program interruption.

Exposure to the ACTIVATE training program (Wexler (2015) differed slightly across all cases, but significantly with one case. The two cases undertaking the Simultaneous intervention format had similar exposure time. The exposure time for the two Sequential format cases were quite dissimilar. Case A Seq experienced almost half the exposure of Case B Seq B. The training exposure time for each of the four cases did however exceed the minimum recommended training time of 600 minutes.

Exposure to the MacqLit literacy intervention program was similar for three of the four

cases, with all three receiving 32 to 35 hours of intervention. Case A Seq received less exposure to MacqLit with 15 hours of intervention.

The relevance of these differences to the three research questions and the identification of literal and/ or theoretical replication will be identified at pertinent points in the presentation of results in this chapter and the discussion in Chapter 6.

Variability in Individual Participant Pre-Post Data

As previously highlighted this current study followed Yin's case study methodology with a deliberate focus on case data analysis rather than individual participant data analysis. This focus was pertinent to this study designed to enable identification of literal and theoretical replication. It was also useful in accommodating variability in individual participant abilities across the range of subskills and capacities within WRA, WM and RSE. This variability in subskill ability or capacity is very evident in classrooms. It is the core business of the primary teacher to accommodate and work with individual differences while in pursuit of academic and developmental goals.

Evidence of this individual variability is quite apparent in the quantitative pre- and post-percentile data for the WRA and WM capacities of all individual participants (refer Appendix K). This variability is further highlighted in Table 5.2. which shows the ranking of each participant according to the difference between their pre- and post-percentiles on each of the seven instruments. The participants were ranked from 1, being the student who had the largest positive difference between their pre- and post-percentile to 13, the student with the least positive or greatest negative difference in pre-post percentile.

As can be determined only one of the 13 participants did not achieve a ranking of 1-2 (high) or 12-13 (low) across the WRA and WM abilities. This suggests the individual abilities were spread not only over a continuum within a particular WRA or WM ability but also across the WRA and WM abilities. It also serves to highlight the importance of

maintaining a data analysis focus on the case and not the individuals within the case. Further discussion relating to this variability within individual participants and across the WRA and WM abilities will be discussed in the ensuing discussion of both the quantitative and qualitative data. It will also be discussed in greater detail in Chapter 6.

Table 5.2

Participants' Pre-Post Percentile Change Ranking: ***Largest 1-2*** ***To*** ***Smallest 12-13***

Participant	Case/ Intervention	Sight Word Efficacy	Phonemic Decoding Efficacy	Reading Accuracy	WM Visual Input	Working Memory - Auditory Input- STAM	Working Memory Auditory Input- AWM	Focused Attention
1	A Sim	6	7	7	8	10	6	1
2	A Sim	12	4	5	6	12	7	8
3	A Sim	6	11	9	11	10	1	12
4	A Seq	13	13	13	1	6	6	5
5	A Seq	10	12	9	4	10	11	10
6	A Seq	11	6	11	10	7	9	11
7	A Seq	1	1	4	3	3	4	2
8	B Sim	2	9	11	12	13	3	4
9	B Sim	6	10	12	5	2	10	9
10	B Sim	10	2	1	8	5	13	6
11	B Sim	8	8	4	9	10	9	13
12	B Seq	4	4	6	13	1	2	8
13	B Seq	4	6	2	2	5	12	3

Data Analysis Format

In line with this data analysis design the results of the quantitative data analysis for each case and cases within each intervention format will be presented first. The results of the qualitative data analysis for each case and cases in each intervention format will follow. In each of these parallel analyses the results will be discussed according to the research questions. The converged results for the two cases undertaking each intervention format will be compared and discussed in relation to the research questions as this chapter concludes.

Quantitative and Qualitative Results

Quantitative Data Analysis and Results

As discussed in Chapter 4, the analysis of the quantitative data was approached using an idiographic rather than a nomothetic approach. The adoption of an idiographic approach enabled analysis of the impact of an intervention format on the WRA and WM abilities of each student. This is important given the students constitute the embedded units of analysis within each case in this multiple case study.

The pre-post test results for individual participants in each of the cases, are presented in separate tables in Appendix K. The results are measured as percentiles. There are pre-post percentiles for three tests relating to WRA and four tests of different WM abilities.

The following discussion of these quantitative results for WRA and WM abilities will refer to the tables in Appendix K as well as Figures 5.1, 5.2, 5.3, and 5.4. The figures have been included at this point for ease of reference.

The data shown in Figures 5.1, 5.2, 5.3, and 5.4 collate two types of information gained from the quantitative data for a range of WRA and WM abilities. The vertical bars show the percentage of case participants who experienced a type of change in each of the word reading or working memory abilities listed horizontally. The type of change is shown via shade coding of the vertical bars for each WRA and WM ability. Eye gaze was used to determine change. A difference of 1 or more percentile points equated to change.

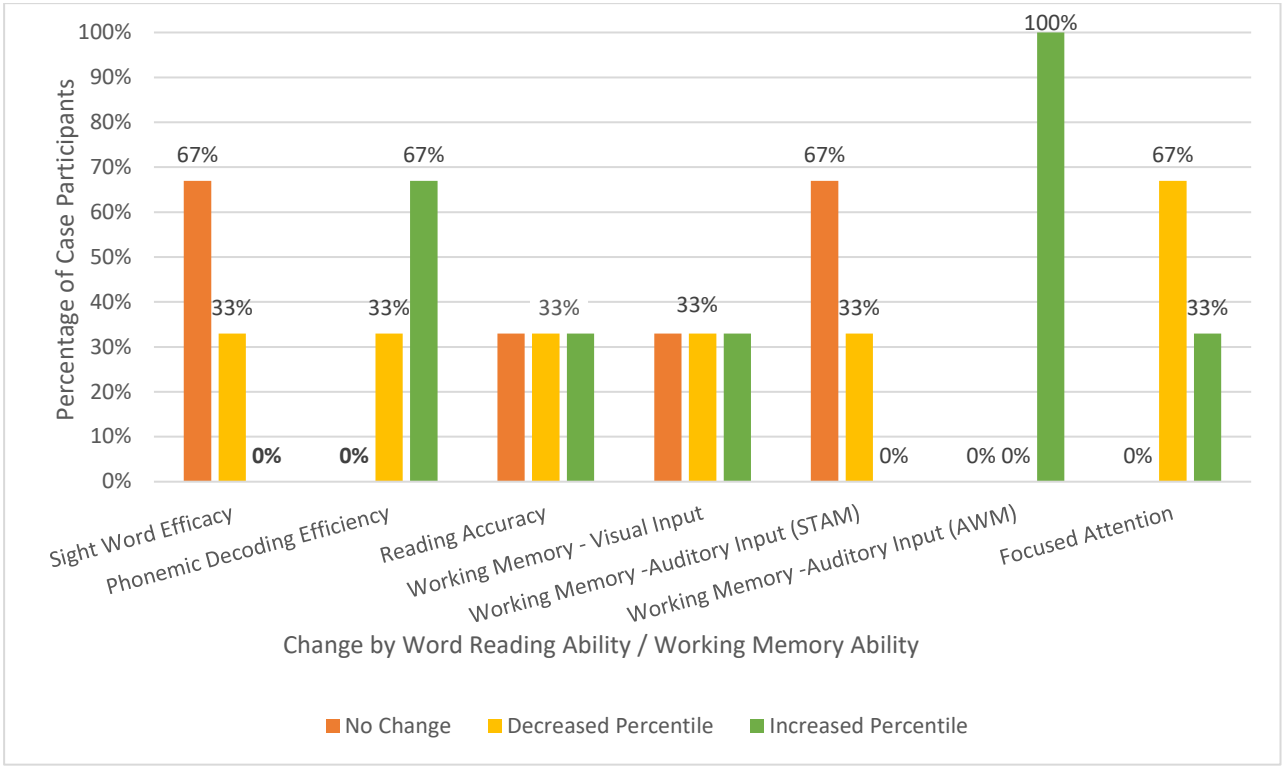

Figure 5.1. Pre-Post percentile changes for Simultaneous Case A (n = 3).

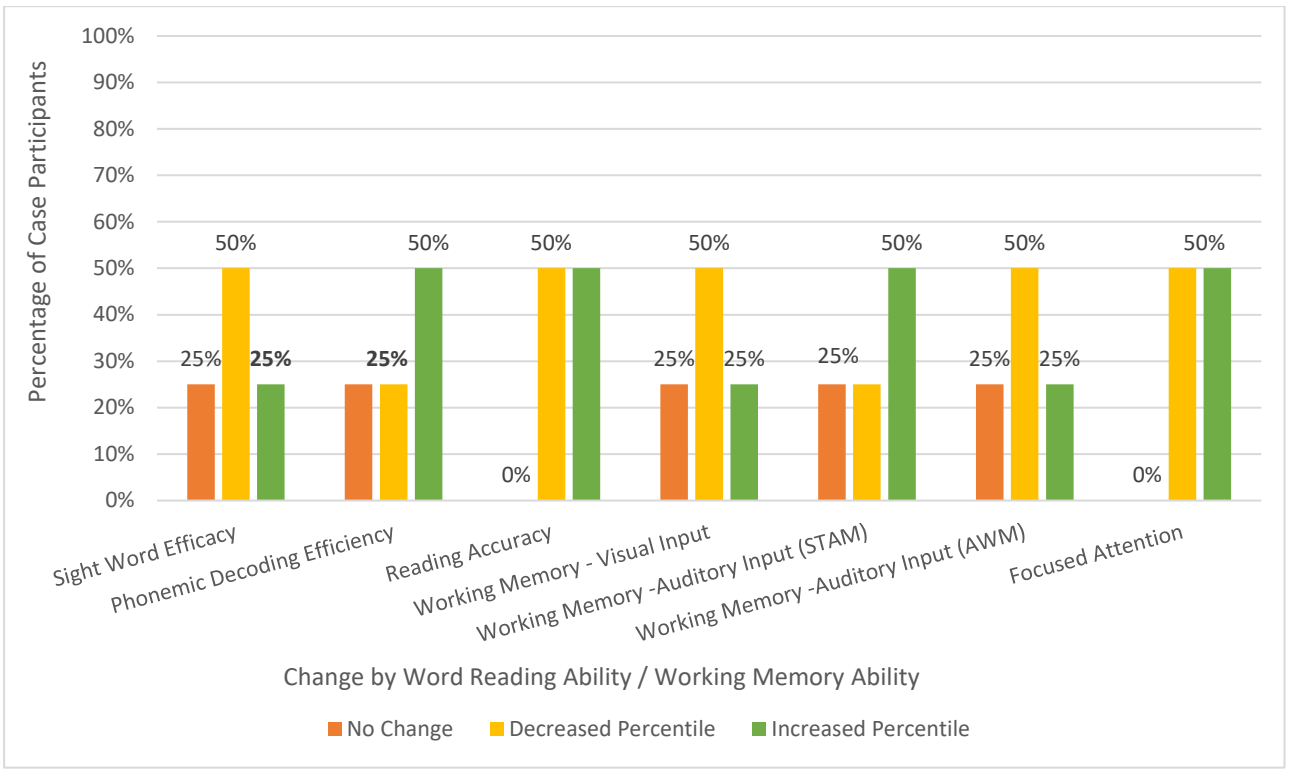

Figure 5.2. Pre-Post percentile changes for Simultaneous Case B (n = 4).

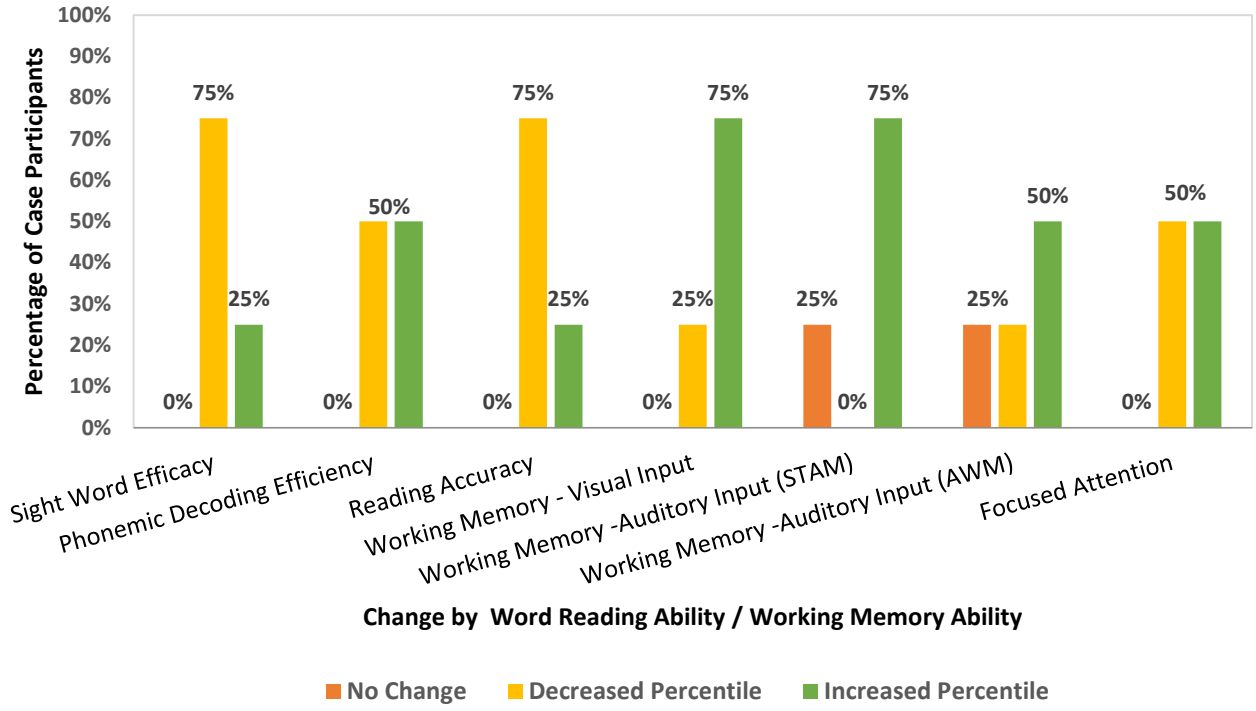

Figure 5.3. Pre-Post percentile changes for Sequential Case A ($n = 4$).

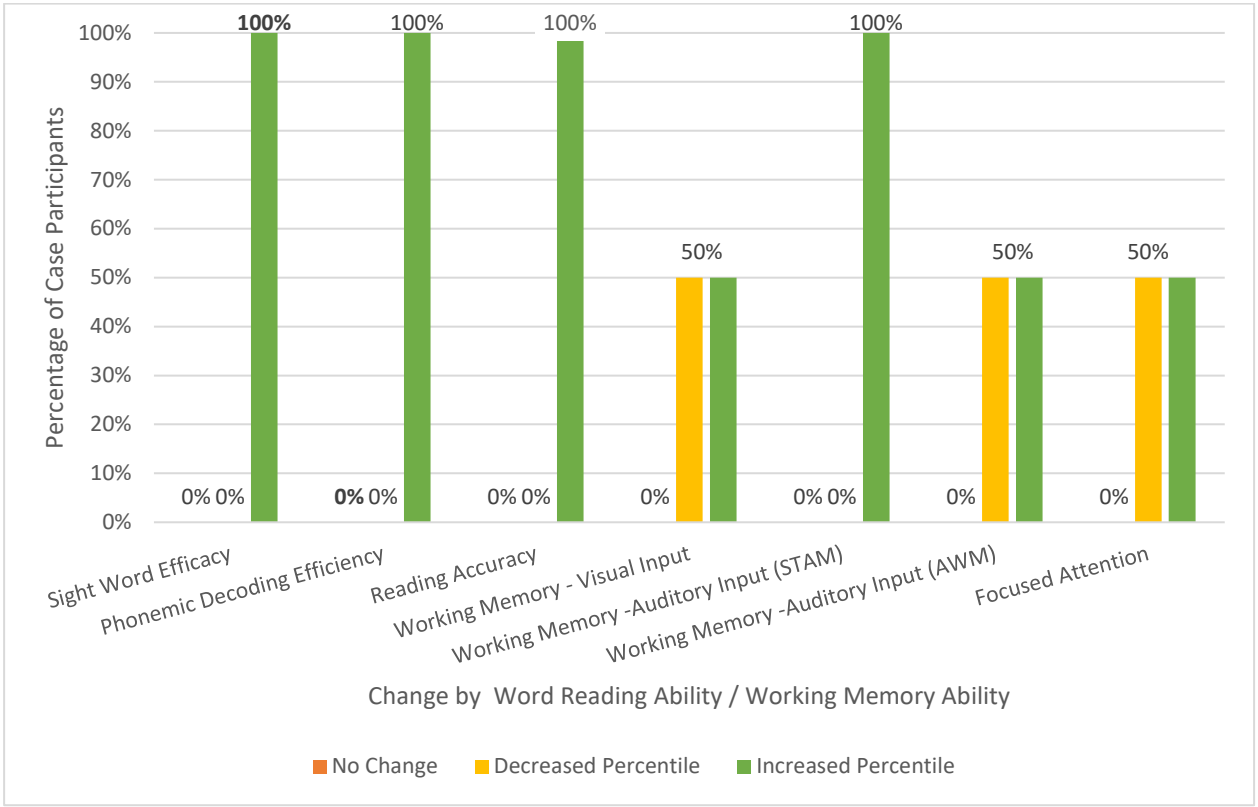

Figure 5.4. Pre-Post percentile changes for Sequential Case B ($n = 2$).

Word reading ability: Pre-post intervention percentiles by case.

Sight word efficacy. Sight Word Efficacy (SWE) was measured using the Sight Word Efficiency subtest of the TOWRE 2. This test measures the student's ability to accurately read regular words. The changes in SWE pre-post percentiles by case are shown in Figures 5.1, 5.2, 5.3, and 5.4. A summary of the change in SWE experienced by case participants, across all cases is shown in Table 5.3.

Except for Case B Seq. the SWE response to either intervention format by case, was varied. At this level of analysis, a difference by intervention format is not yet clear. There is, however, evidence there was a growth response in both Sequential cases and not in both Simultaneous cases. The poor response to intervention in Case A Seq compared to Case B Seq could be reflective of the reduced number of reading intervention sessions Case A Seq received, as previously discussed. The difference in the response to intervention by Case A Seq, in all WRA subskills, reflects a similar difference to that observed in Case B Seq.

Table 5.3

Percentage of Case Participant Pre-Post Percentile Change in Sight Word Efficacy

	Sight Word Efficacy (SWE)		
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim	67%	33 %	
Case B Sim	25%	50%	25%
Case A Seq		75%	25%
Case B Seq			100%

Phonemic decoding efficacy. Phonemic decoding efficacy (PDE) was measured by the Phonemic Decoding Efficiency Subtest of the TOWRE. This test measures the student's ability to accurately read phonemically regular non-words. The changes in

PDE pre-post percentiles by case are shown in Figures 5.1, 5.2 5.3, and 5.4. A summary of the change in PDE experienced by case participants, across all cases is shown in Table 5.4.

Table 5.4

Percentage of Case Participant Pre-Post Percentile Change in Phonemic Decoding Efficacy

Phonemic Decoding Efficiency (PDE)			
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim		33 %	67%
Case B Sim	25%	25%	50%
Case A Seq		50%	50%
Case B Seq			100%

At case level it appears both intervention formats have been effective in leading to growth in the PDE of case participants. A difference by intervention format is again difficult to ascertain at this level of analysis.

Reading accuracy. Reading accuracy (RA) was measured by the YARC Passage Reading Test. This test measures the RA of the student as they read two short, printed texts.

Table 5.5

Percentage of Case Participant Pre-Post Percentile Change in Reading Accuracy

Reading Accuracy (RA)			
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim	33%	33 %	33%
Case B Sim		50%	50%
Case A Seq		75%	25%
Case B Seq			100%

The changes in RA pre-post percentiles by case are shown in Figures 5.1, 5.2, 5.3, and 5.4. A summary of the changes in RA experienced by case participants, across all cases is shown in Table 5.5.

At case level it appears both intervention formats have been effective in leading to growth in the RA of case participants. A difference by intervention format is again difficult to ascertain at this level of analysis.

Working memory ability: Pre-post intervention percentiles by case.

Working memory – Visual input. Working Memory capacity as tested via Visual Input (WM-VI) was measured by the WM test in ACTIVATE. This test measures the student's ability to accurately recall sequences of visual images. The changes in WM-VI pre-post percentiles by case are shown in Figures 5.1, 5.2, 5.3, and 5.4. A summary of the change in WM-VI experienced by case participants, across all cases is shown in Table 5.6.

