Coventry University

MASTER OF SCIENCE BY RESEARCH

An exploratory study into the effects of development movement exercises on primary school children's academic performance

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Award date:
2012

Awarding institution:
Coventry University

An exploratory study into the effects of development movement exercises on primary school children's academic performance

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A thesis submitted in partial fulfilment of the University’s requirement for the Degree of Master of Research

2012

Coventry University in collaboration with
Coventry City Council

The work described has already been published elsewhere:

Curley, E., Duncan, M. J., and Birch, S. (2011) *The efficacy of a movement intervention on primary school children's reading and mathematical performance* [Poster] The British Association of Sport and Exercise Science Conference. Colchester: University of Essex, 7 September 2011

Curley, E., Duncan, M. J., Birch, S. (In Press) The Efficacy of Exercise in Enhancing Children's Reading Ability. In: Duncan, M. and Birch, S. (Eds.) *Reviews in Pediatric Exercise Science*. New York: Nova Science Publishers

Acknowledgements

The author would like to thank the children and staff that participated in the study. The author would also like to give a special thank you to Mike Duncan, for his continued support throughout the research project, and of course the long suffering patience of friends and family.

The study was funded by Coventry City Council.

Contents	**Page**

Abstract 8

Chapter 1: Introduction 10

1.1 Physical activity and its associated benefits 11

1.2 Animal studies: exercise induced changes in the brain 13

1.3 Human studies: physical activity and young person's academic performance 16

1.4 The impact of exercise on cognitive functioning 19

1.4.1 Using neuroimaging techniques to investigate the impact of exercise on cognitive functioning 21

1.5 The impact of movement based interventions on academic performance 23

1.5.1 Movement interventions based on the replication of primitive reflexes 24

1.5.2 The 'Fit to Read' intervention 28

1.6 The impact of population characteristics and backgrounds on academic performance 32

1.6.1 The influence of weight status 32

1.6.2 The influence of socioeconomic status 35

1.6.3 The influence of ethnicity and learning English as an Additional Language (EAL) 38

Delimitations 44

Aims, objectives and hypothesis 45

Chapter 2: Methods 46

2.1 Participants 46

2.2 Procedure 46

2.3 Measures 47

2.3.1 Anthropometry 47

2.3.2 Habitual physical activity levels 47

2.3.3 Reading comprehension 48

2.3.4 Mathematical ability 49

2.3.5 Scoring the reading and mathematical tests 49

2.4 The Intervention 50

2.4.1 Delivery 50

2.5 Statistical analysis 51

Chapter 3: Results 52

3.1 Group (experimental/control) differences in reading age 52

3.1.1 Group (experimental/control) differences in reading age 54

3.1.2 Gender and reading age, study two 55

3.2 Group (experimental/control) differences in standardised reading scores 57

3.3 Group (experimental/control) differences in mathematical performance 59

3.4 Results summary 66

Chapter 4: Discussion 68

4.1 The impact of the movement intervention on reading performance 68

4.2 The impact of the movement intervention on mathematical performance 70

4.3 Contrasting the present findings with prior movement interventions 71

4.4 Detrimental effects of study participation on reading performance 76

4.4.1 The influence of learning English as an Additional Language 76

4.4.2 Socioeconomic status 77

4.4.3 The influence of motivation 80

4.4.4 The influence of self-handicapping 81

4.4.5 Expectancy research 82

4.5 Interpreting the gender differences observed in reading performance 83

4.6 Interpreting the gender differences observed in mathematical performance 86

4.7 Conclusion 91

4.8 Study limitations and suggestions for future work 94

References 97

Figures

1 ERP waveforms across session and task congruency 22

2 Standardised academic baseline scores 52

3 Absolute mean reading age, baseline (TP1) to 2 weeks post-intervention (TP3) 53

4 Mean reading age, baseline (TP1) to 2 weeks post-intervention (TP3) 53

5 Reading age (absolute means), TP4 to TP6 54

6 Gender effect on reading age (absolute means), TP4 to TP6 55

7 Gender effect on reading age, TP4 to TP6 55

8 Differences in absolute mean standardised reading scores, baseline (TP1) to 2 weeks post-intervention (TP3) 57

9 Mean standardised reading scores, baseline (TP1) to 2 weeks post-intervention (TP3) 58

10 Mean standardised reading scores, TP4 to TP6 58

11 Experimental group’s absolute mean standardised mathematical scores 59

12 Control group's absolute standardised mathematical scores 59

13 Experimental group’s standardised mathematical scores 60

14 Control group’s standardised mathematical scores 60

15 Experimental group's absolute standardised mathematical scores TP4-TP6 62

16 Control group's absolute standardised mathematical scores TP4-TP6 62

17 Experimental group’s standardised mathematical scores 64

18 Control group's standardised mathematical scores 64

Tables

1 Descriptive statistics for reading age (months) assessed at TP4 to TP6 56

2 Descriptive statistics for standardised mathematical scores assessed at baseline (TP1) to two weeks post-intervention (TP3) 61

3 Descriptive statistics for standardised mathematical scores assessed at 63

4 Association between mathematical standardised scores and HPA (average step count) 65

Appendices

The ‘Fit to Read’ programme

Exercise aimed to improve co-ordination, concentration and balance

Appendix 1: First cycle 132

Appendix 2: Second cycle 133

Appendix 3: Third cycle 134

Exercises aimed to inhibit retained reflexes

Appendix 4: First cycle 135

Appendix 5: Second cycle 138

Appendix 6: Third cycle 141

Abstract

Previous research has hypothesised that through the repetition of developmental movements cognitive and academic performance may be improved. However, the research on this topic is equivocal and further scrutiny of the role that movement training may play in academic achievement is warranted. Therefore, the purpose of this quasi-experimental, controlled, cross-over design study was to evaluate the efficacy of a school based movement intervention called 'Fit to Read' on improving the reading and mathematical performance of Year three primary school children (*n* = 31).

The study was conducted in two parts. Study one relates to results collected pre study cross-over, and study two relates to results collected post cross-over. For study one, children were randomly allocated to an experimental group (*n* = 15) to participate in a nine week, school based movement intervention (five days/week, 20mins per day), or a control group (*n* = 16) in order to continue with their daily routine. The 'Fit to Read' programme required participants to replicate developmental movement patterns usually observed in the first year of an infant's life. The 'Fit to Read' programme consisted of three, three-week cycles. The first cycle targeted the tonic labyrinthine reflex, the second cycle targeted the asymmetrical tonic reflex, and the third targeted the symmetrical tonic neck reflex.

The reading and mathematical ability of all children (*n* = 31) was measured by means of a standardised group administered reading comprehension test (*The Group Reading Test II, 6-14*, NFER, Nelson, 2005) and a standardised mathematical test (*Progress in Maths,* NFER, Nelson, 2004), prior to the onset of the intervention, post-intervention and two weeks post-intervention. BMI was calculated for all participants (*n* = 31) along with habitual physical activity (HPA) via piezoelectric pedometers and included as covariates, given reports of their potential influence on academic and cognitive performance.

For study one, a main effect for time was found in relation to standardised reading scores, with deterioration exhibited in both the control and experimental groups' performance. The mean standardised reading scores measured post-intervention were significantly lower than

baseline scores. In terms of mathematical achievement, a significant time by gender by group interaction, and significant gender by group interaction was reported. Participation in the 'Fit to Read' programme appeared to be detrimental to the boys' (n = 8) mathematical progress, whilst moderate improvements were reported for the girls (n =7).

For study two, statistical analysis showed that participation in either the control (n = 15) or the experimental (n = 16) group did not differ significantly in terms of their impact on standardised reading scores. However, a significant main effect for gender was found for reading age, with the girls reported to exhibit gains six times greater than the boys. By two weeks post-intervention, these gains were not sustained as declines in reading age were reported for both the boys and girls. A significant main effect was found for both the boys' and girls' control group, yet the girl controls exhibited a more notable overall increase of approximately nine months in reading age. For study two, significant mathematical improvements were confined to the girls in the control group, with scores collected at two weeks post-intervention significantly higher than the preceding two assessments.

The findings show that the developmental movement intervention was not effective in improving reading and mathematical performance. Explanations for these results are presented, including a reflection of student disengagement, negative self-fulfilling prophecy and self-handicapping behaviours, taking into account the ethnically diverse and low socioeconomic status of the population under study.

Chapter 1

Introduction

Primitive reflexes are automatic stereotyped movements controlled by the brain stem and unrestrained by cortical influence (Bobath, 1985 and Goddard Blythe, 2005). Initially they aid a newborn's survival; however, reflexes which persist beyond 12 months are indicative of neurological dysfunction and believed to be the source of certain learning difficulties (Goddard Blythe, 2005). The inhibition of persistent primitive reflexes form the primary focus of movement interventions aimed at remediating the problems associated with retained reflexes (including poor motor and cognitive development). The Primary Movement programme and the INPP programme both administer exercises based upon the replication of primitive reflexes (Goddard Blythe, 2005, Goddard Blythe, 2006, Jordan-Black, 2005 and McPhillips, Hepper and Mulhern, 2000). Reflexes are naturally inhibited by the movement patterns usually performed during the first months of life (Goddard, 2005). However, parents with busy working lives may over rely on baby seats, for instance, subsequently reducing valuable time for the baby to lie stomach down on the floor and increase head control, a crucial requirement for the successful development of all later functions (Goddard, 2005). Given the developing brain's plasticity, reflex inhibition interventions aim to give the brain another opportunity to experience movement patterns missed during early development and thus establish new neural connections (Goddard, 2005). Hence, it is claimed that the rehearsal of certain movements omitted during development will inhibit abnormal reflex activity and correct many of the associated physical, emotional and academic problems. Few studies have examined the effectiveness of these reflex inhibition interventions. Therefore, as the aforementioned reflex interventions are exercise based, the present study broadened its literature review to incorporate studies which have investigated the effects physical activity on school children's academic attainment and cognitive functioning. The inclusion of neurological research provides further insight into the effects of physical activity on brain function. Furthermore, the impact of the present intervention and previous work cannot be judged without considering the potential effects which different population characteristics and backgrounds may have on study results. The influence of weight status, ethnicity and socio-economic status, which are all reportedly linked to academic achievement, will therefore be included for review.

Review of the literature

1.1 Physical activity and its associated benefits

Evidence to support the positive health benefits of physical activity (PA) abounds (Warburton, Nicol and Bredin, 2006), including increased cardiorespiratory fitness and muscular strength, reduced body fatness and reduced symptoms of depression and anxiety (World Health Organisation, 2010). Research demonstrates a dose-response relationship, in that as PA increases so do the associated health gains (Janssen and LeBlanc, 2010). Physical inactivity on the other hand increases a person's risk of suffering non-communicable diseases, such as cardiovascular disease, diabetes and cancer (World Health Organisation, 2010). In view of these risks, children's PA levels give reason for concern, as only 32% of boys and 24% of girls in England were reported to have achieved recommended guidelines in 2008 (The NHS Information Centre, 2010). Unfortunately given the self-reported nature of this data, young people's inactivity levels may be somewhat higher than testified (Basterfield *et al.,* 2008).

To date, the main objectives driving government plans to increase PA levels, appear to have been focused around reducing individual health costs of inactivity and the economic burden to society and the National Health Service (Department of Health, 2009). It seems that academic gains are a less prominent motivating factor behind the promotion of PA, yet both animal (Cotman and Berchtold, 2002, Cotman, Berchtold and Christie, 2007) and human studies (e.g. Davis *et al.,* 2011, Hillman, Erickson and Kramer, 2008 and Travlos, 2010) indicate that exercise can enhance the health of the brain and facilitate learning. Although the effects of PA on school children's academic performance remain unclear (Taras, 2005), studies have found that increased time allotted to PA does not compromise school achievements (Ahamed *et al.*, 2007, Carlson *et al.*, 2008 and Trudeau and Shephard, 2008).

Physical activity is a broad term used to describe any bodily movement produced by skeletal muscle that entails energy expenditure (Caspersen, Powell and Christenson, 1985 and World Health Organisation, 2010). As PA can be classified in a number of ways, certain categories of PA employed throughout literature will now be explained in order to facilitate cross-study comparisons.

Exercise is a structured, repetitive, planned subset of PA (Caspersen, Powell and Christenson, 1985 and World Health Organisation, 2010). Its main objective is to improve or sustain one or more elements of physical fitness (Caspersen, Powell and Christenson, 1985 and World Health Organisation 2010). Physical fitness relates to a number of measurable attributes one possesses or attains, which affects one's ability to partake in PA (Caspersen, Powell and Christenson, 1985). These attributes can be health-related, such as a measure of cardiorespiratory endurance, body composition, muscular strength and endurance, and flexibility, or skill-related, which relates to agility, balance, coordination, speed, power, and reaction time (Caspersen, Powell and Christenson, 1985). School sport refers to structured out of school hours learning, which involves skilful PA and offers the potential to enhance and build upon the skills achieved in PE (Association for Physical Education, 2008). School breaks, also referred to in some studies as recess, are periods of the school day which provides students with a break from teaching and an opportunity for active unstructured or structured free play (should they chose) usually outdoors (Rasberry *et al.*, 2011). Classroom based PA includes interventions designed to create opportunities for increased PA, such as skipping or dance, within the context of the classroom and in addition to scheduled school breaks and PE classes (Ahamed *et al*., 2007 and Rasberry *et al*., 2011).

The majority of articles included for review focus on school-based PA, including physical education (PE), school sports, classroom based PA and free play. Physical education is experienced by all students as part of the school curriculum. It aims to improve physical competency, provide an understanding of the benefits of healthy active lifestyle choices and enhance the enjoyment of being physically active in order to increase the likelihood of pupils continuing to be physically active in their own free time (Association for Physical Education, 2008). In terms of increasing young people's physical activity, it is customary to use school-based interventions (Cale and Harris, 2006) as they have a large captive audience and the infrastructure in place to implement programs which can be incorporated into the regular school curriculum and staff development (Stone *et al.,* 1998).

1.2 Animal studies: exercise induced changes in the brain

Berg (2010) presents a review of empirical findings in relation to the beneficial effects of exercise on brain functioning in an attempt to raise the profile of PE in American schools. His review includes a number of studies to support anatomical and physiological changes in the brain following bouts of exercise. For instance, animal studies have shown that the production of brain-derived neurotrophic factor (BDNF) increases in the hippocampus, as a result of several days of running. BDNF is a neurotrophic factor or protein, proposed to enhance the survival and growth of neurons in the brain, whilst the hippocampus plays a part in spatial memory (Kolb and Whishaw, 2011) and learning (Vayman, Ying and Gomez-Pinilla, 2003). Berg (2010) was encouraged by studies, which have found a link between increased BDNF in rats and their ability to solve mazes quicker, as such findings may benefit cognitive functioning and learning in humans. An investigation into the link between exercise-induced cognitive enhancement and BDNF action, discovered that by blocking BDNF in rats, former exercise-induced improvements in learning was eliminated (Vayman, Ying, and Gomez-Pinilla, 2004). Although a number of studies have demonstrated that synaptic-plasticity changes in the brain are enhanced by exercise, and that BDNF is utilised in exercise to improve learning acquisition and memory retention (Berg, 2010, Vayman, Ying and Gomez-Pinilla, 2004 and Vayman, Ying, and Gomez-Pinilla, 2003), further research is needed to clarify the type, frequency and amount of exercise needed in order for significant benefits to be experienced (Cotman, Berchtold, and Christie, 2007). In addition, a call has been made for animal studies to increase their relevance to humans, since human studies tend to analyse the completion of tasks involving executive function co-ordinated by the forebrain, whilst animal studies usually assess hippocampus-dependent learning (Cotman, Berchtold, and Christie, 2007).