At case level it appears both intervention formats have been effective in leading to growth in the WM-VI of case participants. A difference by intervention format is apparent with much stronger growth responses in the Sequential cases.

Table 5.6

Percentage of Case Participant Pre-Post Percentile Change in Working Memory -Visual Input

	Working Memory – Visual Input (WM-VI)		
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim	33%	33 %	33%
Case B Sim	25%	50%	25%
Case A Seq		25%	75%
Case B Seq		50%	50%

Working memory – Auditory input. Working Memory capacity as tested via Auditory Input (WM-AI) was measured using the Number Memory Forward (NMF) and the Number Memory Backwards (NMB) Subtests of the TAPS-3.

The NMF test is strongly indicative of Short-Term Auditory Memory (STAM) ability and requires students to accurately recall auditory sequences of digits. The NMB subtest measures the student's ability to accurately recall auditory sequences of digits in the reverse order to that given. For the purposes of this study this is referred to as auditory working memory (AWM).

The changes in WM-AI -STAM and WM-AI-AWM pre-post percentiles by case are shown in Figures 5.1, 5.2, 5.3, and 5.4. A summary of the change in WM-AI -STAM experienced by case participants, across all cases is shown in Table 5.7. A summary of the change in WM-AI-AWM experienced by case participants, across all cases is shown in Table 5.8.

Table 5.7

Percentage of Case Participant Pre-Post Percentile Change in Working Memory – Auditory Input – Number Memory Forward

Working Memory- Auditory Input – Short Term Auditory Memory- (WM-AI -STAM)			
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim	67%	33 %	
Case B Sim	25%	25%	50%
Case A Seq	25%		75%
Case B Seq			100%

The data displayed in Table 5.7 indicates the Simultaneous cases experienced more variation in their response to the intervention format than the Sequential cases did to their intervention format. At case level it would appear the Sequential intervention format was

more effective in leading to growth in the WM-AI-STAM of case participants. A difference by intervention format is apparent with much stronger growth responses in the Sequential cases.

The data in Table 5.8 indicates an interesting response to intervention with respect to WM-AI-AWM by Case A Sim. The response of Case A Sim in this WM ability is markedly stronger than it was in any other WRA or WM ability. The growth response is also greater in this instance, than in any other case. The pre-intervention TAPS NMB percentiles displayed in Appendix K, indicate the participants in Case A Sim commenced the study with lower WM-AI-AWM ability than those in other groups. The intervention format appears to have been highly effective in realising growth in this WM ability for all participants in Case A Sim.

Table 5.8

Percentage of Case Participant Pre-Post Percentile Change in Working Memory – Auditory Input – Number Memory Backwards

Working Memory- Auditory Input – Auditory Working Memory (WM-AI-AWM)			
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim			100%
Case B Sim	25%	50%	25%
Case A Seq	25%	25%	50%
Case B Seq		50%	50%

At case level it appears both intervention formats have been effective in leading to growth in the WM-AI-AWM of case participants. A difference by intervention format indicates the Simultaneous format may have been more effective in encouraging a growth response in this WM ability.

Focused attention. The Focused Attention (FA) of each student was measured within ACTIVATE using the Flanker Task. The ability to focus and maintain attention is a specific capacity of WM seemingly regulated by the Central Executive (CE). The changes in FA pre-post percentiles by case are shown in Figures 5.1, 5.2, 5.3, and 5.4. A summary of the change in FA experienced by case participants, across all cases is shown in Table 5.9.

At case level it appears both intervention formats had mixed responses to intervention in this WM ability. It is not possible to detect a difference by intervention format at this level of analysis.

Table 5.9

Percentage of Case Participant Pre-Post Percentile Change in Focused Attention

	Focused Attention (FA)		
Case	**No Change in Percentile**	**Decrease in Percentile**	**Increase in Percentile**
Case A Sim		67 %	33%
Case B Sim		50%	50%
Case A Seq		50%	50%
Case B Seq		50%	50%

Multiple case word reading ability and working memory pre-post percentile change by intervention format (Simultaneous vs Sequential). The ensuing discussion of combined case results within each intervention format relates to the data presented in Figure 5.5 and Figure 5.6. These figures show the percentage of all participants across both cases in an intervention format who showed no change, a decrease, or an increase in their pre-post percentile in the WRA and WM ability tests administered in this study. Figure 5.5 shows the combined results for the Simultaneous Intervention cases (Case A Sim and Case B Sim) and Figure 5.6 the combined results for the Sequential Cases (Case A Seq and Case B Seq).

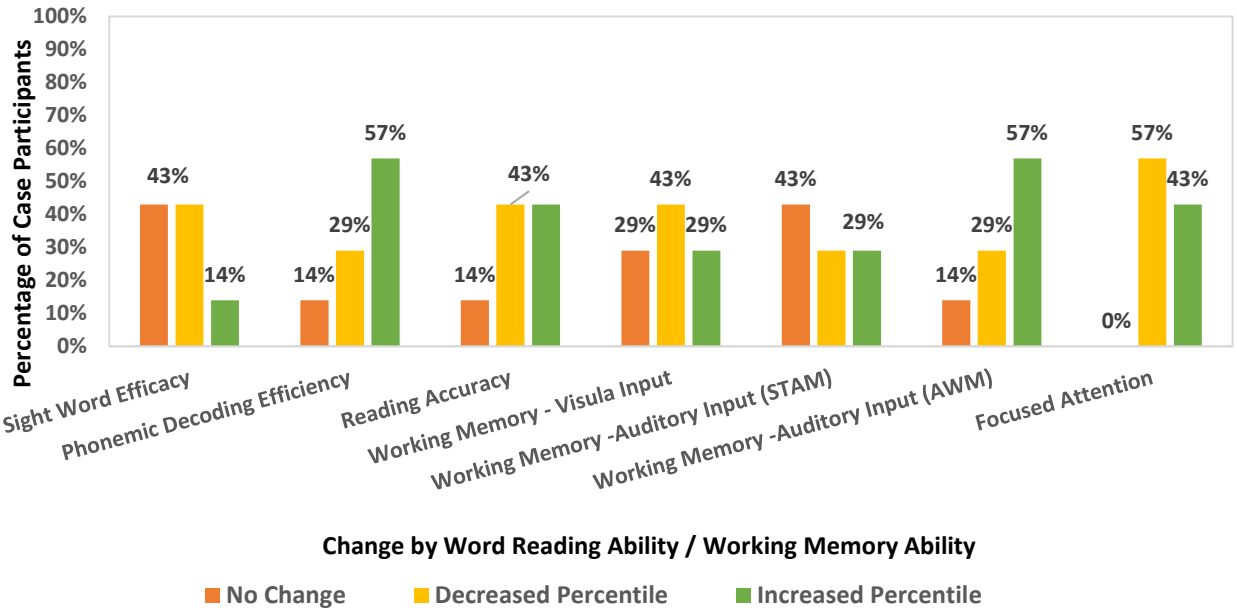

Figure 5.5. Pre-Post Percentile Change Following Simultaneous Intervention (n = 7).

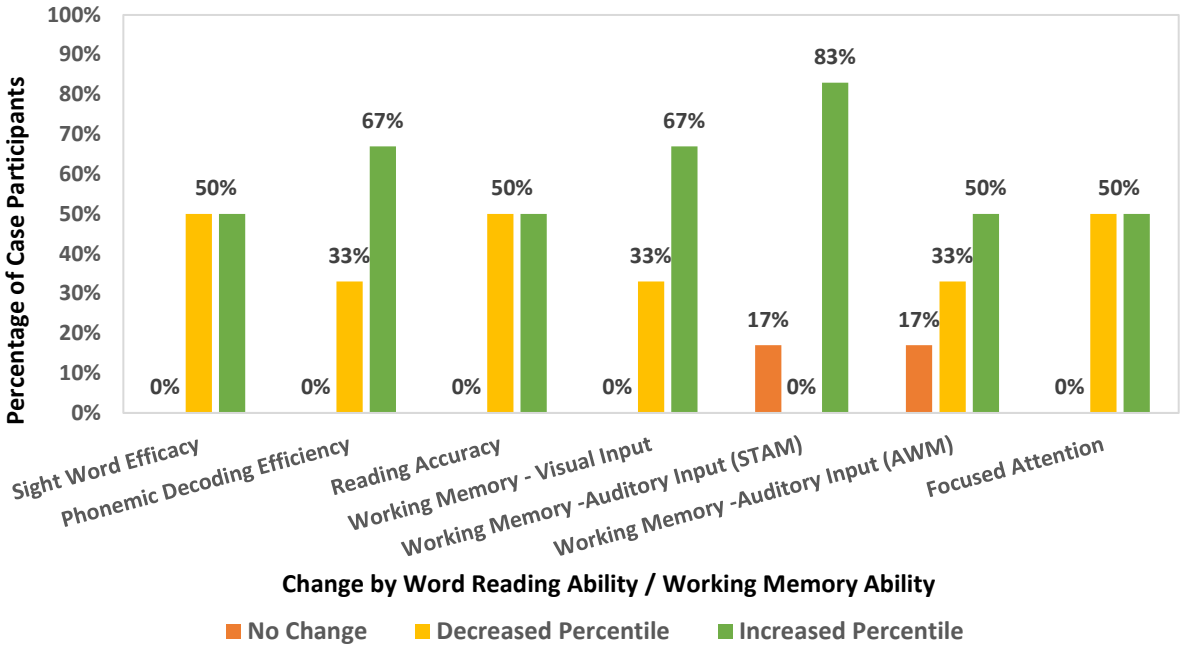

Figure 5.6. Pre-Post Percentile Change Following Sequential Intervention (n = 6).

Multiple case word reading ability pre-post percentile change by intervention format (Simultaneous vs Sequential). Before discussing the combined WRA results for the two groups which undertook each intervention format, it needs to be noted again that the Sequential groups received differing amounts of exposure to the literacy intervention program.

The Seq A group had considerably less exposure to the reading intervention program compared to the Seq B group and the Sim A and Sim B groups. As discussed in the previous section, the effect of this is quite noticeable when comparing the vastly different reading skill results for Seq A and Seq B (refer Figure 5.3 and Figure 5.4). Being a case study and not an experiment, this difference in reading intervention delivery did not negate the use of the results for the purposes of this study. It did affect the ability to identify evidence of literal replication as will be discussed in Chapter 6. It also highlighted the complexities involved in the use of intervention programs in primary schools which will be discussed in Chapter 6.

The SWE percentile increased for 14% of the Simultaneous intervention participants compared to a percentile increase in 50% of Sequential intervention participants. Forty-three percent of the Simultaneous participants showed a decrease in percentile compared to 50% of the Sequential intervention participants. Forty-three percent of Simultaneous participants showed no change in SWE percentile whereas none of the Sequential participants experienced a nil change in percentile. This comparison in this skill area indicates the Sequential intervention was more effective than the Simultaneous intervention based on quantitative data analysis.

The PDE percentile increased for 57% of the Simultaneous participants compared to 67% of the Sequential participants. Twenty-nine percent of the Simultaneous participants decreased in percentile compared to 33% of the Sequential intervention participants. Fourteen percent of Simultaneous participants experienced no change compared to all Sequential participants experiencing some change. The comparison in this skill area indicates the Sequential intervention to be more effective in effecting improvement than the Simultaneous intervention based on qualitative data analysis.

The RA percentile also increased for both interventions, with 43% of the Simultaneous participants and 50% of the Sequential participants showing an increase post

intervention. Fewer of the Simultaneous participants showed a decrease in percentile (43%) than the Sequential intervention participants (50%) however 14% of the Simultaneous participants also showed no change compared to no participants in the Sequential format. The comparison in this WRA indicates the Sequential intervention format to be slightly more effective than the Simultaneous intervention format based on the quantitative data analysis.

In summary, the combined WRA results for the Sequential groups revealed higher percentages of participants in the Sequential format had an increase in WRA percentiles when compared to the results for the Simultaneous participants. Likewise, higher percentages of participants in the Sequential format had a decrease in WRA percentiles compared to the participants in the Simultaneous format. All participants of the Sequential format experienced an effect on their reading skills whereas there was evidence of nil change in percentile across the participants in the Simultaneous groups. In terms of which intervention format had a greater effect on WRA, these quantitative results indicate the Sequential Intervention format to be more effective.

Multiple case working memory ability pre-post percentile change by intervention format (Simultaneous vs Sequential). The WM-VI percentiles increased for 29% of the Simultaneous participants compared to 67% of the Sequential intervention participants. A higher percentage of Simultaneous participants displayed a decrease in this area (43%) than the Sequential participants (33%). Only Simultaneous participants showed a nil change in post intervention percentile (29%). The Sequential intervention was more effective in effecting change in this skill area based on quantitative data analysis.

The post-intervention WM-AI-STAM percentiles indicated a marked difference by intervention type. Twenty-nine percent of the Simultaneous participants had an increase in percentile compared to 83% of the Sequential intervention participants. None of the Sequential participants showed a decrease in percentile while 29% of the Simultaneous

participants did. There was also a higher percentage of participants in the Simultaneous intervention who experienced no change (43%) than in the Sequential intervention (17%). The Sequential intervention was exceptionally more effective in this skill area based on quantitative data analysis.

The post intervention WM-AI-AWM percentiles were similar for both formats (Sequential and Simultaneous), with the Simultaneous format showing slightly more effective results. An increase was experienced by 57% of Simultaneous participants compared to 50% of Sequential participants. The Simultaneous participants showed slightly less decrease in percentile (29%) than the Sequential participants (33%). The Simultaneous participants also showed slightly less no change (14%) than the Sequential (17%). In this skill area, the Simultaneous intervention appeared to be more effective based on quantitative data analysis.

The post intervention FA percentiles were quite similar for both intervention formats. The Sequential intervention participants increased by 50% and the Simultaneous participants by 43%. Fifty percent of the Sequential participants declined in percentile compared to 57% of the Simultaneous participants. In this skill area, there were no participants in either format who showed no change in skill. In terms of the difference in growth in percentiles, the Sequential format appeared to be slightly more effective based on quantitative data analysis.

As can be determine from Figure 5.5 and Figure 5.6 most of the quantitative memory instruments' percentiles increased for both types of interventions although noticeably more so in the Sequential intervention. There was one exception in WM-AI-AWM where the results for the Simultaneous format were slightly more effective than those in the Sequential format.

Qualitative Analysis and Results

As discussed in Chapter 4, Yin's (2016) five phase model of qualitative data analysis was employed to guide the analysis of the qualitative data. The results of the qualitative data analysis will initially be presented in relation to the WRA, WM abilities and RSE of the participants in the individual cases which undertook each intervention format. This will be followed by a comparison of the qualitative results in WRA, WM and RSE for the two cases undertaking each of the intervention formats. The discussion will then move forward to focus on the converged qualitative and quantitative data for each of the cases in both intervention formats. The fifth and concluding phase of the model will be briefly addressed in the concluding section of this chapter but explored in greater depth in Chapter 6.

In the first phase the qualitative data were sorted, collated, and assembled according to individual participant. In the second phase the assembled raw data moved through a first level of coding according to its relevance to the three research questions. In the third phase the data were again coded using a second level of coding called category coding (Yin, 2016). The categories used in this level of coding were developed through a process of thinking conceptually about the research questions.

RQ.1. Pre and post intervention WRA (SWE and PDE) qualitative data were coded in terms of Skill Acquisition and Skill Application. Individual differences in Skill Acquisition and Skill Application were identified through the application of one of three possible descriptors: Dependent, Semi Dependent, and Automatic. These descriptors relate to the participant's level of dependency on others to continue to develop skills and apply them in reading.

RQ.2. Pre and Post intervention qualitative data relating to FA and WM-VI abilities were extracted from ACTIVATE individual participant reports and included in the tables in Appendix L.

RQ.3. Pre and Post intervention RSE data were coded in terms of the four behaviours: Task Persistence, Task Effort, Task Confidence, and Task Choice. A principal identifier was selected for each behaviour. Task Persistence was identified in data relating to the time the participant spent in reading; Task Effort in data speaking about the amount of effort a participant needed to invest in order to read; Task Confidence in statements about the participant's belief about their own ability to read; and Task Choice in data related to the participant's view of reading as an activity or the value of reading to their life. Individual differences in these behaviours were identified through the application of a range of descriptors appropriate to each behaviour.

The second level codes and descriptors applied to the WRA and RSE qualitative data are displayed in Appendix I, Table I.4.1. The second level coded data for both Case A Sim and Case B Sim are displayed in Appendix L, Table L.5.1. The second level coded data for Case A Seq and Case B Seq are displayed in Appendix L, Table L.5.2.

To ensure the qualitative data analysis takes account of the richness evident in the voice of the participants, quotes of relevance to second level codes for WRA, WM and RSE were compiled from the questionnaires and intervention teacher interviews. These are displayed in Appendix M, Tables M.5.1, M.5.2, M. 5.3, M. 5.4, M.5.5, and M.5.6. These quotes alongside the Second Level Coded data displayed in Appendix L, enabled the qualitative data analysis to progress to the fourth, interpretative phase of data analysis. The results of the fourth phase analysis will now be presented in detail, and as it relates to WRA, two capacities of WM and RSE.

Qualitative data interpretation by case.

Patterns relating to word reading ability pre-post intervention.

Sight word efficacy. Participants in the Simultaneous format showed a consistent pattern of response. All participants except one commenced the intervention

dependent in both sight word skill acquisition and skill application. One Case A Sim participant showed improvement in both skill acquisition and skill application post intervention and likewise three Case B Sim participants (refer Appendix L, Table L.5.1).

The narrative behind the dependent skill and application codes spoke of limited known sight words and often restricted ability to remember and identify sight words when reading. No participants in Case A Sim indicated their sight words had increased post-intervention but two students displayed improved independence in word reading attempts. In Case B Sim there was mention of increased sight words in two students and some improvement in fluency and accuracy post-intervention. The Case B Sim intervention teacher also noted one student was noticing more. The teacher wondered if this might be attributable to ACTIVATE. (refer Appendix M, Table M.5.1). On checking the ACTIVATE-VI post intervention data this student made minimal progress. As a group however, the participants of Case B Sim did make more progress in ACTIVATE WM-VI than the participants in Sim A (refer Appendix L, Table L.5.1).

The participants in the Sequential format also showed a consistent pattern. All participants commenced with dependent sight word skill acquisition and skill application. There was no change in participant skill acquisition in Case A Seq but improvement in skill application in two of the four participants. In Case B Seq, both students improved in both skill acquisition and application (refer Appendix L, Table L.5.2).

The narrative behind these patterns indicate the Sequential participants commenced the intervention with limited sight words, and difficulty remembering and learning sight words. All Sequential participants who showed improved skill application post intervention were described as reading at a faster personal pace. Compared with standard reading rates for middle primary aged students, their reading rate would still be considered slow, but for these participants it was improvement. Reading fluency was also noted to improve (refer Appendix M, Table M.5.2).

Phonemic decoding efficacy. There was consistency in the patterns of post intervention change in PDE across the Simultaneous participants. Participants in Case A Sim commenced the study with mixed levels of skill acquisition. Two out of the three had semi-dependent PDE skill acquisition however all were dependent in their PDE skill application. In Case B Sim, all participants were dependent in skill acquisition and skill application. Post- intervention all participants with dependent skill acquisition had improved to a level of semi-independence. All participants except for one in Case B Sim, improved their level of skill application from dependent to semi-independent (refer Appendix L, Table L.5.2).

The narrative behind these codes indicated participants with dependent pre-intervention skill acquisition often appeared to lack decoding strategies; preferring to use visual cues to guess unknown words rather than employ phonetic decoding skills. Pre-intervention, semi-independent skill acquisition was observed in participants who had limited strategy knowledge but required frequent prompts and support to discourage guessing unknown words.

The pre-intervention, dependent skill application narratives spoke of difficult words being hard to sound out or participants simply refusing to attempt. There was also a lack of independence in strategy use. While participants could be encouraged to employ strategies to decode single words, the preference when reading text, was to revert to guessing rather than decoding unknown words.

The narrative indicating improvement in the post intervention skills and application included comments describing good decoding skills, participants using a ‘few’ or a ‘range’ of strategies, and indication of improved reading fluency and accuracy. Participants were self-correcting more independently, were more patient in their decoding attempts, and had gained in confidence. A participant in Case B Sim was described as ‘picking things up better’ (refer Appendix M, Table M.5.3).

While the patterns emerging from the second level codes for the Sequential format looked very similar to those in the Simultaneous format, the narrative behind the changes spoke of some distinct differences between formats.

The Case A Seq participants commenced the intervention with two participants having semi dependent skills and two having dependent skills. One of the two participants with stronger skills also commenced with semi dependent skill application but all the others were dependent in their skill application. Both participants in Case B Seq were dependent in both skills and skill application (refer Appendix L, Table L.5.2).