The term executive function describes a range of complex cognitive processes compelled to work together in order to accomplish a desired objective (Davis *et al.*, 2011 and Elliott, 2003). Executive function includes the ability to solve new problems, the flexibility to alter one's behaviour in response to new information and skilful use of strategies (Elliott, 2003). The Stroop colour-word task is one example of a tool used in human studies to assess executive function involving the recruitment of the prefrontal cortex (Adleman *et al.*, 2002 and Buck, Hillman, and Castelli, 2008). During this task subjects are presented with words conveying the name of a colour printed in a contrasting coloured ink (i.e. BLUE printed in red ink) and asked to identify the colour of the ink rather than read the word (Adleman *et al.,* 2002). Response inhibition (i.e. restrain from inappropriate responses of word reading), interference resolution (i.e. overcome cognitive interference by inhibiting the stronger automatic tendency to read the presented word) and selective attention (to the colour), are some of executive control processes assessed using the Stroop colour-word task (Adleman *et al.,* 2002). In contrast, the tasks normally employed by animal studies, such as the Morris water maze, are measures of memory skills involving the hippocampus (van Praag *et al.,* 2005).

Neuroscience underlies much of Berg's (2010) attempts to defend the value of PE. However, the main objectives driving the *PE and Sport Strategy for Young People* (DCSF, 2008a) centres upon achieving healthy active lifestyles, leadership skills, self-confidence, positive behaviour and citizenship. Furthermore, PE aims to develop young people's physical competency, ensuring that the benefits of making healthy active lifestyle choices are understood, enjoyed and therefore, more likely to feature as part of their own free time (Association for Physical Education, 2008).

Berg's (2010) review presents evidence to support the association between exercise and enhanced brain functioning and the opportunity that PE offers in improving academic performance. This reasoning appears to contrast however, with the aims of the national curriculum (QCA, 2007), who present PE as a means of developing young people's competence and interest in PA. This disparity in views underlines the ambiguity often surrounding the purpose and nature of PE (Green, 2008).

One may question whether the potential cognitive gains of PE should be at the forefront of research or whether PE's contribution to young people's health should underpin its inclusion within the school timetable. The views held by academics do not appear to correspond with the views held by the teachers who deliver PE and what is more, this differs still from young people's reported viewpoint on PE (Green, 2008). As the 1980s and 1990s saw a marked shift in the subjects (PE) focus towards health promotion, in particular health-related exercise, Green and Thurston (2002) interviewed 35 PE teachers from 17 UK secondary schools, to discover their views regarding the purpose and nature of PE. Many justified PE as a means for health promotion as there seemed to be an accepted view that young people were less fit nowadays, compared to 20 years ago. The study reported a 'sporting ideology' amongst teachers, with an assumption that sport was 'good for you' and, therefore, the main vehicle for the promotion of health. It is suggested that the importance attached to sport within government policy is restrictive and consequently pushes PE teachers toward the promotion of sport, rather than schools which are healthy and active (Green and Thurston, 2002). The *PE and Sport Strategy for Young People* (DCSF, 2008a) state that it wants to make sure that 'sport becomes a natural part of every young person's life' and continues to be so into adult life. Ironically competitive sports have been identified by young people as one of the barriers to participating in PA, whereas enjoyment was a key motivator (NICE, 2007). Activities, referred to as lifetime activities, which are most likely to be continued into adult life, are those which require minimal equipment and organisation, such as cycling, jogging and tennis (Fairclough, Stratton and Baldwin, 2002). Although PE attempts to promote young people's lifelong interest in being physically active, a questionnaire study reported that PE in 51 UK secondary schools provided only limited opportunities for lifetime activities, as greater importance was given to team games (Fairclough, Stratton and Baldwin, 2002).

Berg (2010) argues that defending the health enhancing benefits of PE to school administrators is inadequate and perhaps too much of an idealistic approach. However, by broadcasting the academic rewards that may be gained from PE, he believes that school administrators are more likely to sit up and listen and offer their support (Berg, 2010). It is evident that for PE teachers, PE is a key factor in promoting health amongst young people, whereas many academics appear to be devoting their attention to the cognitive benefits it may offer. School's pressure to raise standardised test scores (Berg, 2010 & refs) offers one explanation for literature's growing pre-occupation with PA and its links with enhanced learning (e.g. Davis *et al.*, 2011, Hillman, Erickson and Kramer, 2008 and Travlos, 2010), yet the 'persistent and enduring uncertainty surrounding the nature and purpose of PE' (Green, 2008) remains.

1.3 Human studies: physical activity and young person's academic performance

Reports of young people's declining PA levels across many countries, (Dollman, Norton and Norton, 2005), offers a further explanation regarding the increased interest in the role that schools may have upon students' involvement in regular PA (Berg, 2010, Taras, 2005 and Trudeau and Shephard, 2008). Schools provide young people with an opportunity to engage in and understand the importance of regular PA through the provision of PE (Association for Physical Education, 2008).

Taras (2005) concludes from a review of 14 studies exploring the association between PA and academic outcomes, that although PA may improve a pupil's concentration as measured by the d2 Test and Woodcock-Johnson Test of Concentration, to date, literature does not demonstrate a clear association between PA and enhanced academic performance. However, the article reasons that the current lack of evidence should not be viewed as means to justify restrictions to children's PE, rather a reason to conduct further exploration so that the relationship between PA and academic performance may be better understood.

Although an advocate of PE, the studies included for review by Taras (2005) did not focus solely on the association between academic performance and PE, rather studies which examined a range of school-based PA contexts as well as physical fitness. One study examined the influence of increased PA during school breaks on the concentration levels (d2 Test and Woodcock-Johnson Test of Concentration) of second to fourth grade students (ages not disclosed), by comparing 15 minutes of stretching and aerobic walking alongside non-activity (Caterino and Polak, 1999). Aerobic walking and stretching exercises was associated with significantly enhanced levels of concentration for fourth grade students, however, no differences were detected between the activity and non-activity groups for grades two and three. Of the four studies which investigated the impact of self-reported levels of sport involvement on academic performance, two reported a positive association with academic performance (Field, Diego and Sanders, 2001) and homework completion (Harrison and Narayan, 2003), whilst the remaining half reported no association (Fisher, Juszczak and Friedman, 1996 and Sanders *et al.,* 2000). A descriptive study found a small but significant correlation between academic ability and the skills and knowledge gained from a qualification (General Certificate of Secondary Education) in PE (Dexter, 1999). Although the remaining studies which focused upon PE found no association between academic performance and interventions, either aimed at increasing the time allotted to PE (Raviv and Low, 1990, and Shephard, 1996), improving the quality of PE (Sallis *et al*., 1999), or the intensity of PA included in PE (MacMahon and Gross, 1987), no detrimental effects were reported. Physical fitness on the other hand tended to be positively associated with academic ability (Knight and Rizzuto, 1993, and Hye-Young *et al*., 2003).

It is difficult to draw a firm conclusion based on a relatively small number of studies, particularly as Taras (2005) based a proportion of the review on abstract articles rather than complete records. In addition, at least a third of the studies included for review had relied on self-reported measures of PA levels, a method subject to risks of under or over reporting (Watkinson *et al.*, 2010). Half of the studies included small sample sizes and all but two of the studies (MacMahon and Gross, 1987 and Sallis *et al*., 1999) were cross-sectional in design, which prevented examination of how the relationship between PA and school outcomes changed over the course of a student's academic career. A further limitation was the failure of certain studies (Caterino and Polak, 1999, Field, Diego and Sanders, 2001, Fisher, Juszczak and Friedman, 1996) to disclose the mean age of the participants rather the grade. This hindered international comparisons given that the age for school entry varies between countries (Klein, 2011). Some studies (Caterino and Polak, Dexter, 1999, Knight and Rizzuto, 1993) did not collect contextual data such as socioeconomic status and ethnicity which are reported to influence academic achievement (e.g. Akhtar and Niazi, 2011, Bradley and Corwyn, 2002, Gillborn and Mirza, 2000, Kingdon and Cassen, 2010, Liu and Lu, 2008, and Sirin, 2005). The strengths identified related to the longitudinal study designs of two of the studies (MacMahon and Gross, 1987 and Sallis *et al*., 1999), enabling the investigation of causality and the large samples (n = 517 – 50168) recruited by half of the studies included for review.

Trudeau and Shephard's (2008) review of the effects of school PE on academic performance examined the results from seven quasi-experimental and ten cross-sectional studies. The quasi-experimental studies provided data corresponding to the effects of reduced school tuition (by up to four hours in certain cases) in order to accommodate extra time for PE, and in some cases the influence of adding other forms of school based PA in addition to PE classes. For instance one study examined the impact of increasing the PA levels of school children (143 boys, 144 girls, aged 9-11 years) by administering approximately 47 minutes per week of classroom based activities, such as skipping, chair aerobics and hip hop dancing, in addition to scheduled PE classes (Ahamed *et al,* 2007). Although additional PE time did not lead to significant academic improvements, academic results for experimental and control groups were comparative, thus leading the review in question to conclude that learning efficiency was enhanced as a result of increased time allotted to PA (Trudeau and Shephard, 2008).

In contrast, the cross-sectional studies included in Trudeau and Shephard's (2008) review, generally showed a positive association between PA and academic performance, with only two studies (Daley and Ryan, 2000, and Tremblay, Inman, and Willms, 2000) having reported an inverse association with academic attainment. A large Canadian study (*n* = 6923, aged 12 years) reported a weak negative relationship between PA and standardised measures of academic achievement, yet a positive correlation with self-esteem (Tremblay, Inman, and Willms, 2000). PA levels were collected by means of a four itemed questionnaire which asked students how many days in the previous week they participated (in and outside of school) a) in sports which caused them to breath hard, b) walked or cycled for a minimum of 20 minutes, c) did stretching exercises such as touching their toes, knee bending or leg stretching, and d) did strengthening or toning exercises such as push-ups, sit-ups or weight-lifting. The results for the four aforementioned questions were added together and then divided by four to give each student a combined activity score. The failure to differentiate between cardiovascular and strengthening activities prohibited an investigation into how each mode of activity may have differed in its impact on academic performance. An English study of 232 boys and girls aged 13-16 years found no association between the most recent Mathematics and Science examination results and sports-based physical activities derived from the Physical Activity Participation Questionnaire (Daley and Ryan, 2000). However, a weak negative association between the amount of minutes spent in sports-based physical activities and English scores for students aged 13, 14 and 16 years was reported. The self-reported nature and basic overview of students' PA levels, along with the cross-sectional study designs restrict the inferences that can be taken from these studies (Daley and Ryan, 2000 and Tremblay, Inman, and Willms 2000).

The positive relationships between PA and academic performance reported in relation to the remaining cross-sectional studies remained significant, despite confounding variables such as socio-economic status (SES), a significant predictor of both children's PA levels (Borraccino *et al.*, 2009, Drenowatz *et al.*, 2010, and Raudsepp, 2006) and academic achievement (Dollman, Boshoff, and Dodd, 2006, and Walker, Petrill, and Plomin, 2005), having been controlled for in a number of these cross-sectional studies. Furthermore, the positive associations between PA and academic achievement were drawn from large samples of between 5810 and 11957 participants (apart from one study where $n = 921$), increasing the likelihood that the results were derived from representative samples. However, the findings tended to be based on self-reported questionnaires and surveys, including data from a seven day recall questionnaire regarding the number of days involved in PE and school-based sports each week (Nelson and Gordon-Larsen, 2006), or the number of hours spent participating in sport per week (Field, Diego and Sanders, 2001). As well as the frequency, time period and intensity of physical activity during PE, school sport, school breaks, transportation to school (Dwyer *et al.*, 2001) or just in general (Pate *et al.*, 1996), questionnaires were also utilised to obtain details of out of school sport involvement (Sigfúsdóttir, Kristjánsson and Allegrante, 2007) as well as levels of fitness (measured by means of a 1.6 kilometre run, sit-ups, push-ups, 50 metre sprint and standing long jump) (Dwyer *et al.*, 2001). A causal relationship cannot be construed from the cross-sectional data as PA levels may drop or rise at different points in time. Although, a starting point for more in depth future research, the value of certain data may be questioned due to its vague nature. For instance, one study simply asked the participant to recall how many times they had taken part in both hard and light exercise during the past 14 days (Pate *et al.*, 1996). Firstly, questionnaire data is prone to the risk of under or over reporting (Watkinson *et al.*, 2010), a risk which may have been increased by the expectancy to recollect details spanning a two week period. Secondly, as details of activity type were not questioned, judgements regarding which type of PA may positively benefit academic achievement cannot be made.

1.4 The impact of exercise on cognitive functioning

Tomporowski (2003) reviewed 21 studies investigating the effects of acute exercise on the behaviour and cognitive functioning of young persons, the majority of which had clinical disorders. Of the four studies that had examined the acute effects of exercise on children without clinical disorders, significant improvements in mathematics computation was observed in one study following 50 minutes vigorous relay activities rather than 20, 30 or 40 minutes (Gabbard and Barton, 1979). In another, mathematics computation was immediately enhanced significantly after 30 and 40 minutes of paced walking rather than 20 minutes, and enhanced performance was only observed when analysed at midday and in the afternoon, rather than in the morning (McNaughton and Gabbard, 1993). A further study which had sampled second, third and fourth grade children (age was not reported), found that 15 minutes of vigorous aerobic exercise only enhanced fourth-grade children's performance on the Woodcock Johnson Test of Concentration, whereas 15 minutes of stretching exercises had no significant effects on either of the grades (Caterino and Polak, 1999).

The remainder of Tomporowski's (2003) review concentrated on the effects of antecedent exercise on behaviour and cognitive functioning in children with attention-deficit disorders, autism or learning disorders, and behavioural disorders. Disruptive behaviours were less frequent following exercise interventions which differed in duration and intensity. Exercise also facilitated cognitive functioning in adolescents with mild learning disabilities, although the effects were greater for participants with the higher fitness levels (VO_{2max} greater than 45 $ml/kg \cdot min^{-1}$). However, the benefits of exercise in some cases were short lived. For instance, the disruptive behaviours of autistic children were found to reduce after a high intensity 15 minute run, yet effects only lasted for a period of approximately 90 minutes. Similar results were observed in children with severe learning disabilities; reduced rates of inappropriate behaviour were observed immediately after exercise, yet between one and two hours post exercise, there was a regression to increased rates of inappropriate behaviour.

In summary, Tomporowski's (2003) review does provide some evidence that behaviour and cognitive functioning can improve as a result of acute exercise, however, the bulk of the studies leant towards the study of subjects with clinical disorders making it difficult to generalise findings to populations without clinical disorders. Given the diverse types of individual characteristics, cognitive demands and exercise intensities under review, it is impossible to reach a strong conclusion regarding the effectiveness of acute exercise on children's cognitive performance. In addition, results were largely based on small samples of around four participants.

1.4.1 Using neuroimaging techniques to investigate the impact of exercise on cognitive functioning

Research into the neuroelectric changes that may underlie cognitive functioning has been conducted via the recording of the P3 component of event-related potentials (ERPs, see Figure 1) (Hillman *et al.*, 2009). This non-invasive technique maps the brain's electrical activity in response to a specific sensory event (Kolb and Whishaw, 2011). P3 is a positive brain-wave occurring around 300 milliseconds after presentation of a stimulus (Kolb and Whishaw, 2011). Unlike the more apparent measures of cognitive performance, ERPs provide an opportunity to study covert aspects of cognitive processes that take place leading up to, and in response to, a stimulus (Hillman *et al.*, 2009). Based on previous research, Hillman *et al's* (2009) study into the effects of acute moderately-intense aerobic exercise on cognitive control, hypothesised that following a single bout of exercise children would present greater P3 amplitude (thought to indicate improved allocation of attentional resources) as well as shorter P3 latency (thought to indicate a quicker stimulus classification/cognitive processing speed) compared to baseline measures.

Hillman *et al*. (2009) recruited 20 children with an average age of 9.6 years to participate in the within-subject design study. On the first visit, one half of the participants received a 20 minute seated resting session and the remainder received a 20 minute aerobic treadmill session at around 60% of their maximum heart rate. Then, following the resting or aerobic exercise session subject to group allocation, participants completed a modified flanker task whilst wearing an electrode cap. The modified flanker task consists of congruent and incongruent trials which require the participant to respond as to a central target arrow. Please note that the flanker task was only administered to those who had participated in the 20 minute aerobic session once their heart rate had returned to within 10% of their pre-exercise levels. On removal of the electrode cap, standardised achievement tests (WRAT3) were administered to assess reading, spelling and mathematical ability. Finally, the cardiorespiratory fitness of the rested group was assessed once all cognitive tests had been completed.

Figure 1. ERP waveforms across session and task congruency (Hillman *et al*., 2009)

On the second visit, each group was required to swap conditions and repeat the former cognitive assessments. Compared to rest, significant improvements in reading comprehension were reported following an acute bout of aerobic exercise. However, this was not the case for spelling or arithmetic. Improved response accuracy during incongruent flanker task trials were recorded post aerobic exercise, yet an acute bout of exercise did not enhance response pace. A general exercise-induced increase in P3 amplitude was observed in the fronto-central, central, and parietal regions, though the greatest P3 amplitude was reached in the central-parietal region in response to incongruent trials post exercise. The utilisation of neuroimaging in earlier studies have also reported greater activation in the prefrontal and parietal regions of highly fit or aerobically trained adults, compared with adults of low fitness, when tasks demanding inhibitory control were administered (Colcombe *et al.*, 2004). Hillman *et al* (2009) believe that the aforementioned results and previous findings (Colcombe *et al.*, 2004), suggest that the parietal region is open to exercise interventions, and that younger populations may too profit from benefits to the neural networks effecting cognitive functioning during inhibitory control.

Although these results indicate that an acute bout of aerobic exercise may be an effective means of enhancing children's cognitive control of attention and academic performance, it is possible that other factors, such as motivation, may have influenced performance. The study appears to have recruited volunteers, reimbursed for their involvement, which as a result may have exposed the research to a source of bias. The sample's mean intelligence quotient (IQ), according to the Kaufman Brief Intelligence Test, was 120.7, a classification of above average to upper extreme intelligence (Kamphaus, 2005). Such demographic data along with the recruitment method utilised suggests that the study attracted children who possessed a strong motivation to succeed in their studies. Further research into the whether such benefits would be experienced by other populations, such as children with learning difficulties, is necessary.

1.5 The impact of movement based interventions on academic performance

Poor reading skills may hinder some individuals from achieving national academic expectations. A review conducted by the Office for Standards in Education, Children's Services and Skills (Ofsted, 2010), into the best teaching practices in England, found that systematic phonic teaching lay behind the success of 12 outstanding schools boasting high standards of reading. However, movement based interventions have also been linked with reading improvements in children with specific learning difficulties such as dyslexia and Dyslexia Dyspraxia Attention deficits (Reynolds, Nicolson and Hambly, 2003 and Reynolds and Nicolson, 2007), and neuro-developmental delays (Goddard Blythe, 2006, Goddard Blythe, 2005, Jordan-Black, 2005, and McPhillips, Hepper, and Mulhern, 2000). Reynolds, Nicolson and Hambly (2003) maintain that the Dyslexia Dyspraxia Attention Treatment (DDAT) intervention is an effective means of improving cerebellar function, cognitive skills and literacy performance via a 'complex programme of integrated sensory stimulation incorporating visumotor and vestibular therapy.' However, this intervention has been heavily criticised for its methodological flaws (McArthur, 2007, Rack *et al.*, 2007, and Snowling and Hulme, 2003). In view of the current study's purpose, namely to investigate the efficacy of an intervention based upon the replication of primitive reflexes, on academic performance, previous reflex inhibition interventions will be now be reviewed.

1.5.1 Movement interventions based on the replication of primitive reflexes

Primitive reflexes are automatic stereotyped movements controlled by the brain stem and unrestrained by cortical influence (Bobath, 1985, and Goddard Blythe, 2005). During the first few months of life they aid survival and provide a good foundation for future motor skills, however, abnormal maintenance (beyond six to 12 months of age) may impede the acquisition of voluntary postural reflexes and normal development (Goddard Blythe, 2005, and Holt, 1991). Certain non-tuition based interventions have been based on the theory that the retention of primitive reflexes underlies a range of learning difficulties (Goddard Blythe, 2006, Goddard Blythe, 2005, Jordan-Black, 2005, and McPhillips, Hepper and Mulhern, 2000). Neuroscience has demonstrated that exercise can support brain plasticity and facilitate learning (Cotman and Berchtold, 2002). The brain possesses the ability to alter throughout a life span in response to experiences and environmental changes encountered (Kolb and Whishaw, 2011). As discussed earlier in the chapter, studies have reported increases in BDNF, an important mechanism which supports learning in response to exercise (Vayman, Ying, and Gomez-Pinilla, 2004). Taking the brain's plasticity into account, the Institute for Neuro-Physiological Psychology (INPP) maintain that the repetition of developmental exercises can induce new neural connections in order that aberrant reflexes, that is to say primitive reflexes actively present after 6-12 months, may be inhibited by higher brain centres (Goddard Blythe, 2005). The retention of primitive reflexes is indicative of an immature or impaired central nervous system (CNS) and the extent of cortical control over neuromuscular functions (Goddard Blythe, 2005).

A sample of sixty children aged 8-11 years, identified with reading delays of between 18 months (Wechsler objective reading dimensions) and 24 months (Neale analyses of reading ability) and persistent primary reflexes participated in a randomised, individually matched, double-blind, placebo controlled study (McPhillips, Hepper, and Mulhern, 2000). Significant reductions in persistent reflexes were observed in the experimental group following a 12 month home administered movement programme, along with significant gains of between

19.6 (Neale analysis of reading ability) and 15.3 (Wechsler objective reading dimensions) months in reading age (McPhillips, Hepper, and Mulhern, 2000). However, it is worth noting that significant literacy improvements were also reported for the placebo group who were required to repeat non-specific movements each day, whilst control groups continued with their normal daily activities. All groups showed significant progress in writing speed, spelling age and spoonerisms. Significant gains in rapid naming speed along with significant reductions in asymmetrical tonic neck reflex (ATNR) persistence and saccadic frequency were isolated to the experimental group. Of the 70 known primitive reflexes, the intervention required the daily ten minute repetition of only four, namely the tonic labyrinthine reflex (TLR), the Moro reflex (MR), the symmetrical tonic neck reflex (STNR), and the ATNR. ATNR was purported to be a good indicator of total reflex persistence as well as an important function in visual development. Participants were well matched and randomly assigned to different treatment groups which reduced the possibility of random error (Mitchell and Jolley, 2010); a placebo-control group and non-treatment control group allowed for any effects in addition to any potential Hawthorne effects to be evaluated, as well as controlling for the effects of maturation (May-Benson and Koomer, 2010); and a double-blinded design helped to reduce the threat of potential bias, as the administrator/assessor and participant were unlikely to have manipulated the results in support of the hypothesis (Mitchell and Jolley, 2010: 358).

However, the study was not without limitations. The study recognised that it may have fallen victim to a certain degree of sampling bias as parents had volunteered for their children to participate, and so motivation may have partially influenced the results. Good ‘at-home’ parenting, which involves taking an interest in your child’s educational progress, is reported to be a significant factor in a child’s academic progression, carrying even more weight than the parent’s level of education or SES (The National Literacy Trust, 2005). In addition, there was a higher ratio of boys to girls in the sample (16 females and 50 males met the inclusion criteria) and as statistics indicate that girls in England outperform boys in Key Stage two English (Department for Education, 2010), one could question whether the reading delays were partly down to gender. The small scale of the study also hinders confidence in the results, as there is a chance that the small sample size may have over-estimated the strength of association (Hackshaw, 2008). A full description of the intervention is not disclosed and this lack of transparency could elicit reader mistrust: independent replication to aid an informed decision would be impossible. The researchers may harbour a fear that total exposure may draw interest away from their training course (www.primarymovement.org) which provides teachers with the complete sequence of movements at a charge. Although these findings need to be considered tentatively, the aforementioned study (McPhillips, Hepper, and Mulhern, 2000) has shown that the retention of primitive reflexes may be a risk factor in certain reading problems. However, as the primary author developed the programme and was involved in the research, there is a chance of reporting bias. It is therefore it is beneficial to discover that the intervention’s effectiveness has been investigated by an alternative researcher on a larger scale (Jordan-Black, 2005).

A large comparative study (*n* = 683 children, aged six to 11 years) conducted over a two year period, investigated the effects of the Primary Movement programme on reading performance, mathematical ability, spelling and ATNR levels (Jordan-Black, 2005). Alongside the comparative study, a second quasi-experimental study tracked the progress of four parallel groups of children, comprising of an experimental and control group from Year three (*n* = 82) and an experimental and control group from Year five (*n* = 97). Control groups continued with normal daily activities. In contrast to prior home administration (McPhillips, Hepper, and Mulhern, 2000), the decision was taken to administer the intervention to complete classes of children over a period of one academic year, as previous findings (McPhillips and Sheehy, 2004), have indicated that mild levels of retained reflexes can be present in children with average and above reading levels. Baseline data for both studies (reading ability assessed by WORD, mathematics by Wechsler Objective Numerical Dimensions, Non-Reading Intelligence Tests for Year three and five as Year seven were too old, and ATNR by means of the Schilder test) were collected at the end of the academic year in spring and summer 2002. The longitudinal study and quasi-experimental treatment groups began the movement intervention the following school year. Reassessment was not carried out until the end of the following academic year in spring and summer 2004.

Consistent with prior research (McPhillips and Sheehy, 2004), for the comparative study, multiple regression analysis reported verbal IQ to be the strongest predictor of reading, spelling and mathematics. ATNR played a significant role in the prediction of these academic areas, although to a lesser extent. When the 2002 baseline data was compared to the 2004 data, significant reductions were observed in ATNR levels for both year groups; significant improvements in reading and mathematics, but only a small effect on spelling. Effect sizes demonstrated that the magnitude of the treatment effect was relatively strong in relation to reading gains and ATNR, whilst very strong for mathematics. However, the study noted that the influence of other mediating factors could not be ruled out on account that reassessment was conducted a full academic year post-intervention.

The quasi-experimental treatment group reported significantly larger reading and mathematical gains compared to the control group, although spelling did not improve significantly for either group. It was noted that even though significant improvements observed in the experimental group were greater than those seen in the controls, the experimental group were in fact further behind academically. As a result, one cannot be sure whether improvements were due to group imbalances or treatment effects. This may be overcome by randomisation, controlling statistically for baseline differences or through a match-group design.

In summary there is evidence that the rehearsal of specific movements intended to mimic and subsequently inhibit retained primitive reflexes, may contribute to the reduction in continued reflex levels (specifically ATNR) and consequently facilitate progress in reading (McPhillips, Hepper, and Mulhern, 2000, and Jordan-Black, 2005) and mathematics (Jordan-Black, 2005). Although the positive results should not be dismissed, a review of the available evidence, which to date is sparse, has unanswered questions and limitations that cannot be overlooked when interpreting these results. For instance, the aforementioned movement studies (McPhillips, Hepper, and Mulhern, 2000, and Jordan-Black, 2005) are not transparent in their disclosures. The lack of consistency between studies makes it difficult to draw conclusions regarding the most effective way to deliver the intervention. On one hand significant improvements have been observed in reading, writing speed, spelling, spoonerisms, rapid naming speed and ATNR persistence when the movement programme is administered daily at daily home for a year (McPhillips, Hepper, and Mulhern, 2000), whilst significant progress has also been reported in reading, mathematics and ATNR levels when administered by a teacher, accompanied by action songs and rhymes, in a classroom environment, five days per week over one academic year (Jordan-Black, 2005). In contrast, when the INPP, contributors of the movements employed by the Primary Movement programme, evaluated the effectiveness of the INPP programme in primary schools, the impact on reading was small (Goddard Blythe, 2005).

1.5.2 The 'Fit to Read' intervention

The current intervention was based upon developmental exercises employed by the INPP school programme. The 'Fit to Read' intervention reflects the cephalo-caudal and proximo-distal pattern of motor development, and the chronology of reflex inhibition. The movement intervention consists of three, three week cycles. The first cycle targets the tonic labyrinthine reflex (TLR) which emerges in the uterus at 12 weeks and is normally inhibited by 4 months of life. The second cycle targets the asymmetrical tonic reflex (ATNR) which emerges in the uterus at around 18 weeks and is expected to dissipate by around six months of life. The final cycle concentrates on the symmetrical tonic neck reflex (STNR) which does not emerge until approximately six months of life, and normally persisting no longer than nine months of life (Goddard, 2005). The developmental exercise aim to provide participants with an opportunity to experience the inhibitory influence of certain movement patterns which may have been absent or only partially completed during the first 12 months of development, postural reflexes may be promoted, and balance and coordination enhanced (Goddard Blythe, 2005).

The influence of the TLR manifests itself more clearly in children with cerebral palsy (Holt 1991, and Illingworth, 1987). The TLR is elicited by movement of the head and subsequent stimulation of the labyrinths, which yields a tonic influence upon muscle tone distribution (Holt, 1991). In children with cerebral palsy it has been observed that backward movement of the head whilst in the supine position, results in rigid extension of the spine and legs, and retraction of the shoulders (Bobath, 1985). Progressing from supine to a sitting position observed flexion of the spine and head, and protraction of the shoulders. However, should the head rise, the child was liable to fall backwards as extension of the limbs ensued.

The TLR equips the newborn with a basic way of contending with the effects of gravity (Goddard, 2005). The neonate's posture is governed by flexion (Holt, 1991) so the tonic influence of the TLR helps to ‘uncurl’ the newborn and facilitate normal muscle tone, balance and propriocepton (Goddard Blythe, 2005). However, failure to modify the TLR response through the development of oculo- and labyrinthine head-righting reflexes will result in a number of problems such as deficient head control, oculomotor dysfunctions and poor balance due to hypo- or hyper-tonus (Goddard, 2005).

The first cycle (see Appendix 1 & 4) of the ‘Fit to Read’ intervention concentrates on remedying residual TLR retention through the recommended approach of vestibular stimulation (Goddard Blythe, 2005), for instance via rolling exercises (e.g. ‘log rolls’), head extension (e.g. ‘backraisers’, ‘flying a plane), vertical movements (e.g. squats), and rocking actions (e.g. ‘leaning balance’, ‘pendulum’). Although the vestibular apparatus is fully formed at birth, the maturational process takes time and will only improve through practice (Sidebotham, 1988). The integration of visual, somatosensory, and vestibular information underpins successful maintenance of postural control (Hirabayashi and Iwasaki, 1995), movement, spatial orientation and gaze stabilisation (Nandi and Luxon, 2008). A retained TLR may hinder the coordination of sensory information, as creeping and crawling, which promote such integration via vestibular, visual and proprioceptive systems working in partnership, will probably have been bypassed (Goddard, 2005). The first cycle of the ‘Fit to Read’ programme corresponds to the early stages of locomotion development: the majority of exercises are conducted in the prone position where postural control normally begins; elevation of the head whilst in the prone position is encouraged in order to facilitate head control; and participants are required to become proficient at using their arms to pull themselves across the floor before they progress to crawling in the second phase of the program. The ability to stabilise the head in an upright position, in spite of movement, indicates the presence of oculo and labyrinthine head righting reflexes which facilitate controlled eye movements (Goddard, 2005, and Holt, 1991) beneficial for reading.