The pre-intervention narratives of the Sequential participants with dependent skill acquisition and application were different to the dependency narratives of the Simultaneous participants. The Sequential participants reflected similar limited skills and struggle engaging with new vocabulary however there seemed to be greater avoidance of phonic based decoding strategies. More of the Sequential participants employed visual prompts to identify words rather than phonics. There were indications that highly dependent decoding skills could be employed with prompting, but this made reading hard work, robotic and resulted in stressful, word by word progress. Participants tired while reading and there was a lack of enjoyment of reading (refer Appendix M, Table M.5.4)

There was a slight difference in the post intervention change in the Sequential format. In the Simultaneous format, there was one participant who did not change to having semi-independent skill acquisition and application post intervention, however all Sequential participants showed this pattern of change in both areas (refer Appendix L, Table L.5.2).

The narrative behind these changes also looked different for the Sequential participants. The data for the Sequential participants are consistent with purposeful use of decoding strategies and less use of visual prompts. There was not only growth in knowledge and skill acquisition but there was evidence of change in reading habits:

"the habit of reading visually has stopped"
"better able to decode new words – identify syllables"
"better equipped to attack phonically"
"phonic ability now-improved immensely"

There was still evidence the reading was slow and hard work but there appeared to be greater persistence or purpose behind the skill application.

There were exceptions in both interventions where students entered with semi-dependent skill acquisition and application and made very little progress. In both instances there were other affective factors at play with these participants which may have impacted the effectiveness of the intervention and which will be highlighted in the ensuing section addressing the RSE of the participants.

Patterns relating to two working memory abilities pre-post intervention.

Working memory - Visual input (WM-VI). The ACTIVATE Executive Function Test Reports indicate there was variability in the pre- and post-WM-VI ability of the participants in both the Simultaneous and Sequential intervention formats as depicted in Appendix L, Table L.5.1 and Table L.5.2. The pre-post data across all cases are summarised in Table 5.10.

There is a mixture of results within and across cases however at this level of analysis it would appear the Sequential format was more effective in encouraging change in this WM ability.

Table 5.10

Pre-Post Working Memory – Visual Input Ability Patterns for all Cases.

Intervention	Case	Pre-Intervention Ability Range	Pre-Post Intervention Change	Additional Change Information
Simultaneous	A	Below Average to Above Average	One improved	Participant started with either Below Average or Sufficient WM-VI ability.
			One declined	Participant started Above Average so a post score less than pre score would register as decline.
			One no change	Participant was disengaged and disinterested in reading.
	B	Below Average to Sufficient	Two improved	Participants started with either Below Average or Sufficient WM-VI ability.
			One declined	Intervention teacher reported participant to be bored and tired with the repetition in the ACTIVATE games and suspected they did not invest full effort to the tests.
			One no change	
Sequential	A	Below Average to Sufficient	Three improved	Participants commenced with Sufficient WM-VI ability
			One declined[1]	Participant commenced with Below Average ability: a very anxious student in test situations. This participant showed decline in both WM-VI and FA.
	B	Sufficient.	One improved	Participants commenced with Sufficient WM-VI ability.
			One declined[1]	Commenced with Sufficient ability. Reported by teacher to have worked very hard throughout the intervention so much so they visibly appeared to fatigue after 20 minutes in class. Teacher suspected the same in fatigue in final assessments.

Note [1]*The contextual insights in these notes align with the comment in the post- test ACTIVATE Report where an unusual post intervention decline in score was measured: "rarely seen and may be indicative of a developmental setback related to things like stress at home or school or a "bad day" when retesting."*

Focused attention (FA). The ACTIVATE Executive Function Test Reports indicate variability in the pre- and post-FA ability of the participants in both the Simultaneous and Sequential intervention formats as presented in Appendix L, Table L.5.1 and Table L.5.2. The pre-post data across all cases are summarised in Table 5.11.

Table 5.11

Pre-Post Working Memory – Focused Attention Ability Patterns for all Cases.

Intervention	Case	Pre-Intervention Ability Range	Pre-Post Intervention Change	Notes re Change
Simultaneous	A	Moderate to Exceptionally Strong	One improved	
			One declined	Participant declined in both WM -VI and FA and exhibited inconsistency in progress across all subskills. Efforts to learn were observed to require continual and large amounts of effort.
			One no change	*Participant commenced with exceptionally strong ability.*
	B	Moderate to Strong	Two improved	
			One declined	*Participant observed to not have high levels of persistence and consistency in their learning style.*
			One no change	
Sequential	A	All Moderate	Two improved	Participants commenced with moderate ability.
			Two declined	One participant had highly anxious presentation, and one had unavoidable contextual challenges which appeared to impact their school engagement during that period.
	B	Moderate to Strong	One improved	Participants commenced with moderate ability.
			One no change	Participant commenced with strong ability.

The variability in pre-intervention ability in this WM subskill is not as extensive as observed in many other WRA and WM subskills. While there is some variation also in the post-intervention change across cases and intervention formats, it would appear at this level of analysis the results in this subskill are not markedly favoring one intervention format to the other. This may be attributable to all participants commencing with at least moderate pre-intervention ability.

Patterns relating to changes in reader self-efficacy pre-post intervention.

Reader self – efficacy as reflected in task persistence: Time spent reading. All participants commenced the study indicating they invested minimal or required time engaged in reading. Minimal time refers to partial expenditure of required time. Required time refers to the time requirements stipulated by school or parents (refer Appendix L).

The narrative behind these codes indicated participant use of overt and passive avoidance behaviours when asked to read: ask parents to read to them instead of them

reading to parents; openly sharing they do not really read, or they avoid reading. There was also a reluctance to read in front of others in the classroom and a preference to read short paragraphs (refer Appendix M).

The time invested in reading at the conclusion of each intervention format indicated slight differences between formats. At the conclusion of the Simultaneous intervention, one Case A Sim participant and all Case B Sim participants indicated they were now investing more time reading. One Case B Sim participant had a standout improvement with the narrative indicating voluntarily engagement in reading beyond school expectations. At the conclusion of the Sequential format three of the four Case A Seq participants indicated longer time engagement in reading with two now reading beyond school expectations. Likewise, both Case B Seq participants were now reading beyond school expectations. For one of these participants, their code had changed from Minimal to Additional indicating a significant improvement. It would appear from the second level coding that the Sequential format was more effective in increasing Reader Self efficacy as measured by time spent reading each week (refer Appendix L).

The narrative behind the coding also highlighted this difference in intervention format effect. The participants in the Simultaneous format who indicated change in time spent reading, spoke of a slight increase in time spent reading but that much of this reading time was enforced or directed by parents or teachers. The narrative behind the Sequential participants' post intervention increases in time spent reading, indicated greater independence and choice by the reader to engage in reading:

> "Normally at night for 20 mins (read) but if my dad is not home, about 40 mins because mum is putting my sister to bed and she doesn't come in and tell me to stop" (Case A Seq, Participant 4)
> "Was self-motivated to read at home as they wanted to catch the others" (Case B, Participant 12)

Reader self – efficacy as reflected in task effort: The effort required to read. There was consistency in the pre intervention indications of the effort required by all participants to engage in reading. Reading was frequently described as effortful, hard work and tiring. Related to this, all participants indicated they did not voluntarily engage in reading as it was difficult and not enjoyable. There was also evidence across both intervention cases of a high level of participant self-awareness of their personal struggle with reading. Reading required expenditure of high levels of concentration and effort for minimal return in terms of enjoyment or understanding. This was captured well by one parent statement "They try hard but just can't get it".

With respect to changes post intervention, only one Case A Sim participant indicated reading had become slightly less effortful however they still required external direction to engage in and with their reading. Likewise, two Case B Sim participants indicated reading required less effort but there was need for ongoing external direction. An additional Case B Sim participant indicated reading remained effortful but was becoming a more voluntary activity (refer Appendices L and M).

The post intervention changes in effort required to read for the Sequential participants looked different to that observed in the Simultaneous participants. While only one Case A Seq participant indicated less effort required post intervention, two participants indicated an increased independence in their reading despite reading remaining an effortful endeavor (refer Appendix L). Their reading was more fluent even though there was still some misreading. One participant did not appear to be as worried about their reading. The Case B Seq participant narratives spoke of new skill acquisition and application which was making reading easier and less fatiguing although both still had to concentrate and put in effort. Reading was not yet automatic but certainly more accessible and enjoyable for both. The narrative spoke of reading being fun, enjoyable and interest in reading had increased (refer Appendix M).

Reader self – efficacy as reflected in task confidence: The belief in reading ability. Across all participants, the pre intervention level of belief in reading ability was a mixture of extremely low to low confidence in personal reading ability. The narrative indicated the low ability was very dependent on external support and direction. Despite this narrative from teachers and parents, it was interesting to note a couple of students presented with a veneer of reading confidence. This veneer was extremely fragile, not backed by ability and in one case used as an avoidance tactic. In both participants it was used to protect their self-esteem as they were extremely conscious of their limitations as readers. This self-consciousness was a widespread narrative within the data for many of the participants. It spoke of them not feeling good about themselves or their reading. Their reading made them feel 'not smart'. Many did not want to read out loud as they were aware of the higher ability of classmates. For one participant this made them very anxious, with a fear of making a mistake greatly impacting reading ability and fluency. This entrenched fear also impacted assessments which required oral reading (refer Appendix M).

Post the Simultaneous format there was evidence of improvement in self-belief levels in most participants. In Case A Sim, two of the three participants showed improvement in their confidence and belief in their abilities. The narrative spoke of less frustration, being able to read quickly now and the participants having a different attitude to reading (refer Appendix M).

One participant in Case A Sim showed no change but this participant overtly expressed a lack of value for reading and this impacted his overall progress.

The changes observed in Case B Sim participants were consistent with those of Case A Sim. One Case B Sim participant did not however present with consistent, observable change in belief about ability. The intervention teacher attributed this lack of change to a degree of learned dependency. This limited that participant's ability to own the progress

they made in the program. The remaining three Case B Sim participants experienced change in confidence. The narrative reflected greater confidence to approach reading, being keen to read to teacher and peers, of avoidance behaviours disappearing, of enjoyment and feeling relaxed while reading. There was one noteworthy participant whose code changed by one level. The narrative indicated the change for that participant was quite marked. The intervention teacher noted this participant's increase in level of confidence resulted in their whole demeanour changing to a bright, happy, chatty, confident presentation.

The level of post intervention Sequential participant self-belief about ability improved for most participants. In Case A Seq, three out of the four participants indicated increased self-belief in ability with one showing a marked increase (refer Appendix L). The narrative spoke of a change in how the participants perceived themselves. One participant noticed they had improved as they sounded good when they read out loud, another that they could read quickly now but could not before, and another that they do not get as frustrated by mistakes but had strategies to rectify errors. There was a definite sense these participants had a greater sense of empowerment with respect to their reading which is understandable as there was only one participant who concluded the intervention still quite dependent in their skills. This participant experienced unexpected personal complications outside of their control which greatly impacted overall engagement at school and within the intervention. It would appear the low progress of this participant was contextual and not developmental.

In Case B Seq the change in confidence was quite marked for both participants. Both participants commenced the intervention with extremely low confidence in their abilities and concluded with extremely high levels of confidence and belief in themselves as readers. This is captured clearly by one participant who commented that prior to the intervention they did not like reading because they were not good at it but now, they love it because they are good at it. It makes them feel calm. The other participant commented they felt the same as others:

that they read the same as others, they were excited by reading, and enjoyed it.

Reader self – efficacy as reflected in task choice: The value placed on reading by the participant. The pre-intervention level to which Simultaneous participants valued reading ranged from those who placed no value on reading through to those who did value reading because they were able to personally experience benefits from their reading. The participant who did not value reading was adamant it would not be required in their chosen career pathway. Their career role model had left school early. This attitude was quite restrictive for that participant as they did not exhibit notable change in their reading abilities during the study.

Those that knew of the value of reading spoke of books being fun and that reading could be calming however their narratives indicated they lacked sufficient reading skill independence to experience this value for themselves. This is exemplified in a comment by Participant 3 in Case A Sim. They found reading boring and would rather be outside helping their father do the gardening. They found it a little hard.

The pre-intervention level to which Sequential participants valued reading was similar with most knowing of the value of reading and one participant already experiencing the value of reading. Unlike in the Simultaneous format, there were no Sequential participants, pre-intervention, who did not value reading.

The Sequential participant narratives indicated belief that reading was good for their future, that it helps you to learn things and it helps with writing. There was also frequent mention of enjoyment in hearing stories read to them rather than having to read for themselves. The difference in the pre-intervention narrative of the Sequential participant who commenced the intervention already experiencing the value of reading was evident in their statement that reading made them feel “good, nice, and quiet”.

Post intervention one participant in Case A Sim had changed from having some

knowledge, to experiencing the value of reading. One participant continued to not value reading, and the remaining participant continued to find reading very effortful and not enjoyable.

In Case B Sim post intervention, one participant continued not experiencing the value of reading. This was the participant mentioned earlier who had some very entrenched learning behaviours which limited their ability and persistence to grow the progress they experienced in the intervention. All the remaining participants were now able to experience the value of reading and the two participants who entered the study already experiencing the value of reading, valued it even more highly as exemplified in comments that reading was very entertaining, especially if they liked the book and that stories make you want to keep reading.

Post intervention, two Case A Seq participants indicated they were now able to experience the value of reading. The narrative supporting this coding was powerful. The following quote reflects how the experience of reading was quite tangible and novel.

> "It's weird sometimes I might be reading a book, in the middle of it, I go like, in my head, I'm just reading words but for some reason, I'm thinking of it in my head, thinking of what's happening and what they would be doing but reading at the same time." Participant 4, Case A Seq.

One participant moved from having a knowledge of the value of reading to highly valuing reading as reflected in the following quote.

> I enjoy it. I used to not enjoy it at all. I read a lot more now and I get a lot more used to it. Fun and Hard. When I read it feels like I am learning stuff." Participant 7, Case A Seq.

The remaining participant commenced the study already experiencing the value of reading and did not progress their level of experience. This was the participant who encountered unexpected contextual difficulties during the study. They indicated in the post

study questionnaire they were able to experience the value of reading as they said reading took them on an imaginary adventure into a different world and different place where they felt brave and normal.

The participants in Case B Seq both moved from knowing of the value of reading pre intervention to highly valuing reading post intervention despite it still being slightly effortful for both. This is exemplified in a comment from a parent regarding the change in their child post intervention. Prior to the intervention the child did not liking reading as they found it hard but the help they had received in the intervention meant they do like reading now.

Multiple case word reading ability, working memory and reader self-efficacy pre-post qualitative data pattern change by intervention format (Simultaneous vs Sequential). The discussion within this and the following sections relates to the second level coded data, pre and post, for both Simultaneous intervention groups and both Sequential intervention groups. The Case A Sim and Case B Sim codes are displayed in Appendix L, Table L.5.1 and the Case A Seq and Case B Seq codes are displayed in Appendix L, Table L.5.2.

Multiple case, pre-post qualitative data pattern changes for word reading ability by intervention format (Simultaneous vs Sequential). The described changes in sight word skill acquisition were minimal and very similar across both Sequential and Simultaneous interventions. The described changes in sight word skill application were also minor but slightly more evident in participants in the Sequential intervention cases.

The described changes in PDE were more noticeable but also very similar across both intervention formats. The narrative indicated most of the participants across both interventions commenced the study with very effortful and highly dependent phonemic decoding abilities. They concluded the intervention seeing development in both skill acquisition and application. There was a slight difference in the narrative around the change for many of the participants in

the Sequential intervention. The narrative indicated there was slightly less avoidance of the use of phonic based decoding amongst the participants of the Sequential cases than observed in some of the participants in the Simultaneous intervention cases. There was also narrative around the Sequential participants being slightly more persistence and self-empowered in their use of phonemic decoding skills at the end of the study.

Multiple case, pre-post qualitative data pattern changes for working memory ability by intervention format (Simultaneous vs Sequential). The qualitative descriptions of the pre-post changes in WM-VI ability, indicate greater change in ability of the Sequential format participants than those in the Simultaneous intervention. There was more overall gain by the Sequential participants and less decline attributable to ability rather than extraneous influences.

The qualitative descriptions of the pre-post changes in FA ability are very similar making it quite difficult to identify any marked difference in the effectiveness of one format over the other. Both formats had three participants show improvement and all three commenced with moderate ability. Both intervention formats had two participants decline in FA ability. The two in the Simultaneous groups commenced with strong ability and showed decline however the two in the Sequential groups commenced with Moderate ability in FA and declined. This slight difference in commencement ability prior to decline may indicate the Sequential format was slightly more effective due to less decline.

Multiple case, pre-post qualitative data pattern changes for reader self-efficacy by intervention format (Simultaneous vs Sequential). The described changes in reading task persistence measured by time spent reading indicated that while participants across both intervention formats commenced the study generally reluctant to spend time in reading, most concluded the study indicating increased levels of time spent reading. There was evidence there was greater change in the Sequential format than the Simultaneous with many Sequential

participants indicating they were now spending additional time post intervention, reading beyond school requirements or parental requirements.

Reading was generally extremely effortful for most participants within the study. While reading did become less effortful for many participants across both intervention formats, it had not progressed to any level of automaticity for any participant by the conclusion of the study. There was however an identifiable difference in the post narratives for the participants of the Sequential intervention with more of them indicating reading was either less effortful or there was less reluctance to input effort, and more indication of a participant willingness to engage in reading voluntarily. The narratives indicated this difference was attributed to reading tasks being less effortful and more accessible.

The pre-post changes in reading task confidence as measured by self-belief about reading ability were obvious in the post intervention narratives for both intervention formats. Similar numbers of students across the formats indicated greater self-belief in their reading ability. The difference between the formats came in the intensity and consistency of the improvement. The change in confidence for many of the participants within the Sequential formats was quite marked and consistently observed. Conversely, many of the Simultaneous participants were still quite dependent in their abilities and hence a little less consistent in exhibiting their growing self-belief and reading confidence.

The post-pre changes in reading task choice reflected in the value participants placed on reading were more marked in the Sequential intervention cases than the Simultaneous cases. More Sequential participants indicated a change in the value they placed on reading and the extent to which they valued reading as a personal endeavour compared to that expressed by the Simultaneous participants.

Converged Multi-Case Pre-Post Quantitative and Qualitative Analyses by Intervention Format (Simultaneous vs Sequential)

As indicated earlier in this chapter, the true value of the quantitative and qualitative data within a multiple case study is only realised when the two data types are converged. Having reached a point where we have separate pre-post quantitative and qualitative multiple case results, a convergence of the data is now possible to draw conclusions relating to each of the research questions.

Converged multi-case pre-post quantitative and qualitative data analyses for word reading ability by intervention format (Simultaneous vs Sequential). In this section the qualitative and quantitative data for SWE will be converged to identify any difference by type of intervention. Likewise, the qualitative and quantitative data for PDE will be converged to identify any difference by type of intervention. Based on these discussions and the previously presented quantitative results for RA, the discussion will conclude with a statement of the overall effect of the different intervention formats on WRA.

Converged multi-case pre-post quantitative and qualitative data for sight word efficacy by intervention format (Simultaneous vs Sequential). The quantitative and qualitative data indicate the Sequential format had a greater effect on SWE than the Simultaneous format. In the quantitative data for both formats, at least half the participants show a decrease in SWE however this was not evident in the qualitative data of either format. The qualitative data spoke of either improvement or abilities staying the same. With respect to participants showing no change effect this was evidenced in only the Simultaneous cases, in both qualitative and quantitative data.

Converged multi-case pre-post quantitative and qualitative data for phonemic decoding efficacy by intervention format (Simultaneous vs Sequential). The quantitative and qualitative data indicate the Sequential format led to slightly more improvement in PDE than the

Simultaneous format. The qualitative data indicate the improvement was more widespread than the quantitative data portray. It also highlights the continuing effort and lack of automaticity in skill application of all participants, post the study.

***Conclusion: Word reading ability change by intervention format (Simultaneous vs Sequential*).** The immense value of being able to utilise both qualitative and quantitative data to obtain both an objective and subjective view of the impact of the different formats was truly exemplified in this area. The quantitative data provided static, objective results of the ability of the participants on the day of pre- and post-testing. On the other hand, the qualitative data illuminated the affective functioning of the participants – particularly some of the participants as they completed post quantitative tests. The qualitative data spoke to certain participants exhibiting test anxiety or being tired on the day of testing and not producing results truly reflective of their new abilities or at a minimum, their change in confidence, persistence, and independence in using WRA post intervention.