The second cycle of the intervention targets the inhibition of the ATNR which is elicited by sideward rotation of the head. Extension will be observed in the arm and leg, to which the head is turned, with flexion in the opposite limbs (Holt, 1991). It is reported that extension and lying prone can strengthen the influence of the ATNR (Bobath, 1985). The ATNR helps prevent the newborn from rolling over (Illingworth, 1987), facilitates visual motor development (Holt, 1991), and contributes to improved extensor tone (Goddard, 2005). However, a retained ATNR will have a negative impact on several motor behaviours. For instance, reaching for an object is done ‘blindly’ as one has to turn the head in the opposite direction to where the object is placed (Bobath, 1985). Equilibrium whilst walking will also be disturbed, as rigid extension will be experienced by one side of the body and flexion by the other, due the influence of head movement on tone distribution (Bobath, 1985). The ATNR has been likened to an invisible midline barrier which cannot be crossed as objects cannot be grasped by both hands in the midline (Goddard, 2005). Ocular pursuit needed for reading will be impaired, as hesitancy in eye movement will arise from attempts to cross the vertical midline (Goddard, 2005). The continued presence of the ATNR will also impact upon writing skills as head rotation in the direction of the paper will activate extensor activity in the handwriting arm, a force the child will continuously have to try and suppress (Goddard, 2005). The remedial approach to ATNR retention recommends ipsilateral movements proceeding head movement in the same direction, cross pattern movements whilst keeping the head in the midline position, and exercises which require the eyes to track movement from side to side, and from near to arm’s length (Goddard, 2005). These principles are incorporated into the exercises found in the second cycle of the ‘Fit to Read’ program (see Appendix 2 & 5).

The STNR is the final primitive reaction to be addressed by the present movement intervention. As way of illustration, it has been likened by some to a practical response used by animals during feeding time. For instance, to facilitate the intake of food situated on ground level, a cat will flex its head towards the stomach to provoke extension of the rear limbs and flexion of the forelimbs, whereas food intake from a greater height will require raising of the head, as this will elicit extension of the forearms and flexion of the hind legs (Bobath, 1985, and Holt, 1991).

In children the STNR aids the inhibition of the TLR by splitting the latter in two, and limiting its influence on muscle tone distribution to either the upper or lower half of the body (Goddard, 2005). Increased extensor activity in the arms, evoked by head extension, enables the child to support themselves on their arms and progress from the prone to quadruped in training for crawling (Goddard, 2005, and Illingworth, 1987). However, as flexion of the head movement would cause the arms to collapse, retention of the STNR could hinder the progression to crawling (Goddard, 2005, and Illingworth, 1987). The combination of symmetrical and asymmetrical tonic reflexes presents a further barrier to crawling, as head rotation will cause flexion in the opposite limbs to which the face is turned (Bobath, 1985). However, so long as the tonic neck reflexes exert only a mild influence upon muscle tone, progression to crawling may be possible except in an uncoordinated fashion (Bobath, 1985).

Locomotion on hands and knees is not only valuable for mobility development; moreover it has been associated with enhanced oculomotor functioning (Goddard Blythe, 2005, Goddard, 1995, and Holt, 1991). In locomotion the hands serve as a moving stimulus, encouraging the eyes to track back and forth across the midline, an important skill which will assist in reading by reducing the likelihood of losing one's place in a sentence or paragraph (Goddard, 2005). ATNR facilitates the progression from near point fixation to being aware of distances at arm's length (Holt, 1991). Once the influence of the ATNR fades at approximately 6 months of age, the child's visual field expands to far distance (Goddard, 2005). It has been proposed that the emergence of the STNR provides the foundation for further visual skills training (Blythe, 1992 cited in Goddard, 2005) as flexion and extension of the head requires the visual system to adjust from near to far distance objects. As creeping or crawling is a milestone usually bypassed by a child diagnosed with a retained STNR, the opportunity to experience associated benefits gained from such locomotive actions (i.e. integration of visual, vestibular and proprioceptive systems, hand eye coordination) will be subsequently limited (Goddard, 2005). Hence, the impact of a persistent STNR is likely to include, poor hand eye coordination, poor visual accommodation, clumsiness, and poor posture as head flexion will result in slouching (Goddard, 2005). In line with recommendations (Goddard, 2005), the final phase of the 'Fit to Read' program (see Appendix 3 & 6) is predominately based upon crawling. Up to this point bilateral movements may have dominated, the ability for the left side of the body to perform an opposing movement to the right side may have been problematic, and head movements will have influenced posture. The crawling exercises are designed to inhibit the STNR, and enhance locomotion without the associated restrictions of head movement (i.e. head flexion leading to flexed arms and collapse).

1.6 The impact of population characteristics and backgrounds on academic performance

The impact of the present intervention and previous work cannot be judged in isolation of the effects that different population characteristics and backgrounds may have on study results. The influence of weight status, socioeconomic status, ethnicity and learning English as an Additional Language (EAL), which are all reportedly linked to academic achievement, will be reviewed.

1.6.1 The influence of weight status

Based on the British 1990 growth reference, three in ten boys and girls living in England between the ages of 2 and 15 were classified as either overweight (BMI > 85th percentile for age and gender) or obese (BMI > 95th percentile for age and gender) in 2010 (The NHS Information Centre, 2012). Childhood overweight and obesity are associated with many negative effects such as adverse health, including hyperlipidemia, hypertension, sleep apnea, orthopaedic complications and glucose intolerance (Dietz, 1998), psychosocial difficulties (Braet, Mervielde and Vandereycken, 1997, and Dietz, 1998) and poorer academic attainment (Taras and Potts-Datema, 2005). Therefore, given the adverse effects of overweight or obese on academic performance, examining this relationship is valuable for the present study and explains why BMI will be statistically controlled for in the present study.

Being overweight or obese is associated with poorer academic attainment (Taras and Potts-Datema, 2005). However, Datar, Sturm and Magnabosco (2004) analysed data from the US Early Childhood Longitudinal Study (*n* = 11,192) which focused upon the first two years schooling, and found that although overweight kindergartens (typically aged 5 years in the US [NICHD, 2007]) scored lower on standardised tests of reading and mathematics compared to their non-overweight peers, overweight was not a causal factor rather an indicator or marker of academic attainment. The differences in standardised scores became insignificant once differences in socioeconomic status (SES) were controlled for. In addition, ethnicity and mothers' education were more likely to predict academic progression than overweight status. The influence of SES is consisted with the work of Li *et al.,* (2008), who found that the association between overweight and decreased reading and arithmetic scores for a large sample (*n* = 2519) of students aged 8-16 years, became insignificant after controlling for SES. However, the association between increased weight and reduced cognitive functioning (non-verbal reasoning and visuospatial construction, and attention and working memory) remained significant even after controlling for the impact of SES (Li *et al.*, 2008).

With the release of further data, Datar and Sturm (2006) reported that increased body mass index (BMI) during the first four years of schooling put girls at a significant risk of poor academic achievement, but not boys. The study suggested that society's views regarding weight status and gender, along with differences held amongst young people regarding body image satisfaction, may go some way to explaining why overweight girls exhibited significantly more behavioural problems than boys, including arguing, fighting, anger, impulsiveness, and disrupting ongoing activities. Reports of behavioural problems need to be interpreted with caution however, as the authors drew attention to the fact that they were identified by teachers who were not qualified to assess children's psychological states.

Mo-suwan *et al.*, (1999) investigated the relationship between weight status and the academic performance in grades 3-6 students (*n* = 1207, mean age 10.7 (± 1.1) years) and grades 7-9 students (*n* = 587, mean age 13.8 (± 0.9) yrs) in Thailand. The study found overweight was a significant risk factor of a poor Grade Point Average, low scores in Thai language and mathematics for the older students (grades 7-9) but not for the younger students (grades 3-6). However, the study acknowledged that the grades may have been exposed to a certain amount of bias, given that 10% of the final assessment comprised of teachers subjective appraisals.

The psychological challenges experienced by overweight children (Daniels, 2008, Gibson *et al.*, 2008, Mériaux, Berg and Hellström, 2010, Krukowski *et al.*, 2009 and Schwimmer, Burwinkle, and Varni, 2003), can have a detrimental effect on academic performance as reported by Krukowski *et al.*, (2009). The study reported that weight-based teasing was a significant predictor of achievement. Although weight-based teasing effects both genders, as with previous research (Datar and Sturm, 2006, and Gibson *et al.*, 2008) girls were more likely to experience the adverse consequences of overweight status than boys, since girls who were not overweight did significantly better at school than their overweight peers. The ways in which weight-based teasing may impact upon school outcomes are speculative; however, overweight children have been linked with higher levels of absenteeism (Geier *et al.,* 2007 and Schwimmer, Burwinkle, and Varni, 2003) which may reflect attempts to avoid being PE lessons (Geier *et al.,* 2007 and Krukowski *et al.,* 2009) and/or the increased tendency for illness which in turn places the child at an academic disadvantage (Krukowski *et al.,* 2009). A limitation worth noting however, is that the findings were based on data (e.g. height, weight, school performance, occurrence of weight-based teasing) provided by the population's parents. So whilst there is no doubt that overweight children are vulnerable for weight-based teasing, the study conducted Krukowski *et al.,* (2009) may not provide an accurate account of the problem.

Ramaswamy, Mirochna and Perlmuter (2010) suggest re-directing attention away from academic grades, and propose that effort and motivation may provide an alternative explanation. Teachers, who were blind to the study, submitted quarterly effort ratings for 45 boys and girls, aged 7-12 years in relation to academic subjects English, reading, mathematics, social studies and science, along with the corresponding grades. Grades ranged from A (excellent) to F (fail) and effort was rated on a scale of one (academic warning) to four (expectations exceeded). After controlling for gender, age and ethnicity, increased weight was negatively correlated with teacher ratings of effort yet the association between weight status and academic performance was weak. The study concluded that overweight students may not always work to their full potential, and the role that effort may play in their other areas of their life, such as diet and physical activity levels, should also be addressed. A key limitation recognised by the study however, is the subjective nature of the effort ratings. Weight bias has been reported in education, with teachers having lower expectations for overweight students compared to their normal weight peers (Greenleaf and Weiller, 2005).

Research regarding the relationship between weight status and academic performance lacks consistency. Differences exist not only in the study findings in this area, but also in the terminology utilised, making cross-study comparisons difficult. For instance, a certain number of the reviewed studies (Datar and Sturm, 2006, Datar, Sturm and Magnabosco, 2004, and Li *et al.*, 2008) classified overweight children as those with a BMI value equal to or above the 95th percentile for their age and gender, whereas other studies referred to BMI values equal to or above the 95th percentile as obese (Geier *et al.*, 2007). There were studies which classed overweight as a BMI above the 85th percentile for age and gender (Geier *et al.*, 2007, Krukowski *et al.*, 2009, and Mo-suwan *et al.*, 1999), and cases where the definition for overweight or obese was not explicit (Ramaswamy, Mirochna and Perlmuter, 2010). Making comparisons across the different studies is further complicated by the fact that risk associated cut-off values for BMI and adiposity differ according to ethnic groups (Flegal and Ogden, 2011). For example, in certain Black populations some BMI values coincide with a lower body fat percentage and as a result lower health risks compared to a White European population (SEPHO, 2005). Consequently, the South East England Public Health Observatory (SEPHO, 2005) recommends using the waist-hip ratio measures when comparing obesity in different ethnic groups. In addition, to differences in terminology, cut-off points, school outcomes, and population sampled, inconsistent findings may also be explained in part by the frequent use of cross-sectional study designs which does not allow for the influence of fluctuations in weight status over an academic year. Equally, a number of the studies included for review possessed notable strengths, including a longitudinal approach utilised by two of the studies (Datar and Sturm, 2006, and Datar, Sturm and Magnabosco, 2004), large sample sizes in many cases, and the inclusion of confounding variables such as low household income and low parental education, which can independently influence childhood obesity (Lamerz *et al.*, 2005, and The NHS Information Centre, 2012) and academic attainment (Davis-Kean, 2005). In summary, although the relationship between overweight and academic performance is unclear and inconsistent, overweight and obesity is often associated with at least one negative aspect of school performance (Taras and Potts-Datema, 2005).

1.6.2 The influence of socioeconomic status

Socioeconomic status (SES) is a complex variable which can be determined by a combination of factors including family income, parental education, occupational status and habitation (Ardila *et al.*, 2005). The factors selected to measure SES will in part be influenced by a study's research question and the availability of data (Bradley and Corwyn, 2002). Low SES may negatively impact upon many areas of life including health status, nutrition, employment, access to material resources, and education (Buckhalt, 2011). A significant relationship between SES and academic achievement has been well documented, in that children from economically disadvantaged families are associated with lower attainment (Akhtar and Niazi, 2011, Bradley and Corwyn, 2002, Liu and Lu, 2008 and Sirin, 2005). However, it is unclear which factor of SES has the greatest link with academic achievement.

Students of low SES are often linked with reading and mathematical underachievement (Dearing, McCartney and Taylor, 2009, McPhillips and Sheehy, 2004 and Sastry and Pebley, 2010). Low income restricts the family's ability to provide access to cognitive stimulating resources (e.g. number of child owned books) and experiences (e.g. encouragement to learn the alphabet) which are important for cognitive and language development (Dearing and Taylor, 2007). Economic strain is associated with reduced positive parenting practices, including less sensitive, responsive and stimulating care, and increased negative parenting, usually defined as coercive, harsh and unresponsive behaviour (Barnett, 2008 and Bradley and Corwyn, 2002). Such parenting is reported to have a negative effect upon children's cognitive and social outcomes (Barnett, 2008).

Altschul (2011) found that parents' financial resources have a strong impact on achievement. The study of 1,609 Mexican American students' (mean age not provided) progression from eighth grade through to tenth grade, indicated that financial support by means of extracurricular instruction and access to educational resources in the home such a computer, had a stronger positive impact upon academic achievement than the investment of parental time.

There is evidence that parental education is linked with academic performance, yet inconsistencies exist regarding which parent is more influential. In a UK longitudinal study (Scott, 2004) although mother's education, type of residence (e.g. owned/rented) and household income were all significant predictors of attaining five of more A-C GCSE qualifications, mothers' education had the greatest influence. Fathers' education or occupational status did not play a significant role in GCSE attainment. McEwan's (2001) examination of census data from Chile also found that mothers' education had the strongest impact on eighth grade students' (mean age not provided) performance in Spanish and mathematics. The impact of fathers' education was positive but smaller in magnitude, whilst income exerted small and inconsistent effects on achievement. Yet a meta-analytic review (Sirin, 2005) of the literature showed that of the three most commonly used measures of SES, namely parental education, parental income and parental occupation, income had the strongest influence on academic achievement.

DeGarmo, Forgatch and Martinez's (1999) research showed that the education and occupation of single mothers had comparable impact on the academic achievement of 6-9 year old boys. Maternal education and occupation were linked to more effective parenting practices which in turn shaped achievement through skill-building activities in the home (e.g. reading rather than watching television) and school behaviours. The study provided an insight into how changes in SES following a divorce can impact upon school outcomes; however, limitations of the study include its cross-sectional design and the decision to restrict the sample to boys only. As the mothers were recently separated, a longitudinal study which sampled both genders would provide a greater understanding of the long-term effects of such change in circumstances for boys and girls.