Converging the overall result for SWE and PDE with the quantitative results for RA it would appear the Sequential format led to slightly greater improvement in WRA than the Simultaneous format. The quantitative results did not speak as significantly to this change as the qualitative results did.

Converged multi-case pre-post qualitative and quantitative data analyses for working memory by intervention format (*Simultaneous vs Sequential*). In this section the qualitative and quantitative data for WM-VI will be converged to identify any difference by type of intervention. Likewise, the qualitative and quantitative data for FA will be converged to identify any difference by type of intervention. Drawing on these discussions and the quantitative results for WM-AI, the discussion will conclude with a comparison of the overall effect of the different intervention formats on WM abilities.

Converged multi-case pre-post quantitative and qualitative data analyses for working memory - visual input (WM-VI) by intervention format (Simultaneous vs Sequential). The qualitative and quantitative data for WM-VI indicate there was more improvement in WM-VI ability in the Sequential format than the Simultaneous. In this area, the qualitative and quantitative data were very similar.

Converged multi-case pre-post quantitative and qualitative data analyses for focused attention by intervention format (Simultaneous vs Sequential). The convergence of the qualitative and quantitative data for FA indicates mixed results within intervention formats but a degree of similarly across intervention formats. It is difficult to identify one intervention as more effective than the other with respect to this WM ability. If considering the degree of decline in FA across both intervention formats, the qualitative data suggest there may have been less decline in the FA ability of the Sequential participants. The quantitative data indicate similarly, a very slight positive difference in improvement for the Sequential participants to that experienced by the Simultaneous participants. To that end, the converged results could be interpreted to suggest a slightly stronger improvement in FA in the Sequential format.

Conclusion: Working memory ability change by intervention format (Simultaneous vs Sequential). The quantitative data for WM-AI indicated mixed results. While improvement in STAM was more evident in the Sequential format, change in AWM seemed to be slightly stronger in the Simultaneous format.

Converging this mixed result for improvement in WM-AI with the results for WM-VI and FA favouring the Sequential format, the overall results for change in WM abilities by intervention format indicates the Sequential format to be more effective.

Converged multi-case pre-post qualitative data analyses for indicators of change in reader self-efficacy by intervention format (Simultaneous vs Sequential). As discussed in the previous section, the Sequential format was deemed to be the most effective

intervention format in leading to improvement in reading task persistence, reading effort, reading confidence and the value placed on reading by the reader.

Converging all four results, the clear conclusion is that while both formats led to improvement in overall RSE, it was within the Sequential format, where participants exhibited more intense, consistent, and conscious change.

Summary

The overall indication of the data as discussed above is that the Sequential intervention format was more effective than the Simultaneous intervention format in effecting change in WRA, WM and RSE.

The results discussed in this chapter are reflective of the complexity and variability of the reading skill and WM development in most students exhibiting both LDR and WM deficits. The uneven distribution of percentile changes across skills and students in the quantitative data and the similar individualistic patterns within the qualitative data highlight the individual nature of these difficulties and the participant response to intervention.

In Chapter 6, these results will be discussed in specific reference to the research questions being investigated within this study. The discussion will highlight the real-life setting feedback on the complexity and challenges facing educators, health professionals, and parents in the address of LDR and WM deficit. It will also highlight some of the possible trajectories for future research raised by the results around the effectiveness of incorporating cognitive WM training into future school-based educational interventions for students with LDR and deficits in WM.

Chapter 6

Discussion

There can be no settlement of a great cause without discussion,
and people will not discuss a cause until their attention is drawn to it.
(William Jennings Bryan, in Scopes, 1971)

As discussed in the first chapter of this dissertation, the ability to read and interpret the written word continues to be a highly valued skill in the twenty first century. This is despite the dominating prevalence and growing dependency on digital based literacies across all sectors of society (Luke, 2003; Towndrow & Pereira, 2018). Whilst educational providers successfully enable most learners to develop and refine the required subskills involved in the act of reading, there continues to be a sector of students who are prevented from achieving this success due to their inherent and quite specific learning difficulty in reading (LDR) and working memory (WM) deficits (Fuchs, Fuchs, & Compton, 2004; Vaughn et al., 2010).

Students with LDR and students with deficits in WM capacities have long attracted research interest (refer discussion in Chapters 2 and 3). The very strong connection between reading skill development and the development of WM capacities has likewise been the focus of much research interest (Peng et al., 2018). In relation to this, a body of research over the past two decades has shown that WM can show improvement through adaptive cognitive training but there has been limited indication this improvement can translate to improvement in reading skills (Au, Buschkuehl, Duncan & Jaeggi, 2016; Karbach, Strobach, & Schubert, 2015; Loosli, Buschkuehl, Perrig, & Jaeggi, 2012; Melby-Lervåg & Hulme, 2016). This disconnect between trained WM improvement and improvement in academic skills has ignited research interest across many areas of scientific and social science research, but to date, limited transdisciplinary research. Investigation of the available body of transdisciplinary research assisted in the formulation of this study (Rabipour & Raz, 2012; Scheff, Hudson, Tarsha, & Cutting, 2010). There appeared to be a gap in research targeting

the middle primary years where WM training was used with students whilst they undertook a reading intervention program. Additionally, there was little research focus on students with a tandem deficit in both reading ability and WM capacities.

The Study Design

This study was designed to add to understandings around the potential gains in trained WM capacities contributing to and improving the effectiveness of reading intervention programs in schools. It was designed to compare the effectiveness of employing adaptive, cognitive working memory training and reading intervention delivered simultaneously as opposed to sequentially.

The current study utilised a multiple case study method and was undertaken within a school environment where an appropriate reading intervention program was already being delivered. It was rightly anticipated there would be insufficient accessible, eligible students to enable the inclusion of control groups. This would have required two groups undertaking each of the two different intervention formats as well as additional control groups undertaking single interventions: reading intervention program or working memory training. Within an experimental method, the inclusion of control groups greatly enhances the internal validity of a study. Within this case study, set within a school environment, the use of control groups may not have increased the validity of the study for two reasons. The participants across all groups had highly individualised abilities in the word reading subskills and WM capacities around which data were studied. Secondly as this was a naturalistic study, any attempt to control for confounding variables would have disrupted normal school function hence disrupting the validity of the study as a naturalistic study.

As was briefly discussed in Chapter 5 and shown in table 5.2, these considerations were proven to be correct. The pre-post percentiles of the participants reflected high variability in the pattern of strengths and weaknesses of the participants despite all being

eligible for inclusion in the study based on below average reading and WM capacities. This variability was observed within both the WM and reading sub-skill abilities of each participant. This is the reality facing schools as they attempt to provide reading intervention programs to students with WM deficits and LDR (Peng & Fuchs, 2017). These students can, and do, present for reading intervention with quite individualised presentations of strengths and weaknesses across their multimodal WM capacities and their reading skill abilities. Unfortunately, schools are not resourced sufficiently to deliver individual student intervention programs in either reading or WM training. It has been encouraging however, to see the emergence of research based, small group intervention programs in both reading and WM training. These programs enable a level of individualisation across reading and WM subskills and capacities. The two intervention programs utilised in this study are fine examples of this ability to cater to individual patterns of strengths and weaknesses within small group intervention settings.

The reality of performing a case study within a school setting also revealed an uneven distribution of confounding variables across sites within the school and across the participants in all groups. There was variation in school and intervention program attendance due to participant illness, school absence due to unscheduled family mid-term vacation and variations in the impact of whole school activities. Despite this variability in participant sub-skills ability and the impact of confounding variables, the results of this study did indicate one intervention format led to greater changes than the other. The results also highlighted areas for future research.

As will now be discussed this study did reveal that exposure to both WM training and a reading intervention program within a school environment can result in improvement in WM capacities and reading ability. Of pertinence to the design of the study, the format in

which the interventions were delivered did appear to make a difference but not in the specific way predicted by previous research (Christmann, Lachmann, & Steinbrink, 2015).

In Chapter 3, the review of research aimed at observing a transfer of trained WM gains to reading improvement indicated there may be greater transfer if both WM capacities and reading skills were trained at the same time (Christmann et al., 2015). The results of this present study indicated there did seem to be greater improvement in reading ability due to exposure to dual intervention programs, however the stronger gains were not made when the interventions were taken simultaneously. This study identified that greater improvements were observed when the two interventions were undertaken sequentially.

I will now discuss the significance of the results which support this conclusion. The results will be discussed in relation to the three research questions and previous pertinent research, and in relation to how they may contribute to improved reading outcomes for students with LDR and WM deficits. The limitations of this current study will be discussed prior to the chapter concluding with suggestions for future research prompted by this study.

The Results and the Research Questions

As was discussed in Chapter 4, it was necessary to investigate three research questions to address the eight dependent variables in this study. The study of eight variables was necessitated because of the complexity of both reading and WM. Reading is a sophisticated, cognitive function comprised of many subskills. It is also a behaviour which can be influenced by affective variables. Likewise, WM is debated to be a multicomponent as well as multifunctional cognitive function.

The results pertaining to each research question will now be discussed. There will be cross referencing of results throughout due to the research proven interconnection between the complex subskills of reading, the cognitive architecture and function of WM capacities, and the behavioural influence of self-efficacy (Buchsbaum & D'Esposito, 2018; D'Mello &

Gabrieli, 2018; Eriksson, Vogel, Lansner, Bergström, & Nyberg, 2015; Katzir, Kim, & Dotan, 2018; Prins, Dovis, Ponsioen, Ten Brink, & van Der Oord, 2011).

Research Question One: Discussion

Q1. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence word reading ability outcomes?

With respect to reading ability, research question one focusses on word reading ability (WRA) as a foundational and highly WM dependent reading skill. As the ability to read words requires both visual and auditory perception dependent subskills, this introduced the two variables of sight word efficacy (SWE)and phonemic decoding efficacy (PDE). The degree to which these two subskills combine and result in accurate reading created a third variable measured as reading accuracy (RA).

Overall, the results of the study indicated the participants of the Sequential format experienced slightly more improvement in WRA than did the participants of the Simultaneous format.

The greatest impact of the two different intervention formats on the WRA subskills, was on PDE, particularly in the Sequential groups. This was evidenced in both the quantitative and qualitative data. The Sequential format also proved to be slightly more effective in improving SWE and RA, however the difference by intervention format was not as marked as observed in PDE.

As SWE, PDE and RA are all dependent on WM abilities, the variation in results by subskill was interesting. In the absence of control groups, it could be questioned if the marked increase in PDE was due to the phonics-based reading intervention program more so than to any transfer effect from the cognitive, adaptive WM training. Two considerations weaken this argument.

Firstly, participants in both intervention formats undertook the same reading intervention program so one could have expected similar PDE results across intervention formats. In fact, there was a notable difference. Secondly, while participants in both intervention formats also undertook the same WM training program, the timing of exposure to the WM training in relation to the timing of the reading intervention program was the only factor which differed. The WM training was undertaken with the reading intervention program in the Simultaneous format but separately in the Sequential format. This raises the question of whether this difference in results by intervention format for WRA, particularly PDE, might have been due to a transfer effect with the greater transfer observed in the Sequential format?

A second consideration arises if the results of the WM training of short-term auditory memory (STAM) are temporarily referenced. It was insightful to note a similar difference in trained STAM results by intervention format. There was a much stronger increase in STAM ability in the Sequential format than the Simultaneous format. While research supports a very real interdependence between the development of WM abilities and WRA in young readers, this relationship is extremely evident between PDE and STAM. While the results of this study are not conclusive, I believe they are significant in pointing to the possibility there has been a transfer of trained STAM to improved PDE. However, this now raises another question of why there was greater change in the Sequential format than in the Simultaneous format.

Could the improvements in PDE and STAM simply be due to the fact the participants in the Sequential format experienced a much longer total intervention time? With reference to the STAM results, the pre-post testing on STAM occurred at the same time for both intervention formats so there was no intervention program time variation. All groups across intervention formats were pre-tested at the start of the study. All groups then completed the

adaptive, cognitive training for the same number of weeks before all were post tested. Apart from the slight difference in training sessions for one Sequential group which experienced less sessions there was still a resounding difference in improvement in STAM in the combined Sequential groups compared to the Simultaneous groups. This difference existed despite both intervention formats having been trained over the same number of weeks.

In reference to the improvement in PDE, the pre and post testing of PDE for each intervention format occurred at different time intervals by nature of the study design. The study was designed to compare simultaneous dual intervention program delivery compared to back-to-back or sequential dual intervention program delivery. The two formats thus varied in total time length. The PDE post tests for the Simultaneous format participants occurred as soon as the two groups had finished their dual intervention program format. The PDE post-tests for the Sequential format participants occurred as soon as the groups completed the second intervention program. By design, the Sequential participants were in intervention for a longer total time than the Simultaneous participants. Could this factor have contributed to the stronger improvement in PDE in the Sequential groups than the Simultaneous groups? A couple of considerations weaken this contention.

Firstly, for the first half of the total intervention time, the Sequential participants did not attend a reading intervention program. They undertook the adaptive, cognitive WM training whilst continuing to receive normal classroom instruction in reading. Despite this fact, it might be argued these participants should have shown some ongoing improvement in WRA by nature of being in a classroom where reading was being taught. The reality of their identification as students in need of reading intervention because of LDR, casts some doubt on this conjecture. Without reading intervention, one would expect the ongoing development of their WRA to have continued to lag. If in fact, normal classroom instruction had advantaged and led to the higher increase in WRA of Sequential participants then this

advantage would have been expected to be evident consistently across SWE, PDE and RA. This was not the case as both SWE and RA, while slightly more improved in the Sequential groups, did not show the marked improvement seen in the PDE of the Sequential participants. It could be argued that additional testing of SWE, PDE and RA may have provided pertinent data for this discussion. This additional application of WRA testing was ruled out during the study design phase. The application of the WRA test instruments for all groups pre-, mid-, and post may have led to the risk of test familiarity impacting the results. This would have been a greater risk for the Sequential participants and hence was not included in the study design.

A second consideration in this discussion around total intervention time variance comes with respect to exposure time to the reading intervention program. Participants in both intervention formats undertook this program for the same number of weeks although once again, one of the Sequential groups received less sessions in this intervention program than all other groups. Despite this seeming disadvantage for this Sequential intervention group, they exhibited similar improvement in PDE to the two Simultaneous groups and the combined results for the Sequential format groups showed greater improvement in PDE than those of the combined Simultaneous groups. To that end, there is sufficient indication the longer total time in intervention did not specifically advantage the Sequential participants with respect to time spent in the development of academic training in PDE. It did appear to advantage them with respect to greater opportunity for a transfer of trained STAM improvement to improvement in PDE.

The longer intervention time experienced by the Sequential groups may have translated to time for the Sequential participants to receive adaptive cognitive training, experience trained improvement in STAM and then undertake academic training of the phonic attack skills which as previously discussed, are very dependent on STAM. This longer total

intervention time experienced by the Sequential participants may have allowed for the reorganisation of the functional, coordination process described by Christmann et al., (2015).

In discussing the clinical implications of their research into a general auditory processing deficit in developmental dyslexia, Christmann et al. (2015) described reading as the product of a complex, cognitively based, functional coordination process which becomes automatised with practice, over time. They argued that to improve the reading ability in students with LDR, the automated coordination process of reading in the student with LDR, needs to be reorganised and re-automated. Breznitz (2006) referred to this as changing the synchronisation of processes in the brain involved in reading. Christmann et al., (2015), suggested this might be achieved through a combination of cognitive training of basic component cognitive functions and academic training in phonological processing knowledge and skill. This current study was designed to investigate this suggestion by exploring and comparing two different dual intervention [cognitive WM training and reading intervention] program delivery formats -Simultaneous versus Sequential.

The results of this study, particularly the exceptional improvement of PDE by the Sequential intervention groups, would seem to indicate this reorganisation of the functional, coordinated process may be possible. These results add to the research of Christmann et al., (2015) because they indicate the cognitive load experienced by the Simultaneous participants as they undertook two interventions simultaneously may not have facilitated the anticipated cognitive reorganisation. On the contrary, the reduced cognitive load of undertaking one intervention at a time appears to have been more facilitative of the desired reorganisation. These results find alliance in recent cognitive load theory research investigating working memory resource depletion after intensive and extensive cognitive effort (Chen, Castro-Alonso, Paas, & Sweller, 2018).

In the last twenty years, cognitive load theory has continued to evolve and explore possible connections with constructs from other theories. A couple of these research trajectories are quite relevant to the results of this current study: the impact of WM resource depletion and the restrictive impact of stress, emotions, and uncertainty on the capacity of WM – the latter to be discussed in relation to research question three (Sweller, van Merriënboer & Paas, 2019).

In a highly relevant study to this current study, Chen et al. (2018) investigated the connection between WM resource depletion and the spacing effect within the context of learning in a mathematics classroom. The psychology -generated, instructional spacing effect has long been acknowledged but its causation remains contentious (Benjamin and Tullis, 2010; Delaney, Verkoeijen, & Spirgel, 2010; Sweller et al., 2019). The spacing effect is evidenced in superior information processing when information is presented and practised in spaced intervals rather than massed and without interval. The study by Chen et al. (2018) confirmed the validity of the spacing effect but also identified that WM capacity was more reduced with massed presentations than spaced presentations. It also confirmed a strong connection with working memory in resource depletion. Chen et al. (2018) called for more classroom -based research to test the educational significance of the spacing effect; more particularly, their specific findings around the involvement of WM in resource depletion (Gluckman, Vlach, & Sandhofer, 2014). This current study sits within this call and the results seem to align with those of Chen et al. (2018).

With respect to the results for SWE and RA subskills, the evidence that both subskills showed slightly more improvement in the Sequential format but not as marked improvement as PDE, may also be related to the theory around the reorganisation and re-automatisation of functional, coordination processes in reading (Christmann et al., 2015). Sight word efficiency is a subskill of reading which relies heavily on the cognitive ability known as rapid

automatised naming (RAN). Rapid automatised naming refers to the ability to pronounce as quickly as possible, the names of familiar items presented visually (Georgiou, Parrila, Cui & Papadopoulos, 2013). It is a strong predictor of reading success across orthographies but according to Georgiou and Parrila, (2020) the exact reason why it is related to reading remains unclear. Considering the definition of reading as a functional coordination process relying on practice and time to develop to a level of automaticity, it could be conjectured that the Sequential format more so than the Simultaneous format provided greater opportunity for the reorganisation of processes prompted by training, combined with practice and time, to prompt change in automaticity of the newly organised, functional processes. The qualitative results relating to SWE and RA attest to this.

While the qualitative data for both the Simultaneous and Sequential groups spoke of similar improvements in the SWE skill acquisition and application, there was greater evidence in the Sequential groups of some growth towards the development of automaticity in this subskill and that of RA (refer Table 6.1). This slight indication of growth towards automaticity was reflected in very slight differences in the quantitative data for SWE and RA for both intervention formats. The discussion pertaining to research question three and reader self-efficacy (RSE) will highlight this slight difference by format but will also indicate that automaticity in word reading skills remained elusive for most participants across both intervention formats at the end of the study.

It would seem these results for SWE and RA indicate potential in the reorganisation theory but also the need for ongoing research into how cognitive training programs in tandem with educational intervention programs can stimulate development of RAN and reading fluency. There is certainly growing research-based understanding of the cognitive and sensory complexity of the synchronised processes of RAN and automaticity (Kirby, Georgiou, Martinussen, & Parrila, 2010; Norton & Wolf, 2012; Wolf et al., 2009; Wolff,

2014; Yeung, 2016). There also appears to be strong connections in the developing understanding of RAN and automaticity to the research around the dual process theory of higher cognition (Evans & Stanovich, 2013). This theory argues for the existence of two different processing functions in the performance of a task such as reading: autonomous and controlled processes. Research in this area is relevant and highly pertinent to the quest to constantly improve the effectiveness of utilising both WM cognitive training programs and educational intervention programs in developing RAN and automaticity in students with reading difficulties.

Table 6.1

Quotes highlighting slight differences in automaticity by intervention format with respect to sight word efficiency and reading accuracy.

Simultaneous Participants	Sequential Participants
"Still fluency issues even with known words"	"Fluency improved"
"Too many words overwhelm"	"Still slow but fluent"

The results of this current study in relation to research question one, are noteworthy in pointing to the need to be mindful of the cognitive load imposed by cognitive and academic training programs undertaken either simultaneously or sequentially. This has been discussed above in relation to the results for PDE however there were two further indications that cognitive load may have been unproductively heavy in the Simultaneous format.

One indication may have been the fact that it was only in the Simultaneous groups that a percentage of participants experienced no change in their quantitative WRA subskill data. On the contrary, there were no participants in the Sequential groups who had no change after the intervention format in any WRA subskill. Secondly, the qualitative data spoke clearly and

more noticeably to the fatigue and overload of some the participants in the Simultaneous format. This was not as evident amongst the participants of the Sequential format.

Future research into the employment of cognitive training in schools, in tandem with educational interventions, needs to consider that students with learning difficulties need to invest significantly more attention and directed effort into their learning than students without difficulties. There does seem to be a strong relevance in this evidence of taxed cognitive load of students with LDR and WM deficits in ongoing research development of the cognitive load theory (Squires, 2018; Sweller, 2011; Sweller, Merriënboer & Paas, 2019). This was particularly evident in the results of this current study.

Research Question Two Discussion

Q2. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence measures of working memory abilities?

This study was purposed on exploring the suggestion in recent studies (Karbach et al., 2015; Söderqvist & Nutley, 2015) that incorporating WM training into school-based reading intervention programs may lead to the long-debated quest for evidence of a far transfer of trained improvement in WM to related WM dependent, non-trained tasks (Au, Buschkuehl, Duncan & Jaeggi, 2016; Melby-Lervåg & Hulme, 2016). It was fundamentally important therefore to identify evidence of trained improvement in various WM capacities to discuss the correlation to any observed change in reading skills.

Based on Baddeley's (2012) multicomponent model of WM, this study was structured to compare the effect of the different intervention formats on specific components of Baddeley's model of WM. This component specific approach to the data collection may seem odd given Baddeley's multicomponent model is a domain general model of WM. This model presents WM as being non-specific to any domain. The type of WM training task, be it

visual or verbal, should not impact training effects given this domain general conceptualisation of WM (Peng & Fuchs, 2017). The purpose behind the specific component data collection was not, however, to progress the domain general versus domain specific WM debate which continues unabatedly (Uittenhove, Chaabi, Camos, & Barrouillet, 2019). It was purposed on closely monitoring the effect of generalised training of WM on the subskills of reading which are closely dependent on the subcomponents of Baddeley's model. The results of this deliberate data collection design were found to be instructive in identifying change in specific WM capacities through training as well as a difference in the effect of the two different intervention formats. As will be discussed later in this section, the results also appear to provide support for the domain general structure and function of WM (Morey, Rhodes, & Cowan, 2018) particularly as it relates to the development of foundational reading skills (Peng et al., 2018).

There were four specific WM capacities around which data were collected during this current study. Two of the capacities related to working memory measured via auditory input (WM-AI). Data were collected in relation to STAM or the ability to hold a sequence of discreet auditory datum for a fleeting time interval. Data were also collected in relation to the capacity to temporarily retain auditory information whilst it is purposefully manipulated. For the purposes of this study this is referred to as auditory working memory (AWM). A clear example of the AWM capacity is measured in the task of listening to and repeating aloud, a sequence of numbers in the reverse order to that heard. The third capacity around which data were collected was the capacity to temporarily retain visual information while it is purposefully manipulated. For the purposes of this study this is referred to as working memory via visual input (WM-VI). The fourth capacity around which data were collected was focussed attention (FA). The inclusion of data relating to focussed attention was aimed at

capturing insight into the impact of the intervention formats on regulation of attention thought to be a function of the central executive component within Baddeley's model.

The four WM capacities outlined above were deliberately selected for their relationship to specific reading subskills. The development of phonemic decoding abilities is heavily dependent on STAM and AWM. The development and growth of a sight word vocabulary requires the ability to recognise and name words which are either frequently used in written language or are phonically irregular. This recognition and manipulation of written words utilises WM-VI. Lastly, to stay cognitively focussed and attentive whilst engaging in any of the reading subskills in isolation or in the act of reading, does involve attentional regulation capacity. Attention is widely regarded as a critically important component within WM (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014; Eriksson et al., 2015). For the purposes of this study the ACTIVATE pre-post-test data for FA were employed to provide insight into this aspect of the multicomponent WM model.

Impact of intervention format by working memory component. The results of this study indicate the Sequential format had a greater impact on three out of four of these components. The strongest impact and most marked change by format was in STAM and the least impact and difference by intervention format was in FA. The significance of these findings and their transfer to reading subskills will now be discussed.

The impact of intervention format on short term auditory memory. The strongest impact by format was observed in STAM as reflected in the pre-post quantitative data for the number memory forward test. Not only was the improvement greater in the Sequential format but the overall effect on STAM by intervention format was also noticeably different. Whilst most Simultaneous participants showed no change in their ability, most Sequential participants did experience change in their STAM and all of it positive. The difference between formats was noteworthy given the WM training was delivered within the

same time frame to both intervention formats and the pre-post testing occurred at the same time for both formats. The only variable was the Simultaneous groups undertook the reading intervention at the same time as the WM training. As was discussed in the previous section relating to research question one, this raises the question of cognitive load and the capacity of young students to undertake two intensive training programs simultaneously.

With respect to a possible indication of transfer of the observed improvement in STAM to improvement in PDE, there did appear to be evidence of transfer with the greatest being seen in the Sequential groups. Once again, the thought that cognitive load capacity may have been exceeded in the Simultaneous groups is put forward as a possible cause for this difference by intervention format, and as a guide to future research into optimal intervention delivery formats.

The impact of intervention format on auditory working memory. With respect to the impact of the intervention format on AWM, the results were quite similar across intervention formats, however, different to the results for STAM. There was slightly more improvement observed in the Simultaneous format than the Sequential format. This was the only WM capacity where improvement was greater in the Simultaneous format than the Sequential format. This is a surprising result given that STAM improved to a much stronger degree in the Sequential groups and AWM capacity relies to a degree on the short-term storage of auditory information (STAM). Given this interrelationship of STAM and AWM, it may have been anticipated that similar marked improvement may have been seen in AWM in the Sequential format however this did not occur. This result could be considered in two ways.

Firstly, was this evidence of the reorganisation of functional coordination processes which Christmann et al., (2015), suggested might be attainable through exposure to dual and simultaneously administered interventions? For this to be so, there would need to have been

evidence of greater improvement in PDE in the Simultaneous format. This was not evident. There was more improvement in PDE in the Sequential format. As discussed in the previous section, the anticipated transfer of trained AWM improvement to improved PDE may have been inhibited by the excessive cognitive load created during dual application of WM training and reading intervention.

A second possible explanation for the greater improvement in AWM in the Simultaneous Format is one which aligns with the data from this study but also with the working memory-reading development model proposed by Peng et al. (2018). Findings from that meta-analysis indicate domain general WM resources are heavily employed in the development of foundational reading skills such as PDE but as reading abilities and experience grow this relationship becomes reciprocal with reading contributing to the development of WM, particularly verbal or auditory WM. As the WM cognitive training program utilised in this current study is essentially a visual training program the participants in the Simultaneous format had the advantage of also receiving verbal working memory development via their exposure to training in phonological processing within the reading intervention. This could explain the stronger improvement in AWM in the Simultaneous format. Peng and Fuchs (2017) suggest that verbal WM training could be more effective than visual-spatial WM training when the desired outcome is improvement in verbal WM and comprehension. Further research in this area would be highly relevant to the ongoing development of WM training programs, and to research such as this current study into the effectiveness of combining WM training with reading intervention programs (Peng et al., 2018).

The impact of intervention format on working memory measured via visual input. The difference in training effect by intervention format on this component of WM was noticeable. Two thirds of the Sequential format participants showed improvement whereas

less than one third of the Simultaneous participants improved. Likewise, more participants in the Simultaneous format declined or showed no change. Given the WM training time and delivery was identical in both intervention formats, the inclusion of the reading intervention program in the Simultaneous format once again provides a possible reason for this variance in result by intervention format. As discussed previously, the cognitive load of undertaking two interventions simultaneously may have been too great to enable the same level of trained improvement observed in this WM component in the Sequential format.

With respect to a possible transfer of improvement in this WM component to SWE, there was a degree of similarity between the results for WM-VI and SWE within each intervention format. In the Simultaneous format where there was minimal improvement of WM-VI there was likewise but even slightly less improvement in SWE. In the Sequential format where two thirds of participants showed improvement in WM-VI, half the participants also showed improvement in SWE. This could be indicative of a degree of transfer of trained WM-VI improvement to SWE.

The impact of intervention format on focussed attention. The results by format were very similar across both formats. The participants in the Sequential format showed slightly more improvement than the Simultaneous participants and likewise less decline in ability. The qualitative data supported this difference in results by format. The Simultaneous participants' qualitative data spoke of fatigue and rapidly waning interest in the WM training games as the intervention sequence moved towards its conclusion. This was not as evident in the qualitative data for the Sequential participants.

As indicated earlier, there is a line of emerging cognitive load research investigating the effect of factors such as stress, uncertainty, and emotions on the capacity of working memory. Within this research space it is thought that environmentally related factors increase cognitive load which impacts learning and leads to decreased transfer of learning (Moran,

2016). The qualitative data of the Simultaneous intervention groups indicating waning WM training interest and rapid fatigue may support this research. Sweller et al. (2019) discuss the implications of this line of cognitive load research for future instructional design. In this current study it would seem these affective factors had less effect on participants when the intervention programs were undertaken back-to-back in the Sequential format than when taken at the same time within the Simultaneous format.

The overall impact of intervention format on working memory capacities. In summary, the overall results in relation to research question two seem to indicate the Sequential intervention format may have been more helpful in improving most WM capacities than the Simultaneous format. There was one exception with the Simultaneous format being slightly more effective in developing AWM.

The Sequential format may have been more effective in enabling a transfer in trained WM capacities to reading skills which utilise these WM capacities. There seems to be an indication this difference by intervention format might have been attributed to the Sequential format imposing less cognitive load on participants and thus possibly enabling a degree of reorganisation of cognitive processes involved in reading. The results of this current study with respect to possible evidence of a transfer of trained WM capacities to reading skill improvement are supportive of the need for further theoretical exploration and empirical investigation.

Research Question Three Discussion

Q.3. To what extent does adaptive, cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influence reader self-efficacy?

As was discussed in Chapter 2 and in the previous section, reading is a learned, cognitive skill as well as a behaviour. The development of reading skills and ability is not just contingent on the successful development of cognitive capacities and learned, complex

reading skills but also influenced by affective factors such as persistence, motivation, confidence, and values (Fives et al., 2014; Piccolo et al., 2016). Within this current study these four affective variables were studied under the umbrella concept of RSE.

As discussed in previous chapters, self-efficacy is the personal belief in one's ability to do something (Bandura, 1977). It is a dynamic concept as it provides both a basis for motivated action and is further shaped by the outcome of the action. It is strengthened by success but weakened by experiences of failure (Coddington & Guthrie, 2009; Cook & Artino, 2016). Self-efficacy is also specific to task and therefore McGeown, Norgate, and Warhurst (2012) identify reading efficacy as referring to the judgement one makes about one's ability to read. Within this study it is referred to RSE.

In Chapter 2, a review of research around reading difficulties and reading interventions highlighted a historical focus placed on cognitive deficits or reading intervention program inefficiencies. There appeared to be minimal focus on the impact of affective factors such as RSE. In more recent times there has been an increasing recognition in research literature of the multidimensional nature of reading development (Aaron, Joshi, Gooden, & Bentum, 2008; Fives et al., 2014), the need for a more multifactorial model of researching and addressing reading difficulties (Petscher, 2010; Piccolo et al., 2017), and the impact of affective factors on the response of students to reading intervention programs (Grills et al., 2014). To that end this current study included this third research question examining the impact of the two different intervention formats on the RSE of participants. As will now be discussed, the evidence from the results indicated the Sequential format to be more helpful in improving RSE as reflected in changes in four different affective variables: task persistence, task effort, task confidence and task choice.

The impact of intervention format on reader self–efficacy as reflected in task persistence. Within this study, the level of persistence shown by participants was

measured by the time they spent reading. While participants in both formats indicated varying degrees of improvement in task persistence reflected in increased time spent reading, there was a distinct difference by format not just in quantity of time but in who was directing this increased reading involvement.

> "Spent the required practice reading time……reads in bed…
> when not too tired"- Parent of Case B Sim Participant
> "It seems like the level of interest has picked up. Mum said that
> he would have to be told to turn the light off and stop reading"
> – Teacher of Case A Seq Participant

More participants in the Sequential format than in the Simultaneous format indicated they were now engaging in reading above and beyond the reading requirements imposed on them at school and at home by their parents. There was also indication the Sequential participants were engaging in this increased reading time willingly, as a self-directed activity. It appears the greater growth in reading skills amongst the Sequential participants may have translated to greater change in task persistence observed as desire to spend additional time reading.

Recalling that success strengthens self-efficacy, possibly this was evidence of stronger RSE in the Sequential participants. As discussed in relation to both WRA and WM, the participants in the Sequential format experienced greater change and success from the intervention format than the participants in the Simultaneous format. This may possibly be indication of a transfer effect from the WM training. Jaeggi, Buschkuehl, Shah, & Jonides, (2014) argue there are several factors involved in the provision of cognitive training which could moderate improvements apart from RSE. Factors such as differences in the teaching style of the intervention teachers and differences in how they provide feedback to the participants may be argued to have influenced results. In this current study these effects were

somewhat diminished through the employ of a multiple case study design. The two intervention teachers involved in the study, one at each school site, delivered a Simultaneous and a Sequential intervention format to two different cases. There were also multiple participants in each case within each format. This would have worked to weaken the influence of individual differences in relation to response to the WM training program.

To that end it is possible this increased willingness to invest effort in reading may be due to improvement in RSE enabled by a transfer of trained WM capacities to dependent WRA which have also experienced development through the reading intervention.

The impact of intervention format on reader self–efficacy as reflected in task effort. At the commencement of the study participants in both formats indicated reading was extremely arduous. This aligned with the highly dependent level of WRA and the WM deficits across all participants. At the conclusion of the study, there was evidence across both formats that reading had become slightly less laborious but still lacked any real degree of automaticity. There was evidence of this across student, parent, and intervention teacher post questionnaire data. Many students were finding reading slightly easier, but they still fatigued quickly.

> "My jaw can sometimes hurt. I don't like too many pages"
> - Case A Sim participant
> "Feels good that he is improving. Slow but improving"
> -Parent of Case B Seq participant
> "Very eager to read….He does fatigue though"
> – Teacher of Case B Seq participant

The results of this present study support the need for continued research efforts to identify how school-based reading interventions can precipitate this much needed improvement in automaticity (Georgiou & Parrila, 2020; Kirby, Georgiou, Martinussen, & Parrila, 2010; Wolf et al., 2009).

I also believe this current study provides evidence of the efficacy in including cognitive training within these school-based remediation programs addressing reading difficulties. This is evidenced in the fact that while there were small improvements across both intervention formats in the amount of effort required to read, there were identifiable differences between formats.

Amongst the qualitative data for the Sequential participants, there was evidence they were showing greater independence and willingness to invest effort in their reading. There appeared to be an increased willingness to invest effort in employing various reading subskills to read. If cognitive load was a limiting factor in the Simultaneous format, preventing the same level of WM and WRA improvement observed in the Sequential format, this greater sense of independence amongst the Sequential participants may be indicative of increased RSE. The slightly greater improvement in WM capacities and WRA in the Sequential participants may have provided the experience of success proven to translate to improved RSE.

The impact of intervention format on reader self–efficacy as reflected in task confidence. In this aspect of RSE it was interesting to note evidence in the pre-study data of a small number of participants with inflated self-confidence about personal reading ability despite having poor skill levels. This is discussed within Fives et al. (2014), as possibly being a defence mechanism against the continual frustration experienced in early school years by students with LDR.

> "He presented as having a strong belief in himself but he
> had a false belief about himself" – Teacher of Case B Sim participant

There was also evidence across the participants of widespread dislike and avoidance of reading in front of classmates. Research once again links this back to early and ongoing frustration in attempts to learn to read (Fives et al., 2014; Grills-Taquechel, Fletcher, Vaughn,

& Stuebing, 2012). The research by Grills-Taquechel et al. (2012) indicated a cyclical and bidirectional relationship between anxiety and poor achievement. This was also observed and supported by the results of this current study. The evidence of increased reading confidence across both formats, did appear to flow through to increased willingness to engage in reading and even read in front of peers. This increase in confidence was significantly more noticeable within the Sequential format.

As stated previously, the participants in both formats indicated an increase in their self-confidence as readers, however there was a noticeable difference by format in the degree of confidence and the consistency with which it was exhibited. This is particularly evident in some of the quotes from the qualitative data included in Appendix M. Table M.5.5 and Table M.5.6. and represented in Table 6.2. While reading continued to be effortful, it was particularly obvious in the data for the Sequential participants that they were noticing their skills were improving and they were feeling more confident in their abilities.

Table 6.2

Quotes highlighting differences in reader self-confidence by intervention format.

Simultaneous Participants	**Sequential Participants**
"Not a confident reader but more confident in approach to reading"	"I can read quickly now. I couldn't before"
"Slight change in confidence"	"I feel better for myself because I know I am gonna get better at this"

The evidence of increased confidence within the Sequential groups where there was likewise more overall evidence of improvement in WRA also supports the call by Piccolo et

al. (2017), Wolf et al. (2009) and Petscher (2010) for greater consideration of the impact of self-belief in the development of interventions for students with LDR.

The impact of intervention format on reader self–efficacy as reflected in task choice. At the commencement of the study most participants across both formats indicated they valued reading although there was evidence within the data these values were formative and very heavily influenced by the views of parents and teachers.

While some of the participants across both formats commenced the study indicating they valued reading because they personally experienced the value, many of the participants began without that personal validation of the value of reading. Both intervention teachers commented participants simply repeated what they knew to be the value of being able to read.

For most participants, reading was a positive skill but for one, the skill was held with little interest and connection to current and future life.

> "Reluctant reader;……saw no value in reading or school…aiming
> to leave early to be a ……This was a real barrier"
> -Classroom teacher of Case A Sim participant

This participant provided evidence of how powerful poor RSE can be in preventing growth and success. Apart from improving attention, the intervention format had very little impact on this participant and their opinion of reading remained unaltered at the end of the study. The data around this participant also provided further support for the individual difference theory of WM (Jaeggi et al., 2014), discussed earlier in relation to task persistence.

This participant was exceptional and not reflective of most participants who did show evidence of improvement in the value they personally placed on reading. The improvement was more noticeable in the participants in the Sequential format. It was quite noticeable that the Sequential format participants were now experiencing some of the positive emotional responses possible through reading for oneself.

"When I read, I am really quiet. I like it and I love it. It feeds your brain with information and it also takes you on an imaginary adventure."

-Case A Seq participant

"It's enjoyable for me. It's weird sometimes because sometimes I might be reading a book, in the middle of it, I go like, in my head, I'm just reading words but for some reason I'm thinking of it in my head, thinking of what's happening and what they would be doing but reading at the same time"

- Case A Seq participant

There was also evidence some were feeling emancipated; no longer disenfranchised by their limited abilities and accumulated failure experiences. Some were also feeling empowered by the learning opportunities their new reading abilities opened for them.

"It can help me spell words and it is exciting. I really enjoy it now."

-Case B Seq participant

While there was some evidence of this amongst the Simultaneous participants, the data for most of the Simultaneous participants continued to reflect imposed values, not personally developed and experienced values.

"Kind of normal reader. Not sure what more to say about reading"

-Case A Sim participant

Once again, this difference by intervention form may be reflective of the greater change in WRA and WM capacities observed in the Sequential participants possibly as a result of them experiencing less cognitive load demand and greater time to enable the cognitive reorganisation and integration discussed in previous sections above.

The overall impact of intervention format on reader self–efficacy. In conclusion it has been clear within the discussion above in respect to the results for all four aspects of RSE

that the Sequential intervention format appeared to be more effective than the Simultaneous format in improving RSE. This result provides further support for the contention that the Sequential format may have provided greater opportunity for the reorganisation of the cognitive functional coordination processes (Christmann et al., 2015) or resynchronisation of cognitive processes (Breznitz, 2006) than the Simultaneous format. As discussed, this reorganisation theory is proffered as a possible enabler for transfer of trained improvement in WM capacities to improved reading skills. The results of this current study support the need for ongoing research in this area.

The results pertaining to this third research question validate the call by Grills et al., (2014) and Katzir, Kim, and Dotan, (2018) for more research to be undertaken exploring the impact of socioemotional domains on the effectiveness of reading interventions. The results support previous research indicating the importance of motivation as a factor in the success of cognitive training interventions (Pintrich,1999; Prins, Dovis, Ponsioen, Ten Brink, & van Der Oord, 2011) and provide support for Petscher (2010) who identified real potential in developing RSE as part of intervention programs.