It is difficult to establish the exact way in which SES operates to affect child development, including school outcomes (Bradley and Corwyn, 2002). Part of the problem lies with having to unravel the number of factors and conditions which low SES often co-vary with and consequently moderate its impact (Bradley and Corwyn, 2002). Factors which may exacerbate the effects of SES are usually related to resource constraints (e.g. assets, social capital, material and nonmaterial resources) and psychological influences (Bradley and Corwyn, 2002). Resources include access to stimulating learning materials and experiences, housing condition, style of parenting, and teacher attitudes and expectations (Bradley and Corwyn, 2002). Psychological influences include parents' and children's responses to the stress of economic disadvantage (Bradley and Corwyn, 2002).

The association between SES and attainment is further complicated as the impact of certain circumstances may differ depending on the characteristics of a child and/or family (Bradley and Corwyn, 2002). For example, it is argued that teachers often have low expectations of students with low SES (McLoyd, 1998), a view which may be strengthened by ethnicity (Bradley and Corwyn, 2002, and Department for children, schools and families, 2009) given that children from ethnic backgrounds tend to be learning EAL and come homes which offer poor cognitively stimulating experiences (Department for education and skills, 2007). Gillborn and Mirza (2000) argue that social class, determined by the parent's employment status (e.g. manual or non-manual labour), may hinder educational opportunities as low teacher expectations often leads to be being placed in lower ranked/ability teaching groups. The tiered GCSE examination system for England and Wales, means that students put forward for the lower tiered examinations cannot attain higher than grade C regardless of performance, whereas students submitted for the top tiered examinations have the opportunity to attain grade C and above (Office of the Qualifications and Examinations Regulator, n.d.). In addition, a review of the literature has also indicated that the timing of income measure effects school outcomes (Brooks-Gunn and Duncan, 1997). Income quantified between birth and five years of age is reported to have a greater impact on the number of years completed at school compared to income measured between five and fifteen years of age (Brooks-Gunn and Duncan, 1997).

A review of the research shows that the relationship between SES and academic performance is highly complex as the strength of its impact may be influenced by a number of interacting factors. There are a number of ways to determine SES including family income, parental education, occupational status and habitation (Ardila *et al.*, 2005), yet no consensus exists regarding its measurement (Bradley and Corwyn, 2002). Variations in the way that SES is measured, along with differences in the age of the population and the academic subject being studied, may account for why the strength of its effect is inconsistent (Sirin, 2005 and Yang, 2003).

1.6.3 The influence of ethnicity and learning English as an Additional Language (EAL)

Another area which needs to be considered when exploring the risk factors associated with low achievement is ethnic origin, given the multi-ethnic nature of the current study sample. A quarter of state-funded primary schools in England are comprised of ethnic minorities

(Department for Education, 2011) and, although, socioeconomic status remains the strongest predictor of academic attainment, ethnic origin and English as an Additional Language (EAL) play an important part in explaining differences in attainment (Cabinet Office, 2007, and Statistical Bulletin, 1999). Many students of ethnic minority origin (Chinese, Mixed White, Asian, Irish, and Indian) do achieve above the national average. However, many ethnic groups, including students classified as Gypsy/Roma and Traveller of Irish Heritage, all Black categories, Mixed White, Bangladeshi and Pakistani, fall short of the national average (Department for education and skills, 2007).

The GCSE examination results of 1998, provided by UK local education authorities (LEAs), illustrated the complexity of ethnic attainment (Gillborn and Mirza, 2000). There were many reported cases where ethnic minority groups lagged behind their white peers. For instance, in 42% of the LEAs the attainment of all Black categories failed to equal that of white students. Yet on the other hand, of all the ethnic groups reviewed, each one was described by at least one LEA as the highest achieving group. In addition, Indian students outperformed their white peers in eight of the ten LEAs that observed the effects of ethnicity on educational outcomes. These inconsistencies demonstrate that there should be no innate reason why students from ethnic minorities should be pre-disposed to underachievement (Gillborn and Mirza, 2000).

The underlying reasons responsible for the achievement gaps remain complex and unresolved (Cabinet Office, 2007). Some of the explanations which have been debated include the quality of the home learning environment, economic status, the quality of schooling and language.

The Effective Provision of Pre-School Education (EPPE) project (Sylva *et al.*, 2004) found that the quality of all children's home learning environment (HLE) has a greater influence on academic success compared to parental occupation, qualifications or income. In other words parent's actions, such as reading with their child, demonstrating how to sing nursery rhymes, reciting the alphabet, creating opportunities to play with friends at home and so forth, proved more important to a child's cognitive development than parental education and occupational status. However, the quality of HLE differs according to ethnic background, with Pakistani and Black African groups reported to experience a significantly poorer HLE (Department for education and skills, 2007). Furthermore, a poor HLE was more evident where the first language spoken at home was not English and the opportunities offered by pre-schools, in supporting English tuition, were found to be significant (Department for education and skills, 2007). Yet the longitudinal study highlighted that a single factor will not enhance attainment, rather a combination of experiences over a period of time. Experiencing a stimulating HLE, along with higher quality pre-school and effective primary schooling, will reduce the likelihood of poor academic attainment and poor behavioural development. Unfortunately a high proportion of Pakistani children (33%) and those with EAL (38%), who are likely to underachieve at school, do not attend pre-school education.

A further factor, which has been investigated in the disparities often observed in ethnic attainment, is the role of economic status (Gillborn and Mirza, 2000, and Kingdon and Cassen, 2010). A study (Kingdon and Cassen, 2010) into the influence of ethnicity and underperformance at Key Stage four of the National Curriculum (tests taken by pupils usually aged 16 years in England) found that economical disadvantage (those entitled to FSMs) increased the likelihood of low achievement (GCSE grade ‘D’ grade and below) for White British students, more than it did for all other ethnic groups. One explanation put forward for this finding was that FSM status may signify different things for different ethnic groups, for example, the link between FSM status and single parenthood is more pronounced amongst White families compared to all other groups. In addition to LEA data, Gillborn and Mirza (2000) also examined attainment data from the Youth Cohort Study and the impact of social class characterised by ‘manual’ (rough indicator of working class) and ‘non-manual’ backgrounds (middle class). The data confirmed the well documented association between lower achievement outcomes and manual family backgrounds. However, inequalities were apparent when comparisons were made between different ethnicities. For instance, the non-manual background of African-Caribbean students did not seem to place them at an advantage over Pakistani/Bangladeshi and White pupils from manual backgrounds. Whilst important, it is argued that tackling class and economic disadvantage would appear insufficient in narrowing the inequalities observed in academic attainment (Cabinet Office, 2007, Gillborn and Mirza, 2000).

Kingdon and Cassen (2010) suggest that another aspect which plays a partial role in the ethnic attainment gap is the quality of schooling. A review of LEA data found that Black students attainment levels were 20 percentage points ahead of the other main ethnic origins at the onset of compulsory education, yet by GCSE level their attainment had dropped to 21 points below the average (Gillborn and Mirza, 2000). These findings led the article to question whether certain ethnic groups benefit from their schooling more than others. Reports that the probability of school exclusions is four times more likely for students of African-Caribbean origin (Department for education and skills, 2003) along with the potential of experiencing negative stereotypes from the education system (Department for children, schools and families, 2009), are some of the additional barriers which may influence how profitable school is for certain ethnic groups. However, Wilson, Burgess and Briggs (2011) challenge the argument that school practices are accountable for ethnic differences in attainment. The study examined data from the Annual School Census for England (1998 to 2002) in terms of students' progress, and found that between 11 and 16 years of age, students from all ethnic minority backgrounds progressed more than White students. It worth noting, however, that the attainment growth for Black Caribbean students was trivial. As the improvements were more striking during the final exams, the authors suggest that differences in values and aspirations may provide an explanation, because despite school quality Indian students surpassed the White students in 90% of the schools. The acquisition of good test results may be viewed as a requirement for social mobility, and therefore explain why more effort appeared to have had been put into the final exams.

The final factor to be presented is the relationship between learning English as an additional language (EAL) and attainment, as the majority of children from ethnic minority backgrounds are said to be learning EAL (Department for education and skills, 2007). As the proportion of students with EAL attending state-funded primary schools increased from 16 % in 2010 to 16.8 % in 2011 (Department for education, 2011), it is important to understand the impact it may have upon academic achievement. However, the impact of having EAL and low attainment is reported to reduce with age. Cognitive assessments (tests of verbal and non-verbal comprehension, naming vocabulary and spatial awareness) conducted by the EPPE project showed that children of pre-school age with EAL were associated with low cognitive scores, yet by age 7 years this association had weakened. Kingdon and Cassen's (2010) analysis of the Pupil Level Annual School Census also found that the likelihood of EAL impacting negatively on achievement progressively reduced as students moved from age 11 to 16 years. It is thought that although students with EAL may find school initially challenging, the aforementioned progression is the result of improved English fluency over time. Pre-schools were advocated in EPPE report, as these settings increase the opportunities for children learning EAL to interact with English speaking adults and children, which as a result may improve the transition into primary school and academic achievement.

A US study (Hammer *et al.*, 2009) has also documented the supporting role of pre-schools in the English language and literacy development of children (*n* = 72, mean age 4 years, 1 month) who have been exposed to Spanish speaking mothers since birth. It was theorised that the extent of maternal Spanish usage in the home, be it more or less than English, did not have a negative impact upon the children's English literacy development as pre-school attendance provided enough exposure to English tuition. The study was careful to point out that the Spanish-speaking mothers should not stop from using their native language lest the parents reduced command of the English language provides the child with a poor role model as a result. In addition, cases where English usage increased in the home, the children's competency in their native language decreased. In accordance with the developmental interdependence hypothesis (Cummins, 1979) it is beneficial for children to be proficient in their native language as there is evidence to show that this will facilitate and provide a good foundation for the acquisition of an additional language (Yazici, Ilter and Glover, 2010). However, attempting to learn a second language whilst still unaccomplished in the first language may lead to deficiencies in both languages (Jitendra and Rohena-Diaz, 1996).

It is apparent that learning a second language is complex as there are many factors that may affect its success. Jitendra and Rohena-Diaz (1996) draw attention to the importance of understanding the many influences which may impact upon the acquisition of a second language, as learning difficulties may not necessarily form the basis for any students making slower progress. As discussed above, progress may be influenced for example by the HLE, cultural factors and the level of proficiency in one's native language. Bilingual children are often misdiagnosed with learning difficulties or language disorders (Dufresne and Masny, 2006) due to a lack of understanding the aforementioned influences. Children classified as having special educational needs (SEN) were reported as being more likely to have EAL by the EPPE project, however, the frequent issue of misdiagnosis brings into question how complete and accurate schools are in differentiating between students with learning difficulties and those lacking English proficiency.

Although the health benefits of PA are well established, its effectiveness in enhancing cognitive and academic performance remains unclear. Neuroscience is encouraged by research, which has found that improved cognitive functioning can be gained from several days of running (Berg, 2010) or as little as an acute bout of aerobic exercise (Hillman *et al.,* 2009). In considering the value and impact of PE in schools, whilst there remains uncertainty regarding what modes of PA benefit which areas of learning, it may be of comfort for those worried about the decline of PE in schools, that evidence has shown an increase in time allotted to PE does not compromise academic performance (Ahamed *et al.,* 2007, Carlson *et al.,* 2008, and Trudeau and Shephard, 2008). In contrast to moderate intensity PA, movement based interventions have endeavoured to provide explanations and remedies for children struggling with learning difficulties. Interventions based on the theory that the continuation of primary reflexes impedes the progression of learning in certain populations (Goddard Blythe, 2005, Jordan-Black, 2005, and McPhillips, Hepper, and Mulhern, 2000), claim that the rehearsal of primitive reflexes facilitates learning. Evidence has been presented to indicate that the inhibition of primitive reflexes may assist those struggling academically, however, the research on this topic is equivocal and consideration has not been given to its effectiveness on populations who have low socioeconomic status and from ethnic backgrounds. Hence, further scrutiny of the role that movement training may play in academic achievement is needed. The purpose of this study is to work in collaboration with Coventry City Council; to investigate the efficacy of a movement intervention developed by Coventry City Council called ‘Fit to Read’ on improving primary school children’s reading and mathematical performance.

Delimitations

The study acknowledges there are a number of delimitations. The study recognised the diversity of the study sample however, the standardised assessments utilised to measure academic performance were based on the norms of monolingual children due to a lack of standardised tests and qualified professionals available to assess a wide variety of languages.

The author acknowledges that as mathematical development is complex with MD purported to comprise of more than one subtype Geary (2004), standardised tests employed by the present study and prior work (Jordan-Black, 2005) do not identify which areas any deficits may lie (Geary, 2004, and Hulme and Snowling, 2009) and consequently which areas improvements have been made. Furthermore, one reading test is unable to measure all aspects of language (Keenan, Betjemann, and Olson, 2008).

The study did not include children with specific learning difficulties such as dyslexia who were in receipt of additional learning support. The study wanted to increase the chance that any observed effects would attributable to the movement intervention.

The primitive reflex profile of the children was not measured as it was beyond the reach of the study to gain training for such assessments to be conducted.

It was beyond the scope of the present study to control for the numerous confounders reported to influence learning outcomes, such as variations in the participant's social interactions and day to day activities (Best, 2010), parental involvement (in the child's academic success) (DCSF, 2008b), diet quality (Florence, Asbridge, and Veugelers, 2008), motivation (e.g. Logan and Medford, 2011, and Logan, Medford, and Hughes, 2011), and parent's educational status (Dubow, Boxer, and Huesmann, 2009). Given the high number of confounding factors it could argued that there are too many confounding variables to make an accurate assessment in this area of research.

Aims: The primary aim is to investigate the efficacy of a school based movement intervention called ‘Fit to Read’ on improving primary school children’s reading and mathematical performance.

The secondary aim is to assess whether there are any gender differences in relation to the impact of ‘Fit to Read’ on primary school children’s reading and mathematical performance.

Objective:

To randomly allocate a sample of Year three primary school children to either an experimental group in order to participate in a nine week movement intervention called ‘Fit to Read’, or a control group in order to continue with their normal routine.

To measure the reading by means of standardised group administered reading test (GRT II, 6-14, NFER Nelson, 2005) pre-, post-, and two weeks post-intervention.

To measure mathematical performance by means standardised group administered mathematical test (PIM, NFER Nelson, 2004) pre-, post-, and two weeks post-intervention

To compare the reading and mathematical performance according to condition and gender

.

The null hypothesis for this study is:

> H_O: As a result of a nine week school based movement intervention (five days/week, 20mins per day), there will be no significant difference in reading and mathematical performance.

which is tested against the alternative hypothesis:

> H_A: As a result of a nine week school based movement intervention (five days/week, 20mins per day), there will be a significant difference in reading and mathematical performance.

Chapter 2

Methods

2.1 Participants

Study participants were recruited from two primary schools within the Coventry local authority. School one was a Roman Catholic primary school (*n* = 170), comprising of pupils from mainly White British backgrounds, although the proportion of ethnic minority groups was reported to be well above average. School two (*n* = 690) was not a faith school and consisted of a well above average (82%) proportion of pupils from minority ethnic backgrounds, mainly of Bangladeshi and African heritage.

Teaching staff invited children from Year 3, with a reading age below that of their chronological age, to participate in the current study. Pupils already involved in a movement based reading intervention were excluded from the study. Following institutional ethical approval and parental written consent, 31 children (16 boys, 15 girls) gave assent to participate in the study. Participants were aged 88 – 100 months (mean age ± *SD* = 94.9 ± 3.7 months). Details of ethnic distribution were obtained from school records: 41.9% (*n* = 13) White, 29% (*n* = 9) Asian, 19.4% (*n* = 6) Black, 6.5% (*n* = 2) mixed ethnic backgrounds and 3.2% (*n* = 1) were classified other. School records also provided information of those in receipt of free school meals (*n* = 16), as an indication of SES. Participants from each school were randomly allocated to a control group (*n* = 16) who continued with their daily routine, or an experimental group (*n* = 15) who completed the nine week movement intervention.