Limitations

There were two main limitations within the current study. Firstly, while there is unique value in case study as a methodology in the insight it provides into the story behind the participants, it is also a research method in which confounding variables can be difficult to circumnavigate. This was the case in this current study where despite every effort exerted to ensure both groups within an intervention format received identical interventions, there was variability in one intervention format, simply due to the fact the case study occurred within a functioning primary school.

School based intervention programs are delivered within and as part of whole school programs and processes. They are resource heavy to implement resulting in schools often

actively protecting them from many of the interruptions that standard classrooms can experience. This is not always possible however, as the reality of twenty first century learning is that schools are busy environments experiencing constant change and variation in student attendance and daily programs. Often intervention program time is not realised as planned. This was observed in this study where one Sequential received slightly less cognitive WM training and even less reading intervention than the second Sequential format group. As a result, it was not possible to identify literal replication within the Sequential intervention groups. Despite this difference in exposure to the intervention programs, the overall results for the Sequential format were stronger than those in the Simultaneous format. This result indicated a definite difference in the effectiveness of one intervention format over another. To that end there was evidence of theoretical replication but not literal replication, at least within the Sequential format (Yin, 2014).

Despite this limitation, the results of this study highlight the value of utilising a case study methodology. The results and insights gained through analysis of both quantitative and qualitative data provided immense understanding of the story behind the participants and their reaction to the intervention formats. As reading is both a cognitively acquired skill and developed behaviour, the importance of understanding the affective impact of the intervention formats cannot be understated.

The second limitation within this current study was the relatively small sample size. Small sample size is not uncommon in this field of research as observed by Peijnenborgh et al. (2016). As this study did display theoretical replication on numerous accounts as discussed above, this would appear to indicate it to be a worthwhile and contributory piece of research to this field of study.

Implications of the Findings for Reading Intervention Pedagogy and Future Research

This current studied was designed as a transdisciplinary study. It has identified evidence supportive of existing research in several research disciplines and adds to this work with suggestions for future research. This result verifies and supports the call for ongoing transdisciplinary research (D'Mello & Gabrieli, 2018; Hruby & Goswami, 2011; Nevo & Breznitz, 2014; Peng & Fuchs, 2017; Piccolo et al., 2017; Wolf et al., 2009).

This study investigated whether exposing young students to adaptive cognitive training at the same time as an academic intervention program would facilitate evidence of a transfer of trained WM improvement to academic skill development. The evidence from this study strongly suggests that staggering the exposure to each intervention program was generally more conducive to transfer than simultaneous exposure. While possibly providing evidence of the required reorganisation of functional cognitive processes, the results raised a somewhat novel question around the impact of cognitive load restrictions on the quest to identify the optimum delivery format of cognitive and academic training. This finding aligns with recent research developments in cognitive load theory and supports the need for ongoing research in this area.

The results of this study with respect to AWM support the contention postured by Peng et al. (2018) that the relationship between WM and reading varies with development. It is not a relationship which varies according to age or year level of education but according to the level of reading development of the student. Young readers need to develop different reading skills to emerging readers (Nevo & Breznitz, 2014; Peng & Fuchs, 2017). The type of WM training activities and the educational training programs employed with young, dependent readers who are learning to recognise words and decode words, need to be different to those of emerging readers who might now be needing to develop fluency and comprehension abilities more so than WRA. Research into the development and alignment of

WM training programs matched to developmental stages in reading presents itself as an area for future transdisciplinary research.

Another aspect of reading development which this current study and many previous studies suggest continues to limit the success of cognitive WM training and educational intervention programs, is that of naming speed and automaticity. According to Wolf et al., (2009), research in this area spans three decades and continues in the quest for answers around why RAN is such a prevalent predictor of reading success or failure (Wolff, 2014; Yeung, 2016). This current study validates this call for ongoing research as the reading skill improvement noted in participants in this current study continued to be hampered by weak RAN and a lack of automaticity.

Finally, this current study provided evidence in support of further research into the socioemotional factors which inhibit the response to intervention rate of students with low RSE. This current study supports the views of Katzir et al. (2018) and Grills et al. (2014) that the development of intervention programs should be guided by understanding of low RSE and how RSE can be manipulated via carefully paced exposure to intervention programs.

Summary

This study was designed to contribute to ongoing research into the effectiveness of utilising cognitive training programs in conjunction with educational intervention programs to address the WM and reading abilities of students with LDR and WM deficits. It was also designed to provide insight into the effectiveness of employing dual intervention programs within primary school settings.

The study successfully identified the Sequential intervention format may have been more helpful than the Simultaneous format in promoting a transfer of trained WM improvement to reading skill improvement. This result was discussed in reference to possible evidence of less demand on WM resources and cognitive load during the Sequential

intervention format than what may have been experienced by participants in the Simultaneous format. The results were also discussed in relation to the Sequential format offering more opportunity in terms of WM resources and time, to allow for a reorganisation of functional coordination processes required to improve WRA.

The results of this study also affirmed the view that the relationship between WM and reading is a developmental one and not one dictated to by age or year level of schooling. It pointed to the need for further research-based development of cognitive WM training programs which align with different developmental stages in reading. In this way, training would be aligned with the specific developmental needs of the student and hopefully result in optimum intervention growth.

The ongoing development of cognitive WM training programs and reading intervention programs also needs to be guided by ongoing research around RSE and the relationship of RSE and cognitive load as this current study supported previous research in both areas of research. This current study provided strong evidence of the impact of several socioemotional factors on cognitive load, reading success and response to intervention.

Chapter 7

Conclusion

All knowledge is connected to all other knowledge. The fun is in making the connections
(Arthur C. Aufderheide in Krajick, 2005)

The focus of this study was students with learning difficulties in reading (LDR) in addition to working memory (WM) difficulties. Students with persistent and somewhat intervention resistant, learning difficulty in reading (LDR) have been a perennial focus in educational and scientific research as well as in reading intervention pedagogical debate and evolution (Kudo, Lussier, & Swanson, 2015; Savage & Frederickson, 2006). Working memory has likewise attracted an expansive body of research literature as it plays an important role in a wide range of cognitive tasks, information processing, and behaviour guidance (Eriksson, Vogel, Lansner, Bergström, & Nyberg, 2015; Klingberg, 2010). Of relevance to this study is the body of research around the critical role it plays in reading (Peng et al., 2018) and the impact on reading development when there are WM deficits and difficulties (Nevo & Breznitz, 2014; Peng et al., 2018; Swanson & Kong, 2018). This study investigated a specific research problem related to the utilisation of adaptive, cognitive WM training to improve WM capacity and consequently improve academic performance in the specific area of word reading ability (WRA). Research to date has produced mixed findings related to this desired far transfer (Alloway, Bibile, & Lau, 2013; Hovik, Saunes, Aarlien, & Egeland, 2013).

This final chapter provides a summary of this research problem, the key findings related to the study's three research questions and a discussion of the relevance of the study for current and future developments in educational reading intervention pedagogy. Suggestions for future research addressing both the limitations of this study and the new questions it has prompted, bring the chapter and the overall study to a conclusion.

Research Problem and Research Questions

Relatively recent technological advancements in the ability to observe and investigate brain structures and functions involved in reading have greatly enhanced and advanced research into the causative factors involved in LDR (D'Mello & Gabrieli, 2018). Developing understandings around the plasticity of the brain have led to broad based research interest in the effectiveness of adaptive, cognitive WM training programs to improve WM and consequently, improve learning outcomes. This study aimed to contribute to research in both areas by addressing a gap in transdisciplinary research investigating the transferability of trained WM improvement to improved WRA ability in students with both WM difficulties and LDR in the middle years of primary school. The design of this study specifically addressed the suggestion by Peng and Fuchs (2017) that various approaches to the delivery of skills and cognitive training programs be explored. The study investigated the effectiveness of delivering WM training at the same time as a reading skills intervention program (Simultaneous Intervention Format) as compared to delivering them separately (Sequential Intervention Format).

In terms of the data collected and analysed to inform this comparison it was thought pertinent and unique to this study to not only examine and compare the impact of the two different intervention formats on WRA and WM but also on reader self-efficacy (RSE) as reading is a behaviour: it can be modulated by affective factors such as motivation, confidence, and anxiety (Lee & Jonson-Reid, 2016; Schiefele, Schaffner, Möller, & Wigfield, 2012; Yang, Badri, Al Rashedi, & Almazroui, 2018). This was particularly relevant to this study as it was a multiple case study set within a primary school setting.

The study investigated three research questions which probed the extent to which adaptive cognitive working memory training and literacy intervention (delivered simultaneously versus sequentially) influenced WRA, WM, and RSE.

Summary of Key Findings and Pedagogical Relevance

Key Findings

With respect to the effect on WM and WRA, the findings from this study indicated that a far transfer of trained improvement in WM capacities, particularly short-term auditory memory (STAM) to improvement in WRA, particularly phonemic decoding efficacy (PDE) might be possible within a primary school setting through the delivery of both cognitive adaptive WM training and a targeted reading intervention program. While the results of this study supported this contention, they also added to research in this area. There was a strong indication that the format in which the two types of intervention programs (WM training and reading intervention program) were delivered, impacted the degree of far transfer observed.

Based on the functional coordination model of reading discussed in chapter 3 (Christmann, Lachmann, & Steinbrink, 2015; Lachmann & van Leeuwen, 2014) it was anticipated dual, simultaneous exposure to WM training and word reading skill training might lead to evidence of a far transfer of trained WM improvement to improved WRA. By way of comparison, the effect on WRA of spacing the two interventions via a Sequential intervention format was also investigated. The results of this study indicated the Sequential intervention format rather than the Simultaneous intervention format may have provided greater opportunity for the reorganisation of functional coordination processes involved in WRA, particularly in PDE. The Sequential format may also have provided greater opportunity for the employ of the newly organised functional coordination processes such as the retrieval of phonic knowledge from long term memory during phonemic decoding. This in turn may have led to the slightly more evident level of automaticity observed amongst the Sequential participants.

The unexpected result of the greater far transfer effect in the Sequential format rather than the Simultaneous also provided additional insight into the effects of massed versus

spaced instruction. The massed instruction created through the Simultaneous intervention format was not as effective as the spaced instruction delivered in the Sequential intervention format. While the superiority of spaced instruction to massed instruction has been previously established (Delaney, Verkoeijen, & Spirgel, 2010), the replication of the spaced instructional effect in this current study provided unexpected insight into the role cognitive load may play in influencing the degree of far transfer of trained WM improvement to improvement in academic abilities such as WRA. While the results from this study appeared to support the theory that exposure to both WM training and word reading skill intervention can facilitate far transfer of trained WM improvement to improvements in WRA, this appeared to be more effective when WM training and word reading skill interventions were delivered as spaced interventions. The results achieved by the participants in the Simultaneous format appeared to indicate the cognitive load of dual intervention exposure may have been too demanding to facilitate the same level of transfer observed in the Sequential format. The Sequential format data provided evidence of greater improvement across all three WRA subskills around which data were collected: sight word efficiency (SWE), phonological decoding efficiency (PDE) and reading accuracy (RA). This finding aligned with recent developments in cognitive load theory around WM resource depletion when instructional demands are too high (Chen, Castro-Alonso, Paas, & Sweller, 2018; Sweller, van Merriënboer, & Paas, 2019).

With respect to the influence of intervention format delivery on the RSE of participants there was similar indication of greater improvement in RSE in the Sequential intervention participants compared to that reflected in the Simultaneous participants. While it was acknowledged that all participants continued to find reading effortful due to low levels of automaticity and fluency, there did appear to be a greater level of change amongst the participants in the Sequential format than amongst those in the Simultaneous format. There appeared to be a higher level of self-directed willingness to invest effort in reading amongst

the Sequential format participants. This was not as apparent in the participants in the Simultaneous format. The qualitative data spoke of significant investments of effort, concentration, and energy by Simultaneous participants more so than by the Sequential participants. Likewise, the Simultaneous participants appeared to have less confidence in their abilities and less motivation to engage in reading.

These findings support and add to recent research interest in the interactive effects of not just cognitive and linguistic elements in the reading process but that of emotions (Grills et al., 2014; Katzir, Kim, & Dotan, 2018). Similar interest in the impact of emotions, stress and uncertainty on cognitive load has also drawn recent research interest (Choi, van Merriënboer, & Paas, 2014; Moran, 2016). This line of cognitive load research is investigating if the capacity of WM is constrained in instructional situations where environmental (physiological, cognitive, or affective) effects compete with the cognitive and linguistic demands of the learning situation for available WM resources. This line of cognitive load research is supported by the findings of this current study in which the cognitive load of the Simultaneous participants undertaking two interventions at the same time, appeared to be higher than that experienced by the Sequential participants. This increased demand on WM resources appeared to have had a negative interactivity with the aspects of RSE examined within this study. This has important implications for the ongoing development of reading intervention programs (Grills et al., 2014).

Relevance for Current Reading Intervention Pedagogy

The results of this current study add to transdisciplinary research indicating adaptive, cognitive WM training has a role to play in the address of LDR (Peng & Fuchs, 2017). The diversity in WRA subskill ability and WM capacity of all participants in this study and the response of the participants over and above the results by intervention format, strongly supported the view that reading intervention programs and WM training programs must

continue to develop content flexibility and delivery adaptability. Reading skills and WM capacities are both developmental (Peng et al., 2018) hence intervention programs must be flexible enough to meet developmentally diverse needs within each group of students requiring reading intervention. Within schools where competition for resources is high, it is not always possible to provide one to one intervention. Schools need to carefully select intervention programs which provide sufficient scope for meeting, servicing, and adapting to the developing needs of students with LDR and WM difficulties.

A very clear indicator from this research and other recent cognitive load research, was the need for very careful delivery of intervention programs which address both WM and WRA difficulties. While it has been shown that the dual delivery of these interventions can lead to change in both WRA and WM capacities, there is also strong indication this can be a negative impact if delivery formats lead to unproductively high demand on cognitive load resources such as WM.

Thirdly, the results of this study clearly indicated the importance of monitoring the psychological, physiological, and affective characteristics of students undertaking intervention programs. While careful consideration of these factors would hopefully be normal practice within any twenty-first century classroom, this study highlighted the increased cognitive demand these environmental factors place on WM resources within the intervention setting. Often students enter intervention settings quite self-aware of their WRA and WM inadequacies and low RSE. This understanding should guide intervention practitioners to carefully monitor the additional cognitive load placed on not just the cognitive and linguistic abilities of the students but also their affective resources. Locating the tipping point where training and extending abilities of students moves from positive to negative needs to be stressed in the preparation of teachers training to deliver intervention programs. This program adaptability is already built into the development of many WM

training programs, including the one utilised in this study. These programs aim to extend students within and not beyond their zone of proximal development (ZPD) (refer Gredler & Shields, 2007). In delivering both reading intervention and WM training to gain the anticipated transfer observed within this study, it will be important to find the most effective delivery format with respect to demand on cognitive load.

Summary of Limitations and Recommendations for Future Research

The results of this current study are supportive of the ongoing research-based quest to identify how WM training can be most effectively implemented within schools to assist in the intervention of reading difficulties. As with any research there were limitations within this current study which need to be addressed in future research of this nature:

- While the value of this current study as a multiple case study within a real school setting was realised through the unique insights provided into the effectiveness of delivering dual interventions within a real school setting, the impact of confounding variables needs to be acknowledged. While research of this nature would be wise to include contextualised studies, it will be important for future studies to find ways to limit the effect of unavoidable interruptions to intervention program delivery through teacher and student absences and whole school program interruptions.
- The small sample size of this current study while not unique in this area of research does need to be addressed in future research as greater validity would be claimed through results achieved in larger sample sizes. Likewise, replication of these results within experimental study designs would assist in the affirmation and development of the insights gained in this study. To this end it would be pertinent if large scale, experimental studies could investigate the validity of the findings of this study.

- Pre and post data analysis proved insightful; however, it would be helpful in future studies to collect longitudinal data to ascertain if post intervention gains in WRA, WM and RSE are sustained over time.

Summary

The results of this study indicated the possibility of trained working memory improvement being transferable to word reading skills improvement when both WM training and reading intervention are administered in a spaced application format within the school environment. While faced with specific challenges around the conduct of an expansive study over two school sites for an extended period within a busy primary school, this study has proven itself to be contributory to ongoing research in the areas of cognitive WM training and school-based reading intervention programs.

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Appendix A

Human Research Ethics Committee (HREC) Approval Form

ACU
AUSTRALIAN CATHOLIC UNIVERSITY

Human Research Ethics Committee
Approval Form

Principal Investigator/Supervisor: A/Prof Kenneth Smith

Co-Investigators:

Student Researcher: Roselyn Smith (Doctoral Student)

Ethics approval has been granted for the following project:
Working Memory Training and Explicit Teaching: A Transdisciplinary Approach to Reading Intervention

for the period: 31/12/2018

Human Research Ethics Committee (HREC) Register Number: 2017-287H

This is to certify that the above application has been reviewed by the Australian Catholic University Human Research Ethics Committee (ACU HREC). The application has been approved for the period given above.

Researchers are responsible for ensuring that all conditions of approval are adhered to, that they seek prior approval for any modifications and that they notify the HREC of any incidents or unexpected issues impacting on participants that arise in the course of their research. Researchers are also responsible for ensuring that they adhere to the requirements of the *National Statement on Ethical Conduct in Human Research*, the *Australian Code for the Responsible Conduct of Research* and the University's *Code of Conduct*.

Any queries relating to this application should be directed to the Research Ethics Manager (resethics.manager@acu.edu.au).

Kind regards

[redacted]

Date 14/02/2018
Acting Research Ethics Manager

Research Ethics | Office of the Deputy Vice-Chancellor (Research)
Australian Catholic University
T: +61 2 9739 2646
E: Res.Ethics@acu.edu.au
W: ACU Research Ethics

Appendix B

Research Participant Information Letter

PARTICIPANT INFORMATION LETTER

PROJECT TITLE:	Improving Reading Ability via Computer Based Memory Training and Intensive, Explicit Reading Instruction.
PRINCIPAL INVESTIGATOR:	Associate Professor Kenneth Smith
STUDENT RESEARCHER:	Mrs Roselyn Smith
STUDENT'S DEGREE:	Doctor of Education

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

The research project investigates the use of adaptive, cognitive working memory training to enhance the outcomes of a reading intervention program for participating students with deficits in both working memory and reading skill development.
Working memory is a person's ability to hold and use both new, temporary information and stored information. For example, working memory assists a person to work on the answer to a question while holding the question in short term memory. More specifically in reading, working memory would assist a student attempting to read the unknown word 'dog'. Depending on the student's reading strategy in this instance, it might assist the student to recall the sound of each letter (e.g. d/ o/ g/), in order to ultimately blend the sounds to read the word 'dog' or it might hold the word while it retrieves the visually stored memory of the word. Working memory is extremely important not just in learning but in many aspects of daily life.
By participating in this project, you will be benefiting from working memory training and reading skill enhancement, at the same time contributing to ongoing research and development of theoretical understanding in the area of working memory neuroplasticity and training effects.

Who is undertaking the project?

This project is being conducted by Mrs Roselyn Smith as part of her postgraduate research for the award of Doctor of Education through the Australian Catholic University under the supervision of Associate Professor Kenneth Smith. Roselyn commenced her career in education as a primary school/music teacher however quickly identified a special interest in students with additional learning needs, which led to post graduate studies and over fifteen years of teaching and leadership experience in this field. She is currently the Director of the Learning Support faculty of Christian College Geelong.

Are there any risks associated with participating in this project?

Risks in participating in this project are negligible and comparable to those which arise in a school setting where students are removed from regular classes to undertake intervention programs – programs which are aimed at strengthening individual learning weaknesses known to be inhibiting academic progress. This study will employ strategies to mitigate against any loss in normal classroom learning time such as varying the scheduling of intervention classes so the loss in learning time is spread across a number of learning areas, reducing assessment task requirements and un-enrolling students from any non-core subjects highly impacted by the intervention program.

What will I be asked to do?

Students will participate in a daily, small group, reading intervention program for two terms. (MacqLit). These classes will take place in the learning support room at the Junior and Drysdale campus of Christian College.

Students will undertake 20 minutes of daily, working memory training for a period of one school term. This training will be delivered through an online, adaptive training program called Activate and accessed within school hours.

Both of these intervention programs will be provided free of charge to the participant

The student's working memory and reading skills will be assessed prior to, during and at the conclusion of each intervention program. The students and their parents will also be asked to complete an online questionnaire before and after the MacqLit course.

The data collected as part of this research will be shared and discussed with the parents of participating students (and the students as deemed appropriate), and with the student's classroom teacher, on a regular basis throughout the study. As well as contributing to the purposes of this research study, the data collected throughout the project will be used to guide the progressive educational provision for each student, as would be normal practice within a school engaged in the provision of specific intervention programs.

The use of this data outside of the college, for the purposes of this research, will be completed in a highly confidential and non-identifiable manner. The non-identifiable data will be published as part of this dissertation. The final publication will be made available to participating families.

How much time will the project take?

Each participant will be involved in a one hour, MacqLit reading intervention class, five days a week for two terms. (A requirement of the MacqLit program is that participants also read for 20 minutes every day with a parent at home to reinforce skills learned in class.) Participants will also undertake 20 minutes working memory training, five days a week for ten weeks. Half of the students will take this training prior to starting their MacqLit course and half will undertake this training at the same time as their MacqLit course.

What are the benefits of the research project?

While the MacqLit program has been proven to be effective in improving reading skills and Activate similarly proven to be effective in improving working memory, this study is investigating if combining both of these interventions can lead to greater improvements in reading skills in students with working memory deficits.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. The data relating to any person withdrawing from the study will be discarded from the research data collection however will remain within normal Christian College student records.

Will anyone else know the results of the project?

The results will be published in Roselyn Smith's, Doctor of Education dissertation. The data collected will be stored on Christian College's Onedrive and backed up on hard drives. The data will be de-identified within the dissertation.

Will I be able to find out the results of the project?

The results of the project will be available from Roselyn Smith.

Who do I contact if I have questions about the project?

Roselyn Smith can be contacted by email (ro.smith@ccg.vic.edu.au) or phone (0418538846), if there are any questions about the project.

What if I have a complaint or any concerns?

The Human Research Ethics Committee at Australian Catholic University (approval number 2017-287H) has approved the study. If you have any complaints or concerns about the conduct of the project, you may write to the Chair of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Chair, Human Research Ethics Committee
c/o Office of the Deputy Vice Chancellor (Research) Australian Catholic University
Melbourne Campus Locked Bag 4115
FITZROY, VIC, 3065.
Ph: 61-3-9953-3157
Fax: 61-3—9953-3315
Email: res.ethics@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?
Participation is secured by completing the Consent Form accompanying this letter and returning the form to the Learning Support Coordinator at your Christian College campus. The LS coordinator will forward the form to Roselyn Smith at Middle Campus, Christian College.
Yours sincerely,

Principal Researcher Student Researcher

Appendix C

Parent-Child Consent Form

PARENT AND CHILD CONSENT FORM

TITLE OF PROJECT: Improving Reading Ability via Computer Based Memory Training and Intensive, Explicit Reading Instruction.

PRINCIPAL RESEARCHER: Associate Professor Kenneth Smith

STUDENT RESEARCHER: Mrs Roselyn Smith

1. I …… *(the parent / guardian)* have read or have had read to me and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction.
    - I agree to participate in an online questionnaire concerning my child's level of engagement with, and motivation for reading prior to and post their participation in the MacqLit program;

2. I agree that my child ……..who is in Grade…… and who has been attending 'Primary School Name' for …….. years and/or ….months will:
3.
    - Participate in a daily, one hour MacqLit reading intervention class over a period of two school terms;
    - Participate in 20 minutes of daily computer based training of working memory over a period of one school term, using a product called Activate.
    - Complete an online questionnaire concerning their engagement with, and motivation for reading prior to and post their participation in the MacqLit program;
    - Complete all testing required to monitor any change in their level of working memory, word reading ability, reading accuracy, reading rate, reading comprehension.

I realise that I can withdraw my consent at any time without adverse consequences and with any data collected to that point, subsequently being withdrawn from the study and from any future private research although the data will remain the property of the college. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify my child in any way.

NAME OF PARENT/GUARDIAN: ……...

SIGNATURE: …….. DATE: …….....

SIGNATURE OF PRINCIPAL INVESTIGATOR: ……...

DATE: …….

SIGNATURE OF STUDENT RESEARCHER: …….

DATE: …….

Child Assent

I …….. *(the participant aged under 18 years)* understand what this research project is designed to explore. What I will be asked to do has been explained to me.

I agree to:

- Participate in a daily, one hour MacqLit reading intervention class over a ☐ period of two school terms;
- Participate in 20 minutes of daily computer based training of working ☐ memory over a period of one school term, using a product called Activate.
- Complete an online questionnaire concerning my engagement with, and ☐ motivation for reading prior to and post the MacqLit program;
- Complete all testing required to monitor any change in my working memory ☐ and reading abilities.

I realise that I can withdraw at any time without having to give a reason for my decision.

NAME OF PARTICIPANT AGED UNDER 18: ……...……

SIGNATURE: …… DATE: …….....

SIGNATURE OF PRINCIPAL INVESTIGATOR: ……...

DATE: …….

SIGNATURE OF STUDENT RESEARCHER: …….

DATE: …….

Appendix D

Learning Support Staff Participation Information

LEARNING SUPPORT STAFF PARTICIPANT INFORMATION LETTER

PROJECT TITLE:	Improving Reading Ability via Computer Based Memory Training and Intensive, Explicit Reading Instruction.
PRINCIPAL INVESTIGATOR:	Associate Professor Kenneth Smith
STUDENT RESEARCHER:	Mrs Roselyn Smith
STUDENT'S DEGREE:	Doctor of Education

Dear Participant,

You are invited to be a learning support staff participant in the research project described below.

What is the project about?

The research project investigates the use of adaptive, cognitive working memory training to enhance the outcomes of a reading intervention program for participating students with deficits in both working memory and reading skill development.
Working memory is a person's ability to hold and use both new, temporary information and stored information. For example, working memory assists a person to work on the answer to a question while holding the question in short term memory. More specifically in reading, working memory would assist a student attempting to read the unknown word 'dog'. Depending on the student's reading strategy in this instance, it might assist the student to recall the sound of each letter (e.g. d/ o/ g/), in order to ultimately blend the sounds to read the word 'dog' or it might hold the word while it retrieves the visually stored memory of the word. Working memory is extremely important not just in learning but in many aspects of daily life.
By participating in this project, you may have opportunity to:

- extend your professional knowledge of working memory;
- receive training and gain experience in the delivery of a cognitive working memory training program (Activate);
- extend your skill and expertise in the delivery of the literacy intervention program, (MacqLit);
- contribute to ongoing research and development of theoretical understanding in the area of working memory neuroplasticity and training effects.

Who is undertaking the project?

This project is being conducted by Mrs Roselyn Smith as part of her postgraduate research for the award of Doctor of Education through the Australian Catholic University under the supervision of Associate Professor Kenneth Smith.
Roselyn commenced her career in education as a primary school/music teacher however quickly identified a special interest in students with additional learning needs, which led to post graduate studies and over fifteen years of teaching and leadership experience in this field. She is currently the Director of the Learning Support faculty of Christian College Geelong.

Are there any risks associated with participating in this project?

Risks in participating in this project as a learning support staff participant are negligible and comparable to any you would face in your normal practice as a Learning Support practitioner within Christian College Geelong.

All of the testing, teaching, and training time involved in this research will be sourced from standard learning support staff allotments.

You will need to agree to invest some of your own time in completing two, brief electronic questionnaires per intervention group and to being interviewed by the researcher at the conclusion of both MacqLit programs. The survey and the interview questions will focus on the students and not on your practice, and as such will be very similar to any post intervention program reflection and feedback practice currently employed by the learning support faculty.

What will I be asked to do?

You may be asked to complete some of the following tasks:

1. Identify eligible student participants through screening of available data and student records;
2. Test students for research eligibility, seeking permission from parents to screen for working memory deficit if this information is not currently available.
3. Create two groups of students with working memory deficit and below average reading ability.
4. In tandem with the researcher, seek parent approval for the students to participate in the intervention programs that form the basis of this research program. (Ten weeks of working memory training and twenty weeks of daily MacqLit classes.)
5. Supervise the students as they complete a pre and post intervention, online questionnaire concerning their reading engagement and motivation.
6. Supervise the students as they engage in 20 minutes of daily, working memory training over a period of 10 weeks.
7. Instruct two MacqLit groups. One group will commence their MacqLit classes in term 2 and the second group will commence their MacqLit classes in term 3. During term 2 both groups will receive 20 minutes of daily, working memory training. (i.e., In term 2, one group will complete working memory training and MacqLit, and the other group will just complete working memory training.)
8. Test students post the interventions.
9. Liaise with the parents of the students throughout the research period, keeping them informed of progress.
10. Complete an online questionnaire pre and post each MacqLit program, regarding the motivation and engagement of student participants towards their reading.
11. Complete a post MacqLit program interview with the researcher. Questions will focus on the reading behaviors of the student participants.
12. Share instruction records with the researcher.

The data collected as part of this research will be shared and discussed with you as a learning support staff participant, the parents of participating students (and the students as deemed appropriate), and with the student's classroom teacher, on a regular basis throughout the study.

As well as contributing to the purposes of this research study, the data collected throughout the project will be used to guide the progressive educational provision for each student, as would be normal practice within a school engaged in the provision of specific intervention programs.

The use of this data outside of the college, for the purposes of this research, will be completed in a highly confidential and non-identifiable manner. The non-identifiable data will be published as part of this dissertation.

The final publication will be made available to learning support staff participants.

How much time will the project take?

The project will require an investment of core business time by Learning Support coordinators at two junior campuses, in term 1, as they identify, test, and establish the research (MacqLit) groups in preparation for commencement in term 2.

For the learning support staff who will supervise the Activate training, they will need to invest a small amount of core business time in training in the use of this program.

The project will require an investment of core business time by our college speech pathologist if she is required to assist with some of the pre and post testing of working memory and reading skills.

The project will require an investment of core business time by the learning support staff who will assist in the delivery of both MacqLit and Activate supervision.

What are the benefits of the research project?

While the MacqLit program has been proven effective in improving reading skills and Activate similarly proven to be effective in improving working memory, this study is investigating if combining both of these interventions can lead to greater improvements in reading skills in students with working memory deficits.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. The data relating to any person withdrawing from the study will be discarded from the research data collection however will remain within normal Christian College records.

Will anyone else know the results of the project?

The results of this research will be published by Roselyn Smith in her dissertation for the award of a Doctor of Education (Ed.D)
The data collected will be stored on Christian College's Onedrive and backed up on hard drives. The data will be de-identified within the dissertation.

Will I be able to find out the results of the project?

The results of the project will be available from Roselyn Smith.

Who do I contact if I have questions about the project?

Roselyn Smith can be contacted by email (ro.smith@ccg.vic.edu.au) or phone (0418538846), if there are any questions about the project.

What if I have a complaint or any concerns?

The Human Research Ethics Committee at Australian Catholic University (approval number XXXXXX) has approved the study. If you have any complaints or concerns about the conduct of the project, you may write to the Chair of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Chair, Human Research Ethics Committee
c/o Office of the Deputy Vice Chancellor (Research) Australian Catholic University
Melbourne Campus Locked Bag 4115
FITZROY, VIC, 3065.
Ph: 61-3-9953-3157
Fax: 61-3—9953-3315
Email: res.ethics@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

Participation is secured by completing the Consent Form accompanying this letter and returning the form to the Learning Support Coordinator at your Christian College campus. The LS coordinator will forward the form to Roselyn Smith at Middle Campus, Christian College.

Yours sincerely,

Principal Researcher

Student Researcher

Appendix E

Learning Support Staff Participant Consent Form

LEARNING SUPPORT STAFF PARTICIPANT CONSENT FORM

TITLE OF PROJECT: Improving Reading Ability via Computer Based Memory Training and Intensive, Explicit Reading Instruction.

PRINCIPAL RESEARCHER: Associate Professor Kenneth Smith

STUDENT RESEARCHER: Mrs Roselyn Smith

4. I …… *(the Learning Support Staff Participant)* has read and understood the information provided in the Information Letter to Learning Support Staff Participant. Any questions I have asked, have been answered to my satisfaction.

5. I agree to participate in any of the activities outlined below which are pertinent to my role at Christian College Geelong and as required by this research:

    - Identify eligible student participants through screening of available data and student records.
    - Test students for research eligibility, seeking permission from parents to screen for working memory deficit if this information is not currently available.
    - Create two groups of students with working memory deficit and below average reading ability.
    - In tandem with the researcher, seek parent approval for the students to participate in the intervention programs that form the basis of this research program. (Ten weeks of working memory training and twenty weeks of daily MacqLit classes.)
    - Supervise the students as they complete a pre and post intervention, online questionnaire concerning their reading engagement and motivation.
    - Supervise the students as they engage in 20 minutes of daily, working memory training over a period of 10 weeks.
    - Instruct two MacqLit groups. One group will commence their MacqLit classes in term 2 and the second group will commence their MacqLit classes in term 3. During term 2 both groups will receive 20 minutes of daily, working memory training. (i.e., In term 2, one group will complete working memory training and MacqLit, and the other group will just complete working memory training.)
    - Test students post the interventions.
    - Liaise with the parents of the students throughout the research period, keeping them informed of progress.
    - Complete an online questionnaire pre and post each MacqLit program, regarding the motivation and engagement of student participants towards their reading.

- Complete a post MacqLit program interview with the researcher. Questions will focus on the reading behaviours of the student participants.
- Share instruction records with the researcher.

I realise that I can withdraw my consent at any time without adverse consequences and with any data collected to that point, subsequently being withdrawn from the study and from any future private research although the data will remain the property of the college. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify my child in any way.

NAME OF LEARNING SUPPORT STAFF PARTICIPANT: ……

SIGNATURE: …….. DATE: …….....

SIGNATURE OF PRINCIPAL INVESTIGATOR: ……...

DATE: …….

SIGNATURE OF STUDENT RESEARCHER: …….

DATE: …….

Appendix F

Quantitative and Qualitative Data Sources and Data Collection Schedule

Table F.4.1

Data Sources, Purpose and Collection Timetable

Types of Data	***Specific source of information***	***Description***	***Collection Context***	***Timing***
Standardised achievement test: norm referenced	PATR-4th. ed (ACER, 2008)	Standardised test of reading ability.	Delivered online. 40 minutes test time. Teacher administration	Annually in October or February for new students to the school.
Curriculum based measurement.	WARP (Wheldall & Madelaine, 2013)	Three initial assessment texts.	All texts contain 200 words and are read for one minute.	Used to allocate participants to cases.
Standardised achievement test: norm referenced test.	TOWRE 2 (Torgesen, Wagner, & Rashotte, 2012).	Provides an efficient measure of the fluency and accuracy of print-based word and non-word reading.	Sight word and Non-word lists. Administered by Intervention Teacher or Speech Pathologist.	Pre and Post either Simultaneous or Sequential Intervention Format.
Standardised achievement test: norm referenced test.	YARC (Snowling et al., 2009)	Two passages read out loud with questions answered orally. Reading accuracy, rate, and comprehension scores.	Administered by Speech Pathologist.	Pre and Post intervention – Either Simultaneous or Sequential Format
Standardised Test of Auditory perceptual perception skills.	TAPS – 3 (Martin & Brownell, 2005)	Test of how children and teens process what they hear. Includes four sub tests of Auditory Memory which were used to identify WM deficit in this study	Administered by Speech Pathologist	Pre and Post intervention – Either Simultaneous or Sequential Format
National Institutes of Health (NIH) Toolbox Tests Applied by ACTIVATE	Flanker Test	Measures attention and ability to inhibit automatic responses that may interfere with achieving goals (Focused Attention)	Administered by C8Sciences within the ACTIVATE training program.	Pre and Post eight-week training in ACTIVATE Program.
	List Sorting Working Memory Test	Test of Working Memory –Using Visual Input.)		
Electronic questionnaire	Student questionnaire regarding the student's reading self-efficacy.	Open-ended responses to four questions. Two concerning the student's beliefs and values held towards personal reading ability; two concerning the time and effort the student expends in the act of reading.	Student responses scribed by the intervention teacher into an online Microsoft Form.	Pre- and Post- the intervention format taken by each student.
Electronic questionnaire	Parent questionnaire regarding their child's reading self -efficacy.	Open-ended responses to four questions. Two concerning the child's beliefs and values held towards personal reading ability; two concerning the time and effort the student expends in the act of reading.	Completed electronically by a parent of each student participant. Questionnaire link emailed to parents.	Pre- and Post- the intervention format received by their child.
Electronic questionnaire	Classroom teacher questionnaire regarding the reading self-efficacy of each participant in the study.	Open-ended responses to four questions. Two concerning the student's beliefs and values held towards personal reading ability; two concerning the time and effort the student expends in the act of reading.	Completed electronically by the classroom teacher of each participant. Questionnaire link sent by email.	Pre- and Post- the intervention format undertaken by each student.
Interview	Semi Structured Interview	Open-ended questions presented in person to each intervention teacher regarding the reading beliefs and behaviours of the students in each case.	Researcher to interview reading intervention teachers.	At the conclusion of the complete study.
Physical Artefacts	Intervention teacher records of MacqLit classes.	MacqLit session records and reinforced reading records.	MacqLit intervention teacher records.	Compiled during the delivery of MacqLit.
	WARP (Wheldall & Madelaine, 2013)	Progress Test Results	Progress charts created by Intervention Teacher	Pre-, during and post-reading intervention.

Appendix G

Questionnaires

Student Participant Questionnaire.

These are the four questions presented to each student participant via an online form before starting their intervention sequence and on concluding it. The intervention teacher facilitated this process by reading the question and scribing the response into the online form. The teachers were strongly discouraged to seek any further information or clarification from students in this process, nor in any way change the responses given by the student.

Q.1 How would you describe yourself, as a reader?
Q.2 Tell me what you think about reading.
Q.3 Tell me about the time you spend reading every week.
Q.4 When you read, what does that feel like?

Parent of Student Participant Questionnaire.

These are the four questions presented to the parents of each student participant via an online form. Parents were asked to complete one questionnaire prior to their child undertaking the intervention format and again when the child finished their intervention format. Parents entered their responses into the online form.

Q.1 How would you describe your child as a reader?
Q.2 Tell me what you believe they think about reading.
Q.3 Tell me about the time your child spends reading every week.
Q.4 When your child reads, what does that feel like for them?

Classroom Teacher Questionnaire.

These are the four questions presented to the classroom teacher of each student participant. Teachers were asked to complete the questions online before the student undertook the intervention format and once it was concluded. Teachers entered their responses into the online form.

Q.1 How would you describe the student participating in this research program, as a reader?
Q.2 What do you believe this student thinks about reading as an activity?
Q.3 Describe the amount of time you believe this student would spend reading, in an average school week.
Q.4 How effortful is reading for this student when you hear them read?

Appendix H

Interview Questions and Prompts Used in Semi-Structured Interviews with the Intervention Teacher

These are the four questions asked of each intervention teacher about each of the student participants in each of the intervention groups they worked with. The actual prompts used varied according to the responses given initially to each question. Sometimes no prompts were required as the initial response answered the question but other times a prompt was needed to aid the respondent to understand the question, to elicit a longer response, or a little more detail or clarification of an initial response.

Interview Questions and Prompts

Interview Question	Question Prompt
1. Did you notice any change in how the students perceived themselves as readers?	The student's confidence level? The student's perception of their ability as a reader?
2. Did you notice any change in the student's attitude to reading?	The student's level of interest in reading? The level of importance the student placed on the skill or practice of reading?
3. Did you notice any change in the time spent in reading by the students?	Did you notice any change in the student's engagement with reading during lessons? Were you aware of any change in their reading engagement via the reinforced reading aspect of MacqLit intervention?
4. Did you notice any change in the reading behaviours of students?	Did you notice any change in the student's ability to commence or engage in reading? Which aspects of their reading demonstrated change? Decoding / Expression / Comprehension / Effort / Fluency / Rate?

Appendix I

Second Cycle Codes and Descriptors Applied in Qualitative Data Analysis

Table I.4.1

Second Cycle Coding: Codes and Descriptors

SIGHT WORD EFFICACY	PHONEMIC DECODING EFFICACY	SELF EFFICACY INDICATORS
Skill Acquisition	**Skill Acquisition**	**Task Persistence -Time spent reading**
Dependent	*Dependent*	*Minimal (Avoidance)*
Semi-Dependent	*Semi-Dependent*	*Required (Compliance)*
Automatic	*Automatic*	*Additional (Voluntary)*
Skill Application	**Skill Application**	**Task Effort – Effort required to read**
Dependent	*Dependent*	*Directed, significant effort*
Semi-Dependent	*Semi-Dependent*	*Directed and effortful*
Automatic	*Automatic*	*Voluntary and effortful*
		Voluntary and independent
		Task Confidence –Belief in reading ability
		Extremely low confidence and dependence
		Low confidence and dependence
		Confident, emerging ability
		Confident, independent ability
		Task Choice – Value of task to participant
		Does not value
		Knowledge of the value
		Experience the value
		Highly values

Appendix J

Elaboration Relating to the Withdrawal of a Student from Case B Seq

The Case B Seq participant withdrawn early from the study was participating in a single intervention at the time of withdrawal. They were undertaking ACTIVATE training. The parents withdrew the participant citing the student's lack of interest in attending classes. The intervention teacher noted the participant had been making good progress during the ACTIVATE sessions and enjoyed their perceived progress despite the challenge the training presented. The intervention teacher was also aware this participant had continued to dislike being taken out of their classroom to attend training despite a range of motivational and structural strategies being employed.