2.2 Procedure

A quasi-experimental, controlled, cross-over design study was used to investigate the efficacy of a school based intervention called 'Fit to Read' on academic performance. The pilot study was conducted in collaboration with Coventry City Council, who appointed Coventry University to evaluate the impact of the 'Fit to Read' programme on primary school children's reading ability. A further dependent variable, namely mathematic performance, was included for analysis in order to investigate whether the 'Fit to Read' intervention was beneficial to other areas of school attainment apart from reading, given reading and mathematical difficulties often coexist (e.g. Geary, 2004, and Mazzocco and Myers, 2003).

Standardised tests of reading (GRT II, 6-14, NFER Nelson, 2005) and mathematical (PIM, NFER Nelson, 2004) ability were administered to all participants in groups by the study's author (details regarding the standardised assessments can be gained by contacting info@gl-assessment.co.uk). Tests occurred before midday on five separate time points: baseline (TP1 - mid January 2011 to start of February 2011); post intervention (TP2 - beginning of April 2011); two weeks post-intervention (TP3), which also served as the baseline measures for study two; post cross-over (TP4 – July 2011); and two weeks post cross-over (TP5). At study cross-over both groups exchanged conditions. In line with ethical practice this allowed each participant the opportunity to undergo the movement intervention. In addition the cross-over design is reported to eliminate inter-participant variability and increase statistical power (Reed III 2004).

2.3 Measures

2.3.1 Anthropometry

Body mass was measured using a calibrated electronic scale (Seca Instruments, Germany) to the nearest 0.1 kg, whilst the children were wearing school uniforms and footwear. Height was measured using a portable free-standing stadiometer (Leicester Height Measure) to the nearest 0.1 cm. Body mass index (BMI) was calculated as the participant's weight in kilograms divided by the square of the participant's height in metres (kg/m^2).

2.3.2 Habitual physical activity levels

Habitual physical activity (HPA) levels were measured over four consecutive days (two weekdays and two weekend days) using a piezoelectric pedometer (New Lifestyles NL-800). This time frame fell in line with recommendations to achieve reliability coefficients of 0.80 in children (Trost *et al* 2000). The control variable, HPA, was intended to minimise potential threats to the study's internal validity. Prior research has reported changes in children's HPA as a possible response to study participation (Tolfrey, Campbell, and Batterham, 1998).

A pedometer was selected as an objective, reliable, non-reactive, cost-effective, low burdensome motion sensor (Sirard and Pate, 2001). The activity monitors inability to record the intensity, pattern or context of PA have been well recognised (Rowlands and Eston, 2007, Sirard and Pate, 2001, and Welk, Corbin, and Dale, 2000), however, as the current study's main interest was in gaining a general description of total activity, the pedometer was considered an appropriate tool. Compared to spring-levered models, the piezoelectric pedometers have been reported to provide a more accurate measure of step counts in paediatric samples (Duncan *et al.*, 2007). In validation studies the NL-800 has yielded an error rate of less than 3% in child samples whilst walking (Smith and Schroeder, 2010). Verbal and written instructions on how and when to wear the pedometer (i.e. worn on the waistband during all daily activities until bedtime, excluding activities associated with water) were provided before dispensation. Study participants were not blind to the monitor output, as previous research employing both sealed and unsealed pedometers, has not found reactivity to be a problem when employing unsealed units (Ozdoba, Corbin, and Le Masurier, 2004).

2.3.3 Reading comprehension

A standardised, group administered comprehension test (*The Group Reading Test II, 6-14,* NFER Nelson, 2005) was used as a measure of reading ability. It is an untimed 43 item sentence completion test (e.g. The dentist pulled out the bad ___ 'tooth', 'tongue', 'brush', 'toot', or 'hoot') suitable for children aged 6 to 14 years. Sentence Completion Forms A and B were administered on an alternate basis throughout the course of the study, as the guidance (NFER Nelson, 2005) proposed. The content of Forms A and B were appropriate for school years 2, 3 and 4 in England and Wales. Participants were given sufficient opportunity to confirm their understanding of what was expected of them and time for practice questions to be completed (5 picture identification questions). The GRT has been employed in prior reading studies (Logan and Medford, 2011, Logan, Medford, and Hughes, 2011) and tests participants on their decoding, semantic (understanding word meanings) and morphosyntactic (grammatical) skills (Hulme and Snowling, 2009). The untimed aspect of the GRT II offered children of all abilities the opportunity to complete all questions as well as alleviating potential feelings of stress.

2.3.4 Mathematical ability

The *Progress in Maths (PIM)* test (NFER Nelson, 2004) was used as a measure of mathematical ability. The PIM test (NFER Nelson, 2004) is a series of standardised, untimed, group administered tests suitable for children aged 4-14 years. The test questions are read aloud to ensure that reading difficulties do not restrict the assessment of mathematical ability. PIM 7 and PIM8 were selected to meet the present age range being studied. The tests addressed participants' understanding of number (e.g. different algorithms needed to solve mathematical problems), shape, space and measures (e.g. identifying 3 triangles from a selection of shapes), and data handling (e.g. interpretation of bar chart data). Participants are required to respond to questions in a number ways, including drawing, circling their choice of answer, joining up corresponding pictures with a pencil line, or writing a number or word down. PIM 7 provided a measure of the sample's mathematical ability at TP1 and TP2. As the sample's chronological age increased, PIM 8 was age appropriate for testing at TP3 onwards.

2.3.5 Scoring the reading and mathematical tests

Mathematical and reading achievement is presented by means of standardised scores as raw scores do not take into account the wide spread of ages which can be found within school year groups where there can be a tendency for older pupils to achieve higher marks (NFER Nelson, 2005). Standardised scores allow the results from different educational tests to be compared, as standardisation take into consideration the disparity in chronological ages and allows participants to be judged against other students of comparable age, as well as the national average (NFER Nelson, 2005). Reading ages have also been calculated as this is a widely understood and employed method of conveying reading ability.

2.4 The intervention

The current intervention was based upon developmental exercises employed by the INPP school programme and developed by Coventry City Council. The ‘Fit to Read’ intervention reflects the cephalo-caudal and proximo-distal pattern of motor development, and the chronology of reflex inhibition. The movement intervention consists of three, three week cycles. The first cycle targets the tonic labyrinthine reflex (TLR), the second cycle targets the asymmetrical tonic reflex (ATNR), and the final cycle concentrates on the symmetrical tonic neck reflex (STNR).

2.4.1 Delivery

The ‘Fit to Read’ programme was delivered before lunchtime each weekday for approximately 20 minutes during school hours, for a nine week period in addition to any other structured and non-structured school-based physical activity. As the intervention was developed by Coventry City Council, factors such intensity, types of exercises and duration were fixed. The exercises are intended to improve participants’ reflexes, co-ordination, concentration and balance. The complexity of the movements was adjusted every three weeks so that each participant advanced gradually through a total of three stages. Programme modifications were intended to facilitate progress and confidence in the aforementioned areas (e.g. co-ordination) as well as retain participant interest. To promote consistency, the exercises were administered by one teaching assistant (TA) per school. A sports co-ordinator, who had attended the INPP training course, provided the TAs with training. To enhance the consistency of delivery the TAs were supplied with identical manuals to comply with. In addition, the study author observed each TAs delivery to ensure inter-instructor reliability. The exercises are floor based and require minimal equipment (i.e. floor mats, bean bags, balance discs and soft balls). The ‘Fit to Read’ programme is underpinned by the theory that a correlation exists between retained primitive reflexes and academic performance (Goddard Blythe, 2005). By mimicking developmental movements naturally observed in the first year of an infant’s life, it has been reported that the retention of primitive reflexes can be reduced and academic performance improved (Goddard Blythe, 2005).

2.5 Statistical analysis

Descriptive statistics were obtained for demographic, anthropometric, HPA and academic performance data. As groups were unmatched, independent samples t-test were conducted to determine if there were any significant differences in baseline measures of BMI, HPA or academic ability, as a step to minimise threats to internal validity. No significant differences were found between the initial groups.

Academic performance was investigated using a 3 (pre-, post- and 2 weeks post-intervention) by 2 (experimental and control group) by 2 (male and female) within subject repeated measures ANOVA. Analysis was repeated controling for covariates BMI and HPA, given that PA (Hillman *et al.,* 2009, Sibley and Etnier, 2003, Tomporowski, 2003, and Trudeau and Shephard, 2008) and weight status (Clark, Slate, and Viglietti, 2009, Krukowski *et al.,* 2009, and Taras and Potts-Datema, 2005) are reported to influence academic and cognitive performance. Significant effects for time were investigated further using pairwise comparisons (Bonferroni and LSD). Separate one-way repeated ANOVAs and ANCOVAs were run for each subgroup (boys/experimental, boys/control, girls/experimental, girls/control), in order to isolate any gender, group or significant interactions. Data was analysed using Predictive Analytics Software Statistics version 17 (PASW Statistics 17). Statistical significance was set at an alpha level, $p = < 0.5$.

Chapter 3

Results

Baseline measures: The box plot (Figure 2) of standardised scores shows that girls had higher levels of attainment in reading compared to the boys. A comparison of mathematical attainment levels shows that there was no significant difference between the boys and girls at baseline. The scores are clustered towards higher values for the boys hence nullifying the higher mean observed in the girls scores. Independent samples t-tests showed no significant differences between the initial control group and experimental group.

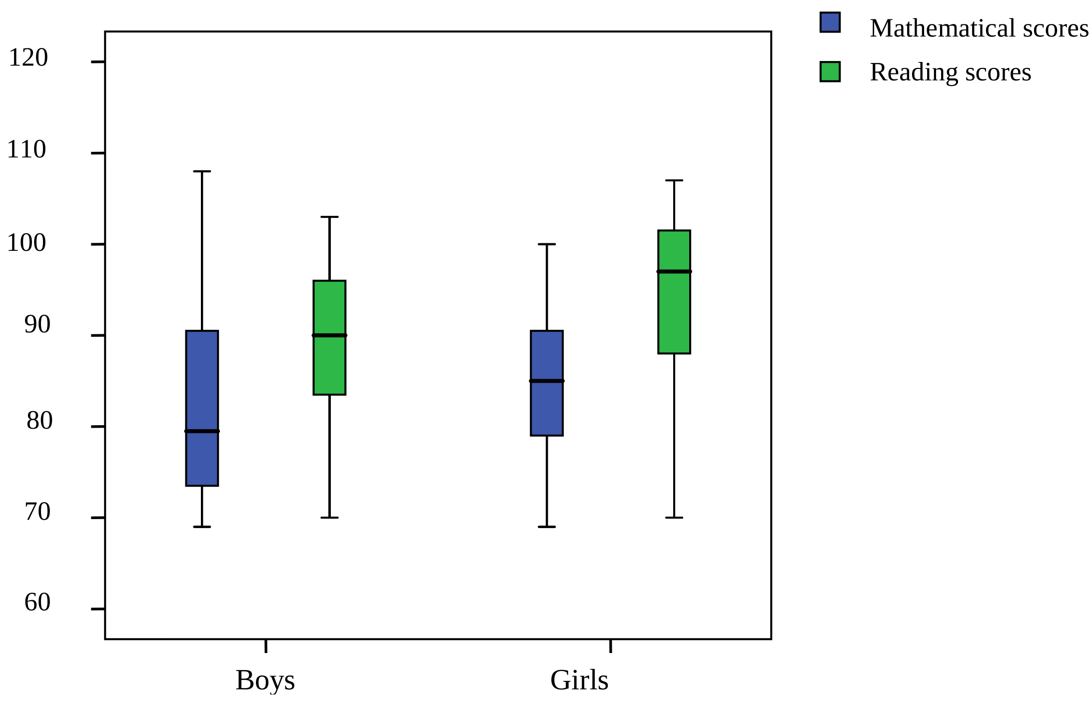

Figure 2: Standardised academic baseline scores

3.1 Group (experimental/control) differences in reading age

Study one: A mixed between-within subjects ANOVA was conducted in order to investigate the impact of the movement intervention on reading age, pre-intervention (TP1), post-intervention (TP2) and two weeks post-intervention (TP3). No significant main effects or interactions were reported for reading age (Figure 3). ANCOVA reported a significant main effect for time, (Wilks Lambda = .73, F (2, 22) = 4.02, p = .033, partial eta-squared (η_p^2) = .27, Figure 4). The control group commenced one month ahead of the experimental group (*n*

= 15). Slight improvements were exhibited by the control group (n = 15) at TP2 whilst the experimental group's reading age declined by about one month. By TP3 the gap in reading age had widened with the control group ahead by around three months. No further main effects or interactions were found, and post-hoc comparisons using LSD, Bonferroni and Sidak did not yield any further significant differences.

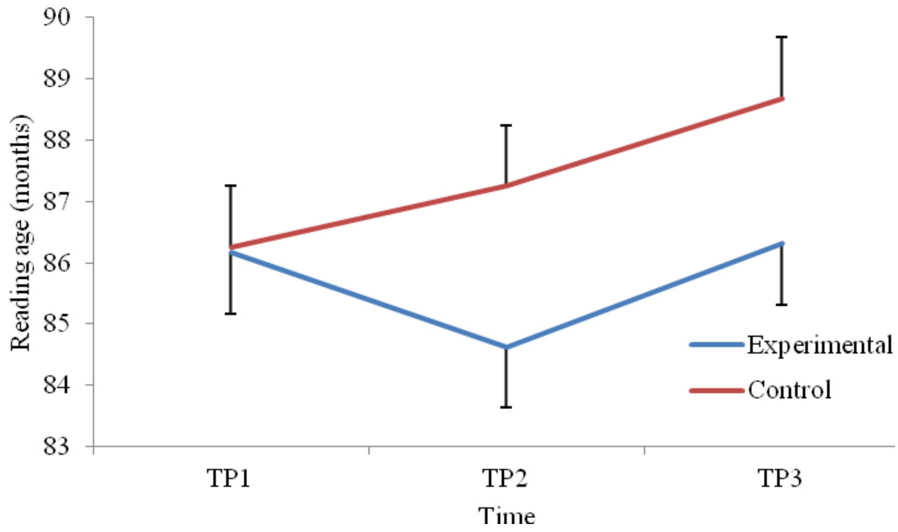

Figure 3: Absolute mean reading age, baseline (TP1) to 2 weeks post-intervention (TP3)

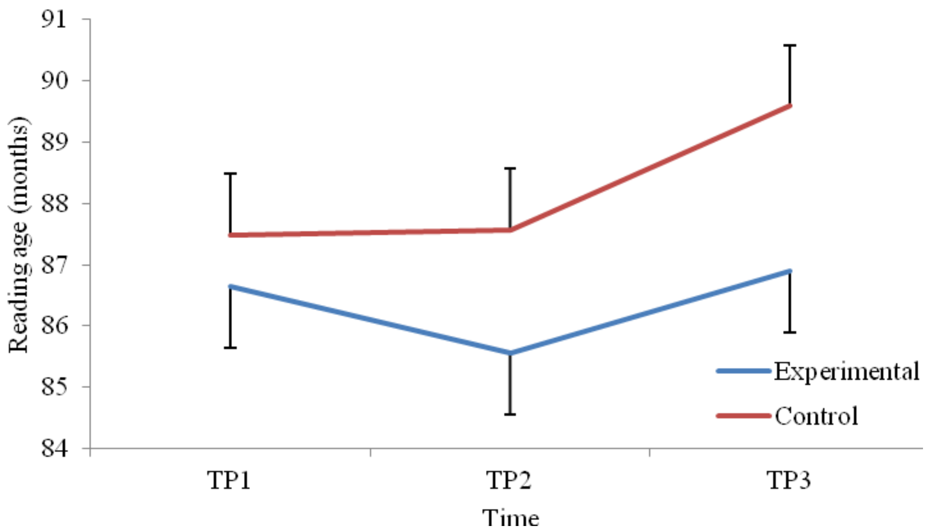

Figure 4: Mean reading age, baseline (TP1) to 2 weeks post-intervention (TP3)

3.1.1 Group (experimental/control) differences in reading age

Study two: At study cross-over the initial experimental group (*n* = 15), who had completed the nine week intervention continued with their daily routines and formed the control group, whilst the initial control group (*n* = 16) commenced the nine week intervention and formed the next experimental group for TP4 to TP6. Measures collected at TP3, served as baseline measures (TP4). Effectively, TP4 to TP6 relates to pre-, post-, and two weeks post-intervention with effect from study cross-over. ANOVA reported no significant interactions following study cross-over. However, a significant main effect for time was reported, (Wilks Lambda = .70, F (2, 26) = 5.61, p = .009, η_p^2 = .30, Figure 5). Post-hoc comparisons using Bonferroni pairwise comparisons detected that reading age was significantly higher at TP5 compared to reading age at TP4 (Mean diff = 3.20, p = .007). At TP5 a rise in reading age was reported for each condition, yet by TP6 improvements continued for the control group only as deterioration was observed in the experimental group's performance. ANCOVA reported no significant interactions or main effects for time or group.