Across all cases there were several participants expressing the same feelings in the first week. For the majority this dissipated as the students progressed and became more engaged in their intervention format.

Appendix K

Word Reading Ability and Memory Instruments Pre-Post Percentiles by Case

Table K.5.1

Demographics and Word Reading Ability and Memory Instruments' Pre-Post Percentiles for Case Simultaneous A Participants

Participant	Case / Intervention	Gender / Age	TOWRE Sight Word Efficiency		TOWRE Phonemic Decoding Efficiency		YARC Reading Accuracy		ACTIVATE WM-VI		TAPS Number Memory Forwards		TAPS Number Memory Backwards		ACTIVATE Focused Attention	
			Pre	Pos	Pre	Pos	Pre	Pos	Pre	Pos	Pre	Post	Pre	Pos	Pre	Pos
1	Case A Simultaneous	Male 10	1	1	2	5	3	3	46	46	1	1	5	16	31	69
2	Case A Simultaneous	Male 9	27	10	18	23	13	16	23	31	9	5	5	9	94	91
3	Case A Simultaneous	Male 9	1	1	14	6	5	4	90	64	16	16	25	75	89	68

Table K.5.2

Demographics and Word Reading Ability and Memory Instruments' Pre-Post Percentiles for Case Simultaneous B Participants

Participant	Case / Intervention	Gender / Age	TOWRE Sight Word Efficiency		TOWRE Phonemic Decoding Efficiency		YARC Reading Accuracy		ACTIVATE WM-VI		TAPS Number Memory Forwards		TAPS Number Memory Backwards		ACTIVATE Focused Attention	
			Pre	Pos	Pre	Pos	Pre	Pos	Pre	Pos	Pre	Post	Pre	Pos	Pre	Pos
10	Case B Simultaneous	Male 9	4	6	16	16	10	8	71	43	16	5	2	16	73	89
11	Case B Simultaneous	Female 10	1	1	6	5	9	4	19	31	2	25	16	9	92	86
12	Case B Simultaneous	Female 8	19	14	10	21	13	30	74	74	16	25	50	16	75	88
13	Case B Simultaneous	Female 9	5	3	7	9	18	25	43	32	9	9	25	25	83	46

Table K.5.3

Demographics and Word Reading Ability and Memory Instruments' Pre-Post Percentiles for Case Sequential A Participants

Participant	Case / Intervention	Gender / Age	TOWRE Sight Word Efficiency		TOWRE Phonemic Decoding Efficiency		YARC Reading Accuracy		ACTIVATE WM-VI		TAPS Number Memory Forwards		TAPS Number Memory Backwards		ACTIVATE Focused Attention	
			Pre	Pos	Pre	Pos	Pre	Pos	Pre	Pos	Pre	Post	Pre	Pos	Pre	Pos
4	Case A Sequential	Male 9	30	9	30	19	53	47	8	66	9	16	5	16	27	41
5	Case A Sequential	Male 9	9	4	14	5	8	7	29	56	2	2	16	1	39	29
6	Case A Sequential	Male 10	14	1	5	9	4	2	31	15	1	5	16	16	53	34
7	Case A Sequential	Male 9	35	53	27	39	16	23	40	72	16	37	25	37	39	70

Table K5.4

Demographics and Word Reading Ability and Memory Instruments' Pre-Post Percentiles for Case Sequential B Participants

Participant	Case / Intervention	Gender / Age	TOWRE Sight Word Efficiency		TOWRE Phonemic Decoding Efficiency		YARC Reading Accuracy		ACTIVATE WM-VI		TAPS Number Memory Forwards		TAPS Number Memory Backwards		ACTIVATE Focused Attention	
			Pre	Pos	Pre	Pos	Pre	Pos	Pre	Pos	Pre	Post	Pre	Pos	Pre	Pos
14	Case B Sequential	Male 10	1	2	5	10	3	4	63	8	9	37	16	37	91	88
15	Case B Sequential	Female 8	5	6	14	18	13	21	43	81	16	25	25	9	55	74

Appendix L

Second Level Coding of Participant Qualitative Data by Intervention Format

Table L.5.1

Qualitative Second Level Codes – Case A and B Simultaneous Participants

Participant	Case Intervention	Gender Age	Sight Word Efficiency (SWE)		Phonemic Decoding Efficiecy (PDE)		Self Efficacy as a Reader		Activate Executive Function Test Report Working Memory - Visual Input (WM-VI) Focused Attention (FA)	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	A/Sim	M/10	Dependent Acquisition Dependent Application	Dependent Acquisition Dependent Application	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Minimal Effort: Directed, significant effort Belief: Low confidence and dependence Value: Does not value	Time: Minimal Effort:Directed, significant effort Belief: Low confidence and dependence Value: Does not value	Sufficient VWM-VI Moderate FA	Very little change VWM-VI Valuable gains FA
2	A/Sim	M/9	Dependent Acquisition Semi-Dependent Application	Dependent Acquisition Semi-Dependent Application	Semi-Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Minimal Effort: Directed and effortful Belief: Low confidence and dependence Value: Knowledge of the value	Time: Required Effort: Directed and effortful Belief: Confident, emerging ability Value: Experiences the value	Below average VWM-VI Exceptionally strong FA	Valuable gains VWM-VI Very little change FA
3	A/Sim	M/9	Dependent Acquisition Dependent Application	Dependent Acquisition Semi-Dependent Application	Semi-Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Required Effort: Directed, significant effort Belief: Extremely low confidence and dependence Value: Knowledge of the value	Time: Required Effort: Directed and effortful Belief: Low confidence and dependence Value: -Knowledge of the value	Above average VWM-VI Strong FA	Decline VWM-VI Decline FA
8	B/Sim	M/9	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Minimal Effort: Directed, significant effort Belief:Low confidence and dependence Value: Experiences the value	Time: Required Effort: Directed and effortful Belief: Confident, emerging ability Value: Highly values	Sufficient VWM-VI Moderate FA	Decline VWM-VI Valuable gains FA
9	B/Sim	F/10	Dependent Acquisition Dependent Application	Dependent Acquisition Semi-Dependent Application	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Required Effort: Directed and effortful Belief: Extremely low confidence and dependence Value: Knowledge of the value	Time: Additional Effort: Directed and effortful Belief: Low confidence and dependency Value: Experiences the value	Below Average VWM-VI Strong FA	Valuable gains VWM-VI Very little change FA
10	B/Sim	F/8	Dependent Acquision Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Required Effort: Directed and effortful Belief: :Low confidence and dependence Value: Experiences the value	Time: Additional Effort:Voluntary and effortful Belief: Confident, emerging ability Value: Highly values	Sufficient VWM-VI Moderate FA	Valuable gains VWM-VI Valuable gains FA
11	B/Sim	F/9	Dependent Acquision Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Dependent Application	Time: Minimal Effort:Directed, significant effort Belief:Low confidence and dependence Value: Knowledge of the value	Time:Required Effort: Directed and effortful Belief: Low confidence and dependence Value: Knowledge of the value	Sufficient VWM-VI Strong FA	Very little change VWM-VI Decline FA

Table L.5.2

Qualitative Second Level Codes – Case A and B Sequential Participants

Participant	Case Intervention	Gender Age	Sight Word Efficiency (SWE)		Phonemic Decoding Efficiecy (PDE)		Self Efficacy as a Reader		Activate Executive Function Test Report Working Memory - Visual Input (WM-VI) Focused Attention (FA)	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post
4	A/Seq	M/9	Dependent Acquisition Dependent Application	Dependent Acquisition Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Time: Required Effort: Directed and effortful Belie: Low confidence and dependence Value: Knowledge of the value	Time: Additional Effort: Voluntary and effortful Belief: Confident, emerging ability Value: Experiences the value	Sufficient VWM-VI Moderate FA	Valuable gains WM-VI Valuable gains FA
5	A/Seq	M/9	Dependent Acquision Dependent Application	Dependent Acquision Dependent Application	Semi-Dependent Acquision Dependent Application	Semi-Dependent Acquision Semi-Dependent Application	Time: Minimal Effort: Directed and effortful Belief:Low confidence and dependence Value: Experiences the value	Time: Minimal Effort: Directed and effortful Belief: Low confidence and dependence Value: Experiences the value	Sufficient VWM-VI Moderate FA	Valuable gains VWM-VI Decline FA
6	A/Seq	M/10	Dependent Acquision Dependent Application	Dependent Acquisition Semi-Dependent Application	Dependent Acquision Dependent Application	Semi-Dependent Acquision Semi-Dependent Application	Time: Minimal Effort: Directed and effortful Belief: Low confidence and dependence Value: Knowledge of the value	Time: Required Effort: Directed and effortful Belief: Confident, emerging ability Value: Experiences the value	Below Average VWM-VI Moderate FA	Decline VWM-VI Decline FA
7	A/Seq	M/9	Dependent Acquision Dependent Application	Dependent Acquision Semi-Dependent Application	Dependent Acquision Dependent Application	Semi-Dependent Acquision Semi-Dependent Application	Time: Required Effort:Directed and effortful Belief: Low confidence and dependence Value: Knowledge of the value	Time: Additional Effort: Voluntary and independent Belief: Confident, independent ability Value: Highly values	Sufficient VWM-VI Moderate FA	Valuable gains VWM-VI Valuable gains FA
12	B/Seq	M/10	Dependent Acquision Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Dependent Acquision Dependent Application	Semi-Dependent Acquision Semi-Dependent Application	Time: Minimal Effort: Directed, significant effort Belief: Extremely low confidence and dependence Value: Knowledge of the value	Time: Additional Effort: Voluntary and effortful Belief: Confident, independent ability Value: Highly values	Sufficient VWM-VI Strong FA	Decline VWM-VI Very little change FA
13	B/Seq	F/8	Dependent Acquision Dependent Application	Semi-Dependent Acquisition Semi-Dependent Application	Dependent Acquision Dependent Application	Semi-Dependent Acquision Semi-Dependent Application	Time: Required Effort: Directed, significant effort Belief:Low confidence and dependence Value: Knowledge of the value	Time: Additional Effort: Directed and effortful Belief: Confident, independent ability Value: Highly values	Sufficient VWM-Vi Moderate FA	Valuable gains VWM-VI Valuable gains FA

Appendix M

Participant Quotations Relating to Word Reading Abilities, Working Memory Abilities and Reader Self Efficacy – Displayed According to Qualitative Data Analysis Coding

Table M.5.1

Simultaneous Case Participant Quotations Relating to Sight Word Efficiency (SWE)

SIGHT WORD EFFICACY (SWE)
Simultaneous

Skill Acquisition		
Dependent	***Semi-Dependent***	***Automatic***
Don't know word. Refuse to read-Pre	Reads most words correctly-Post	
Struggles to remember words-Pre	Increased sight words-Post	
Adds words to text-Pre		

Skill Application		
Dependent	***Semi-Dependent***	***Automatic***
No self-correction-Pre and Post	Slow. Focused on correct naming-Pre	
Unknown words make disjointed reading-Pre	Appeals for help lessened- Post	
	Rushes. Makes errors. Discouraged - Pre and Post	
	Still fluency issues even with known words-Post	
	Improved word recognition. Notices more. Perhaps due to Activate? (Intervention teacher question)-Post	
	Improved fluency and accuracy-Post	
	Too many words overwhelm-Post	

Table M.5.2

Sequential Case Participant Quotations Relating to Sight Word Efficiency (SWE)

SIGHT WORD EFFICACY (SWE)
Sequential

Skill Acquisition		
Dependent	***Semi-Dependent***	***Automatic***
Limited sight word range- Pre/Post Struggles to remember words- Visual Memory is weak - Post	Limited understanding of unfamiliar vocabulary - Post	
Skill Application		
Dependent	***Semi-Dependent***	***Automatic***
Difficult to read unknown words - Post	Fluency improved - Post Slow but improving - Post Still slow but fluent - Post	

Table M.5.3

Simultaneous Case Participant Quotations Relating to Phonemic Decoding Efficiency (PDE)

PHONEMIC DECODING EFFICACY (PDE)
Simultaneous

Skill Acquisition		
Dependent	***Semi-Dependent***	***Automatic***
Lacks strategies, needs support-Pre Lacked strategies. Read using visual cues-Pre		
Skill Application		
Dependent	***Semi-Dependent***	***Automatic***
Difficult words hard to sound out - Pre	Fluency issue -Pre / Fluency improved but still hard work -Post	
Decode in isolation-not in reading - Pre	Can self-correct a bit more independent-Post	
Refusal if word unknown - Pre	Good decoding skills - Pre Excellent but hard work - Post	
Not decoding well - Pre	Tries a few /range of strategies but not while reading - Post Accuracy improved but rate didn't change - Post Picking things up better - Post Lacks independence in use of strategies -Post Gained confidence/more patient to decode - Post	

Table M.5.4

Sequential Case Participant Quotations Relating to Phonemic Decoding Efficiency (PDE)

PHONEMIC DECODING EFFICACY (PDE)
Sequential

Skill Acquisition		
Dependent	***Semi-Dependent***	***Automatic***
Single word: robotic - Pre Struggles with new vocabulary - Post	Learned strategies but did not apply them in reading -Post	

Skill Application		
Dependent	***Semi-Dependent***	***Automatic***
Reduced reading performance due to stress - Pre Some decoding concerns- identifying syllables - Pre	Excellent phonemic skills. Sounds out words when encouraged - Pre Better able to decode new words, identify syllables - Post Started to read in phrases, not word by word - Post Decode most words - Post Applied new strategies - Post Saw less mispronunciations in tests - Post Able to slowly work out words - Post More persistent. Prepared to continue without mumbling about it - Post	

Table M.5.5

Simultaneous Case Participant Quotations Relating to Reader Self Efficacy (RSE)

READER SELF EFFICACY

Simultaneous

Task Persistence - Time spent in reading

Minimal (Avoidance)	*Required (Compliance)*	*Additional (Voluntary)*	
Avoids and reads very little - PRE	Compliant reader - PRE	Enjoys reading own choice -less effort, and concentration - POST	
PREfers short paragraphs -PRE	Reluctant reader - PRE		
Overt/Passive avoidance tactics - PRE	Flipped behaviour/Behavioural issues lessened - POST		

Task Effort - Effort required to read

Directed, significant effort	*Directed and effortful*	*Voluntary and effortful*	*Voluntary and independent*
Complicated,hard, difficult, effortful - PRE	Tries new skills - POST	Trouble reading out loud - POST	
Really struggles; Hard work; Not enjoyable - PRE	Slow and steady progress - POST		
Concentration fails/Severe issue - PRE	Has to concentrate very hard - POST		
	Improved a lot in recent months - POST		
	Less effort but still developing fluency - POST		

Task Confidence - Belief in reading ability

Extremely low confidence and dependence	*Low confidence and dependence*	*Confident, emerging ability*	*Confident, independent ability*
False: fragile/cocky confidence - PRE	Struggles with confidence - PRE	Stand out change in confidence. Thrived on success in ACTIVATE - POST	
Dislikes to read out loud. Compares to others - PRE	Makes anxious - PRE	Happy to try - POST	
Hard. I struggle - POST	Self conscious of low skills/Compares self to others/ Discouraged and frustrated when comparing to others - PRE	Motivated to improve - POST	
	Sees self as a normal reader now - POST	Some measurable improvement but not sufficient to be self motivating - POST	
	Volunteers to read out loud now - POST	Noticed a huge change. Approaches with greater confidence. - whole demour changed. Bright, happy, chatty - POST	
	Slight change in confidence - POST	More confident after ACTIVATE-POST	
		Not confident reader but more confident in approach to reading - POST	
		Keen to read to teacher and peers - POST	

Task Choice - Value of reading held by participant

Does not value	*Knowledge of the value*	*Experiences the value*	*Highly values*
Reluctant reader; saw no value in reading or school as he says he wants to leave early to be a chef like Manu. A real barrier - PRE	Enjoys the concept of reading - PRE	Feels like I am inside the book - PRE	Enjoys reading own choice - POST
	Good for the brain - PRE	Reading is learning but starting to enjoy more - POST	
	Reading is a chore but likes stories if read to - PRE	Very entertaining, especially if you like the book - POST	
	Can make you feel relaxed and calm - PRE		
	Reading is good as you learn new words -POST		

Table M.5.6

Sequential Case Participant Quotations Relating to Reader Self Efficacy (RSE)

READER SELF EFFICACY

Sequemtial

Task Persistence - Time spent in reading

Minimal (Avoidance)	*Required (Compliance)*	*Additional (Voluntary)*	
Avoids at school-PRE	Mum asks me to read every night but my dad's I don't have to-POST	Reads every night. Geat support from the home-POST	
Hardly reads at home. Reading diary not completed-POST		Normally at night for 20 mins (read) but if my dad is not home, about 40 mins because mum is putting my sister to bed and she doesn't come in and tell me to stop (Post)	

Task Effort - Effort required to read

Directed, significant effort	*Directed and effortful*	*Voluntary and effortful*	*Voluntary and independent*
Tries hard but just can't do it-PRE	Struggles concentrate reading, distracted-needs silence-PRE	Practised skills. Improved performance-POST	
Tolerates but doesn't want to-PRE	Drop in focus towards the end. Anxious about a change in school. Affected his assessments-POST	Fun. Enjoyable. Interest picked up-POST	
Compliant but not engaged-PRE	Not as worried about reading to the teacher-POST	Doesn't avoid reading in class-POST	
Forgets strategies and doesn't use unless directed-PRE	More fluent but still misreads a bit-POST	Finding it easier but does fatigue. This was noticeable on his final WARP assessment - POST	
		Finding it easier. Using phonic attack.Eager to read - POST	

Task Confidence - Belief in reading ability

Extremely low confidence and dependence	*Low confidence and dependence*	*Confident, emerging ability*	*Confident, independent ability*
Doesn't believe they are a strong reader-PRE	Low confidence makes them feel they are not 'smart'-PRE	I can read quickly now. I couldn't before-POST	Change in how they perceieved self as a reader. Noticed they had improved. Knew they sounded good when they read out loud-POST
Doesn't feel good about self-PRE	Enjoy if don't make mistakes reading out loud. Self conscious-PRE	Not as frustrated by making mistakes. Used to get mad but now I just go over it again. Frustration levels definitely decreased-POST	Change attitude reading -self belief grown-POST
Shy and timid. No read to class-PRE	Aware of difficulties but wanted to improve-PRE	Good reader. I practise with mum - POST	Self belief has grown enormously. I didn't like it because I wasn't good at it. Now I love it because I am good at it. I feel calm-POST
		Frustration levels definitely decreased-POST	
	Nervous and worried. Doesn't enjoy. Does enjoy when they read well-PRE	I enjoy it. I used to not enjoy it at all. I read a lot more now and I get a lot more used to it. Fun and Hard. When I read it feels like I am learning stuff. I feel better for myself because I know I'm gonna get better at this. I don't get as frustrated. When I make a mistake, I used to get mad but now I just go back over it and get it. - POST	ACTIVATE progress was self motivating. Post They compared their results to others-POST

Task Choice - Value of reading held by participant

Does not value	*Knowledge of the value*	*Experiences the value*	*Highly values*
	Not sure what reading feels like- says right things- "helps learn"-PRE	Says it feel good to read. Nice. Quiet. Gives information. Reading is great. -PRE	Read Roald Dahl books. He is a nice writer and he makes books interesting. - POST
	Reading good for your future. Helps you learn things. Helps with writing-PRE	It takes you on an imaginary adventure. I feel I'm in a different world and a different place. I feel brave. I feel PREtty normal-POST	I enjoy it. I used to not enjoy it at all. When I read I feel like I am learning stuff. I feel better for myself because I know I am gonna get better at this-POST
	Loves hearing stories or reading with parent-PRE	Feels good about reading but knows lower than others-POST	It is exciting. I really enjoy it. It makes me feel like I can be part of the next generation. It makes me feel like everyone else. Everyone was better than me and now I can read the same. I still have work to do but I have done a lot of catching up-POST
		Weird- reading words but a story going on in my head-POST Improved skills but doesn't enjoy reading-POST	