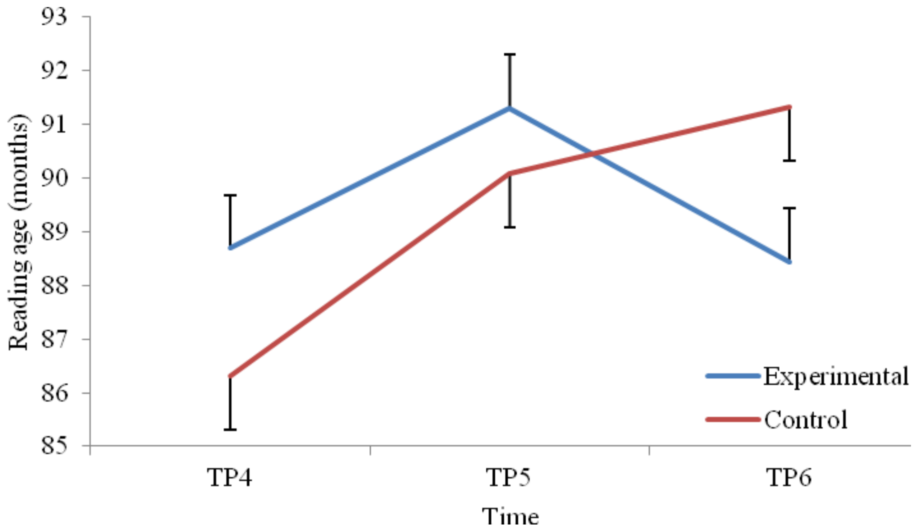

Figure 5: Reading age (absolute means), TP4 to TP6

3.1.2 Gender and reading age, study two: Following study cross-over, ANOVA showed a main effect for gender, F (1, 27) = 4.69, p = .039, η_p^2 = .15 (Figure 6). At TP5 a rise in reading age was reported for each gender. The girls exhibited greater gains compared to the boys between TP4 and TP5, approximately five months in contrast to around one month. However, re-assessments at TP6 reported a decline of almost one month in both the girls' and boys' reading age. Analysis using ANCOVA also reported a significant main effect for gender, F (1, 23) = 4.84, p = .038, η_p^2 = .17 (Figure 7).

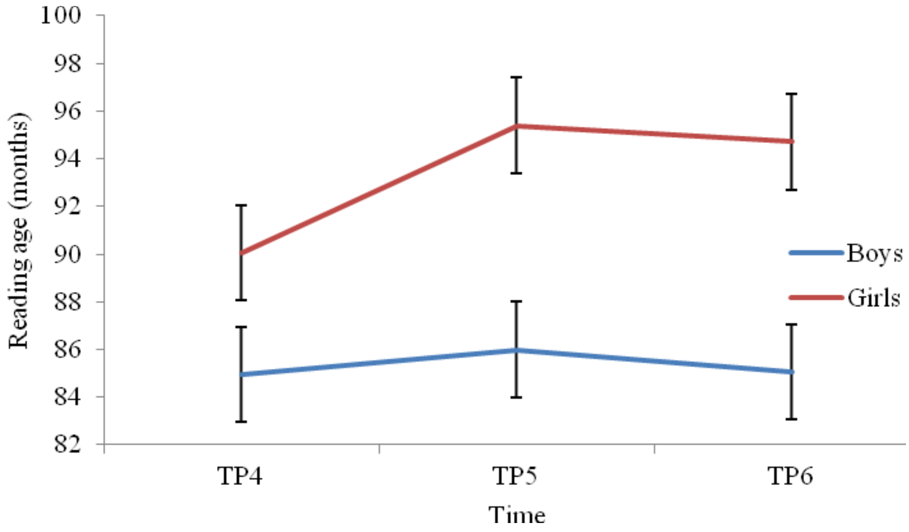

Figure 6: Gender effect on reading age (absolute means), TP4 to TP6

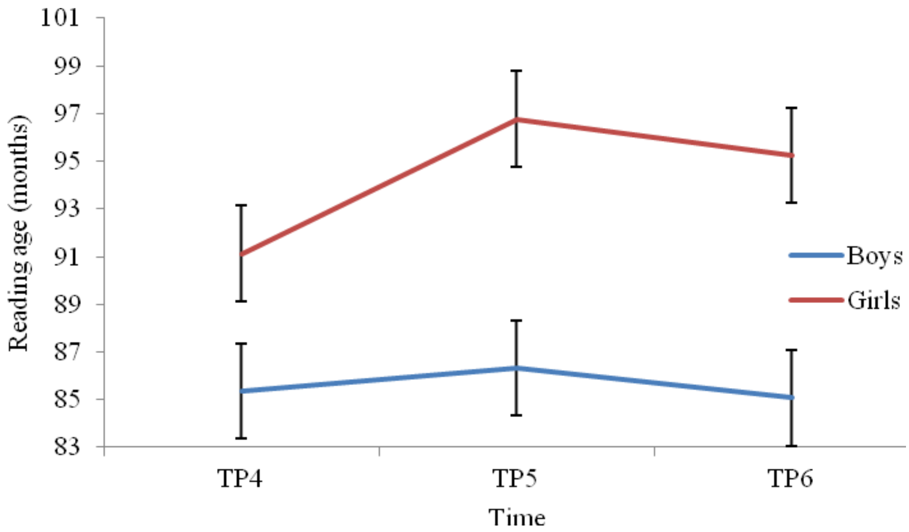

Figure 7: Gender effect on reading age, TP4 to TP6

One-way repeated measures ANOVAs were conducted in order to further explore the significant gender effect on reading age. Separate one-way repeated ANOVAs were run for each subgroup (boys/experimental, boys/control, girls/experimental, girls/control). Analysis was subsequently repeated, controlling for BMI and HPA. Descriptive statistics are presented in Table 1.

Table 1: Descriptive statistics for reading age (months) assessed at TP4 to TP6

	Mean (Standard deviation) reading age		
	TP4	**TP5**	**TP6**
Boys			
Control (*n* = 8)	***82.50 (12.72)/ 84.00(12.95)**	***81.75 (10.59)/ 83.14 (10.62)**	***83.38 (10.61)/ 84.71 (10.70)**
Experimental (*n* = 8)	**87.38 (8.52)**	**90.25 (10.55)**	**86.75 (9.74)**
Girls			
Control (*n* = 7)	**90.14 (8.01)**	**98.43 (11.90)**	**99.29 (11.77)**
Experimental (*n* = 8)	***90.00 (12.08)/ 91.43 (12.30)**	***92.38 (11.59)/ 94.29 (11.07)**	***90.13 (12.67)/ 89.71 (13.62**

*** Unadjusted vs. adjusted**

No significant differences were reported with or without the inclusion of covariates for the boys' experimental group (BMI at 17.50 kg/m^2 and HPA at 10199.77 steps), or girls' experimental group (BMI at 18.21 kg/m^2 and HPA at 8193.13 steps). For the boys control group significant differences were detected after adjusting for covariates BMI (at 16.27kg/m^2) and HPA (at 9490.7 steps), a main effect for time was reported, F (2, 8) = 10.50, p = .006, η_p^2 = .72, although Bonferroni and LSD pairwise comparisons reported no further significant differences. For the girls control group a significant effect for time was reported, F (2, 12) = 5.06, p = .026, η_p^2 = .46. Bonferroni was unable to detect any significant differences, so tests were conducted using LSD, which reported that reading age assessed at TP5 (mean diff = 8.29, *p* = .016) and TP6 (Mean diff = 9.14, *p* = .037) were significantly higher than baseline reading age (TP4). After adjusting for the potential influence of BMI (at 16.44 kg/m^2) and HPA (at 9018.76 steps), significant differences were no longer detected.

3.2 Group (experimental/control) differences in standardised reading scores

Study one: A mixed between-within subjects ANOVA was conducted in order to investigate the impact of the movement intervention on standardised reading scores, pre-intervention (TP1), post-intervention (TP2) and two weeks post-intervention (TP3). No significant main effects or interactions were reported. Figure 8 shows the change in standardised from baseline (TP1) to post-intervention (TP2), and from post-intervention to two weeks post-intervention for both the experimental group and control group. However, ANCOVA reported a significant main effect for time, (Wilks Lambda = .75, F (2, 22) = 3.75, p = .040, η_p^2 = .25). Standardised scores showed that the experimental group commenced ahead of the control group by approximately one mark. However, at TP2 a drop in standardised scores was experienced by the control group and the experimental group, approximately one mark and just over 3.5 marks respectively. By TP3 an overall improvement in performance resulted in comparable standardised levels of reading attainment. Post-hoc comparisons using Bonferroni revealed that the mean standardised reading scores measured at TP2 were significantly lower in comparison to scores measured at TP1 (Mean diff = 2.47, *p* = .028, Figure 9).

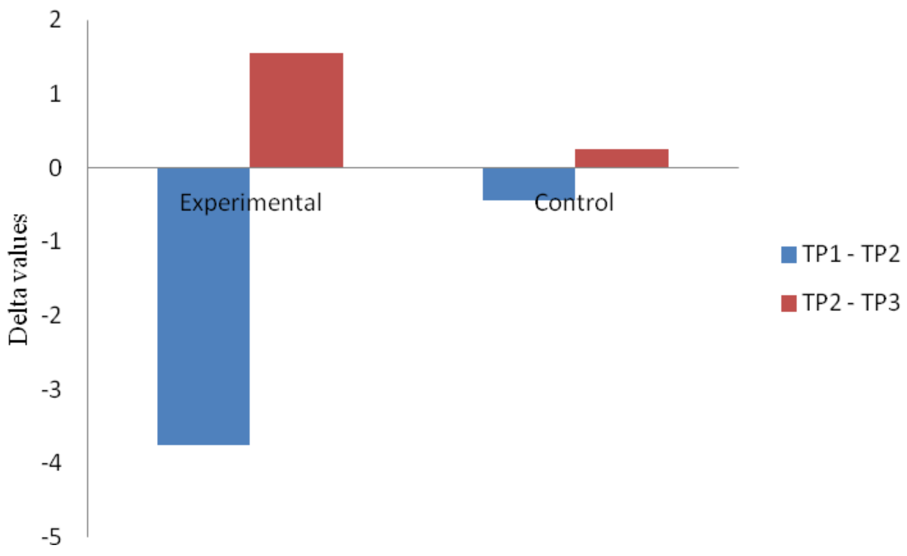

Figure 8: Differences in absolute mean standardised reading scores, baseline (TP1) to 2 weeks post-intervention (TP3)

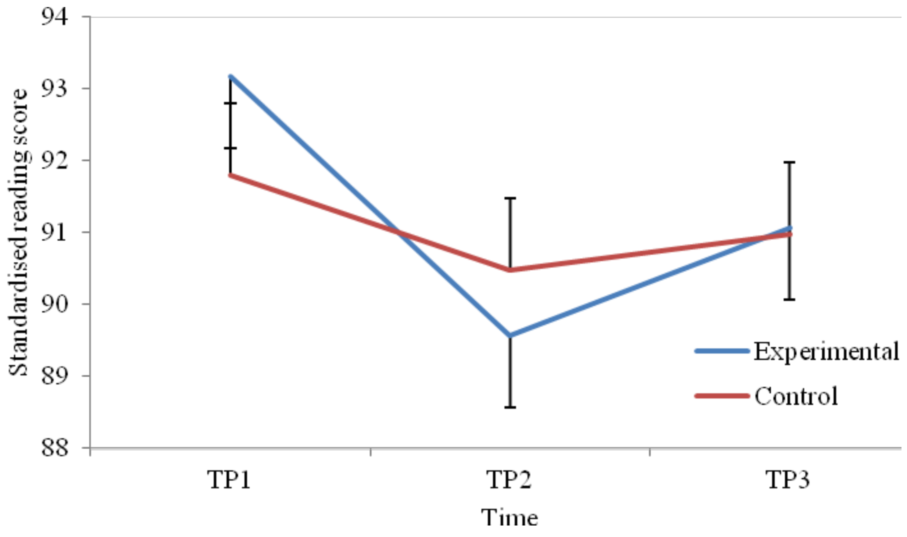

Figure 9: Mean standardised reading scores, baseline (TP1) to 2 weeks post-intervention (TP3)

Study two: Following study cross-over ANOVA reported no significant main effects or interactions in terms of standardised readings scores. At TP5 a rise in standardised scores was reported for both groups, however, by TP6 improvements continued for the control group only as deterioration was observed in the experimental group's performance. Overall, attainment declined by 1.88 standardised marks in the experimental group and increased by 1.69 standardised marks in the control group. ANCOVA reported no significant main effects or interactions (Figure 10).

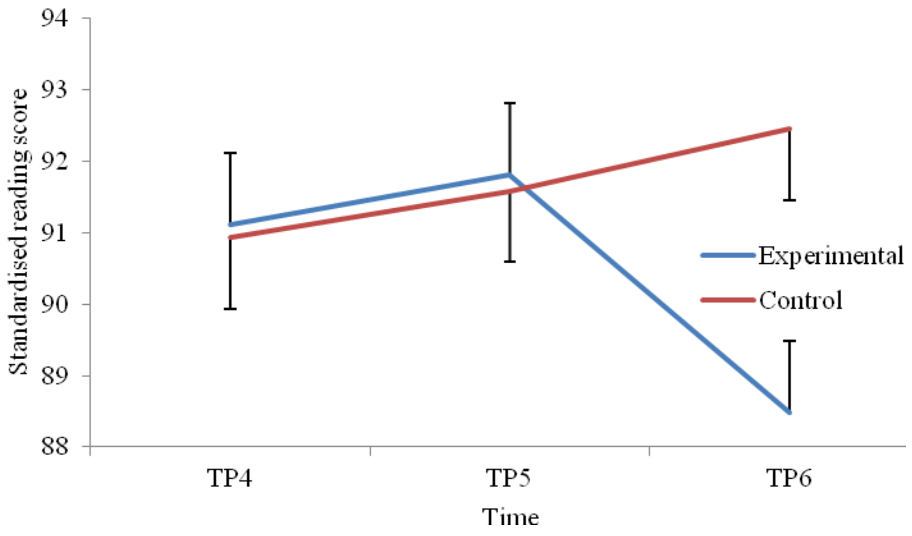

Figure 10: Mean standardised reading scores, TP4 to TP6

Control variables: BMI and HPA levels did not make any significant contributions to reading performance.

3.3 Group (experimental/control) differences in mathematical performance, study one: ANOVA reported a significant interaction between time, gender and group was found, (Wilks Lambda = .74, F (2, 26) = 4.56, p = .020, η_p^2 = .26). In addition, results showed a significant gender by group interaction, F (1, 27) = 7.03, p = .013, η_p^2 = .21. Improvements were observed at TP2 in the girls' experimental group and the boys' control group; however, this was followed by a decline in scores by TP3. Contrasting results were exhibited by the boys' experimental group and girls' control group. (Figure 11-12)

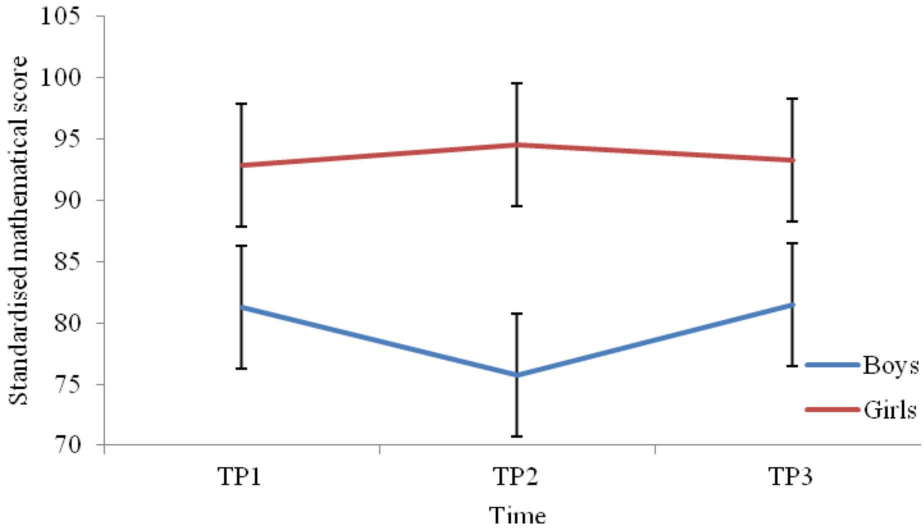

Figure 11: Experimental group's absolute mean standardised mathematical scores

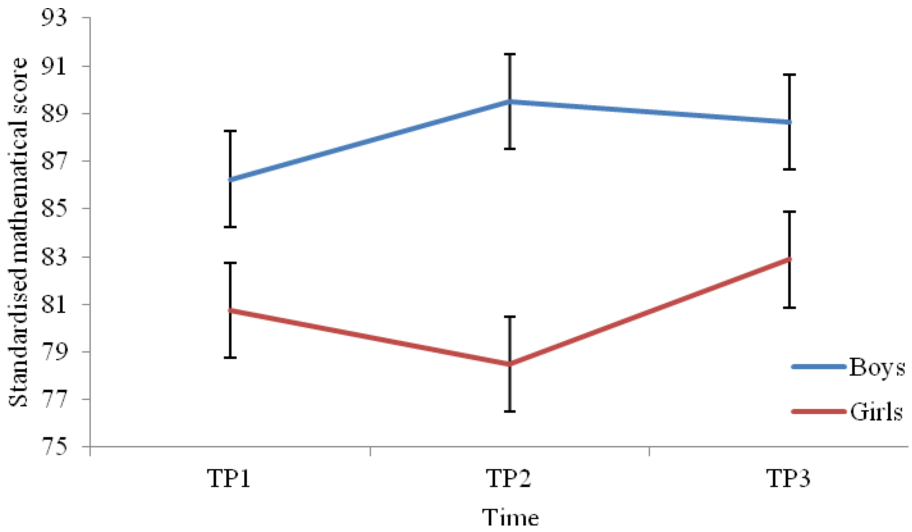

Figure 12: Control group's absolute standardised mathematical scores

ANCOVA reported a significant interaction between time, gender and group, (Wilks Lambda = .71, F (2, 22) = 4.56, p = .022, η_p^2 = .30). Analysis showed no significant main effect for time, gender or group, however, a significant interaction was reported between gender and group, F (1, 23) = 4.59, p= .043, η_p^2 = .17. The plotted data (Figure 13-14) shows how the boys' and the girls' mathematical achievement tended to score in opposing directions. For the experimental group, results show how scores fell for the boys and raised for the girls at TP2, yet by TP3 the girls experienced a drop in scores whilst the boys exhibited an improvement. The same pattern in achievement but in the opposite gender was observed in the control group.

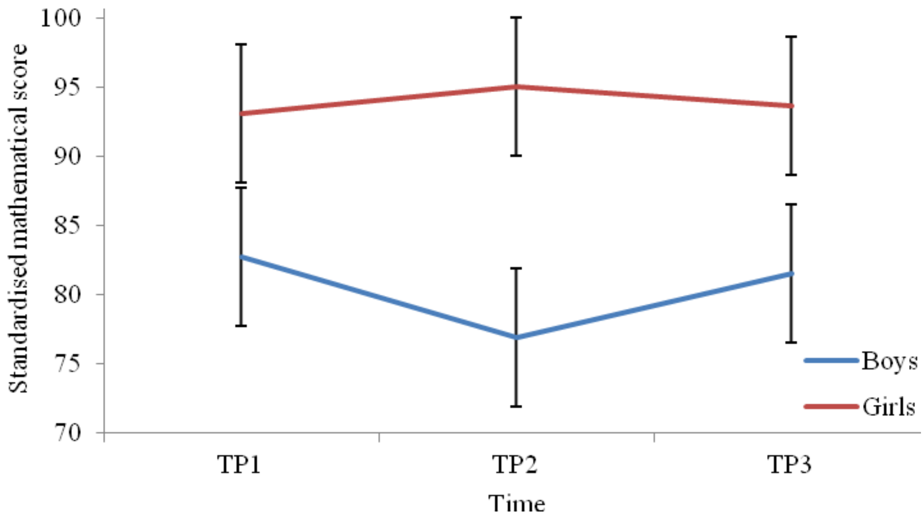

Figure 13: Experimental group's standardised mathematical scores

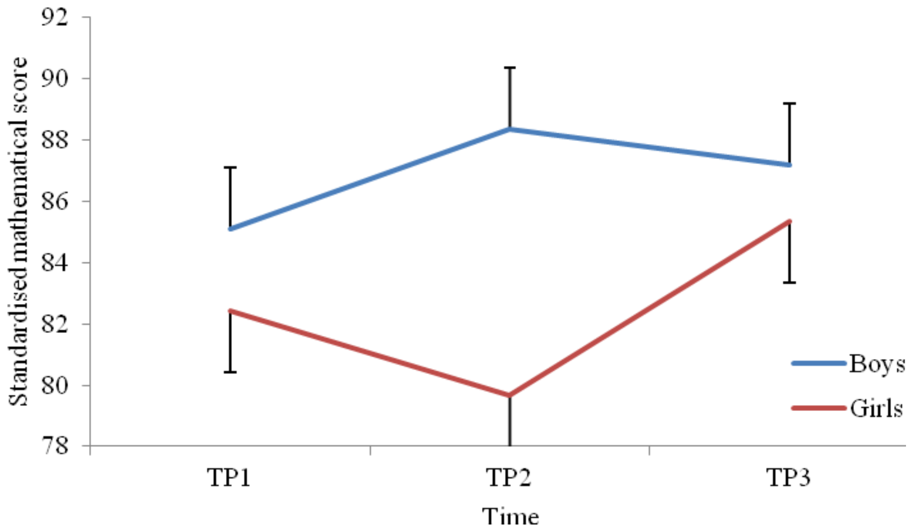

Figure 14: Control group's standardised mathematical scores

One-way repeated measures ANOVAs were conducted to explore the significant interaction effects found for the sample's mathematical scores. Separate one-way repeated ANOVAs were run for each subgroup (boys/experimental, boys/control, girls/experimental, girls/control), in order to investigate the interactive effect of gender and group on mathematical scores, and isolate the time point at which the differences were significant. Analysis was subsequently repeated, controlling for the influence of BMI and HPA. No significant differences were reported with or without the inclusion of covariates (Table 2).

Table 2: Descriptive statistics for standardised mathematical scores assessed at baseline (TP1) to two weeks post-intervention (TP3)

	Mean (Standard deviation) mathematical scores		
	TP1	**TP2**	**TP3**
Boys			
Control (*n* = 8)	**86.25 (12.19)**	**89.63 (13.86)**	**88.63 (9.23)**
Experimental (*n* = 8)	***81.25 (16.71)/ 83.00 (17.24)**	***75.87 (10.63)/ 76.86 (11.08)**	***81.50 (10.52)/ 81.86 (11.31)**
Girls			
Control (*n* = 8)	***80.75 (6.56)/ 81.14 (6.99)**	***78.75 (9.05)/ 78.86 (9.77)**	***82.87 (11.58)/ 83.86 (12.14)**
Experimental (*n* = 7)	**92.86 (13.35)**	**94.57 (14.72)**	**93.29 (11.86)**

*** Unadjusted vs. adjusted**

Study two: Following study cross-over ANOVA reported a significant interaction between time, gender and group in relation to mathematical performance, (Wilks Lambda = .75, F (2, 26) = 4.23, p = .026, η_p^2 = .25). There was no significant main effect reported for gender or group, yet a significant interaction between gender and group was found, F (1, 27) = 5.08, p = .033, η_p^2 = .16 (Figure 15 – 16).

In the experimental group, the boys commenced ahead of the girls by approximately six standardised marks. Due to a decline in the boys' performance and a rise in the girls' performance, this achievement gap had reduced to around 1.5 standardised marks by TP5. By TP6 the female experimental scores had risen by just under one mark, yet greater progress was observed in the male experimental group who advanced by six standardised marks. In terms of the control group, slight improvements were observed across both genders between baseline and TP5. However, Figure 16 shows that the steepest rise in standardised scores was observed in the female controls between TP5 and TP6. Between post- and two weeks post-intervention the experimental girls progressed by around nine marks, which in turn took them ahead of the boys by 20 standardised marks at TP6.

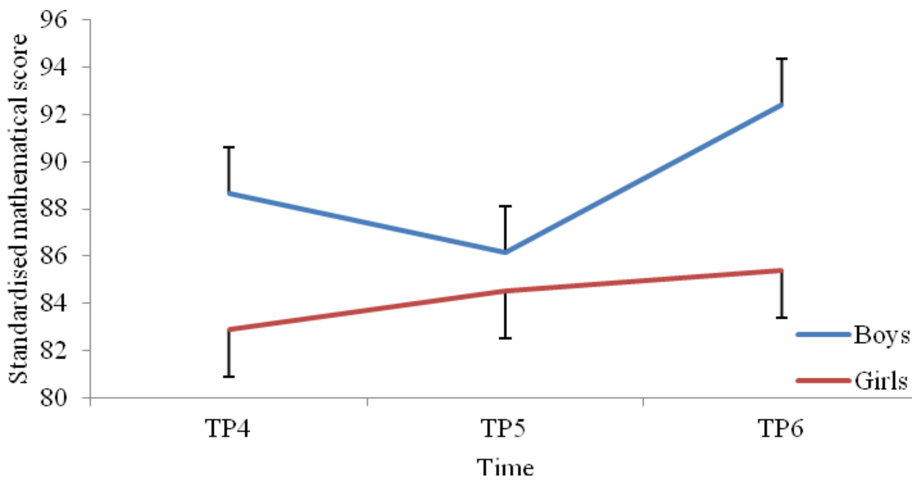

Figure 15: Experimental group's absolute standardised mathematical scores TP4-TP6

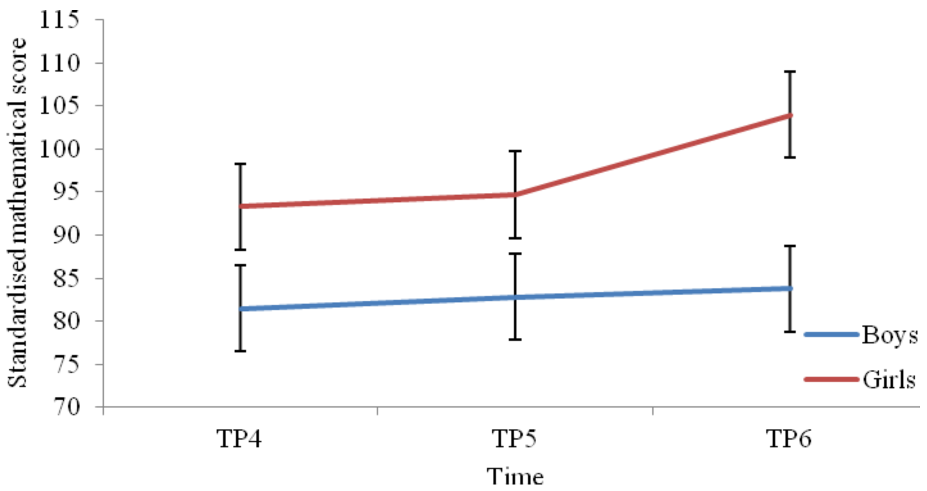

Figure 16: Control group's absolute standardised mathematical scores TP4-TP6

One-way repeated measures ANOVAs were conducted in order to further explore the significant results the interaction effects reported for mathematical performance. Separate one-way repeated ANOVAs were run for each subgroup (boys/experimental, boys/control, girls/experimental, girls/control). Analysis was subsequently repeated, controlling for BMI and HPA. No significant differences were reported with or without the inclusion of covariates for the boys experimental group, however, for the girls control group a significant effect for time was reported, F (1.14, 6.82) = 8.63, p = .021, η_p^2 = .59 (Table 3), with a Greenhouse-Geisser correction. Bonferroni was unable to detect any significant differences, so tests were conducted using LSD, which reported that mathematical standardised scores measured at TP6 were higher when compared to scores collected at TP4 (Mean diff = 10.71, p = .022) and TP5 (Mean diff = 9.29, p = .026). After adjusting for the potential influence of BMI (at 16.44 kg/m^2) and HPA (at 9018.76 steps), a main effect for time was reported, F (2, 8) = 6.26, p = .023, η_p^2 = .61. The significant differences remained when tests were repeated using Bonferroni: scores collected at TP6 were higher when compared to scores collected at TP4 (Mean diff = 10.71, p = .031) and TP5 (Mean diff = 9.29, p = .027).

Table 3: Descriptive statistics for standardised mathematical scores assessed at TP4 to TP6

	Mean (Standard deviation) mathematical scores		
	TP4	**TP5**	**TP6**
Boys			
Control (n = 8)	***81.50 (10.52)/ 81.86 (11.31)**	***82.75 (10.85)/ 82.71 (11.72)**	***83.75 (10.44)/ 83.75 (11.27)**
Experimental (n = 8)	**88.63 (9.23)**	**86.13 (12.64)**	**92.38 (17.53)**
Girls			
Control (n = 7)	**93.29 (11.86)**	**94.71 (12.79)**	**104.00 (16.47)**
	***82.87 (11.58)/ 83.86 (12.14)**	***84.50 (12.40)/ 84.71 (13.38)**	***85.37 (13.59)/ 87.14 (13.64)**

*** Unadjusted vs. adjusted**

ANCOVA reported no significant main effects for time, group or gender in terms of mathematical performance. A near significant interaction was found between time, gender and group, Wilks Lambda = .76, F (2, 22) = 3.41, p = .051, η_p^2 = .24 (Figure 17 - 18).

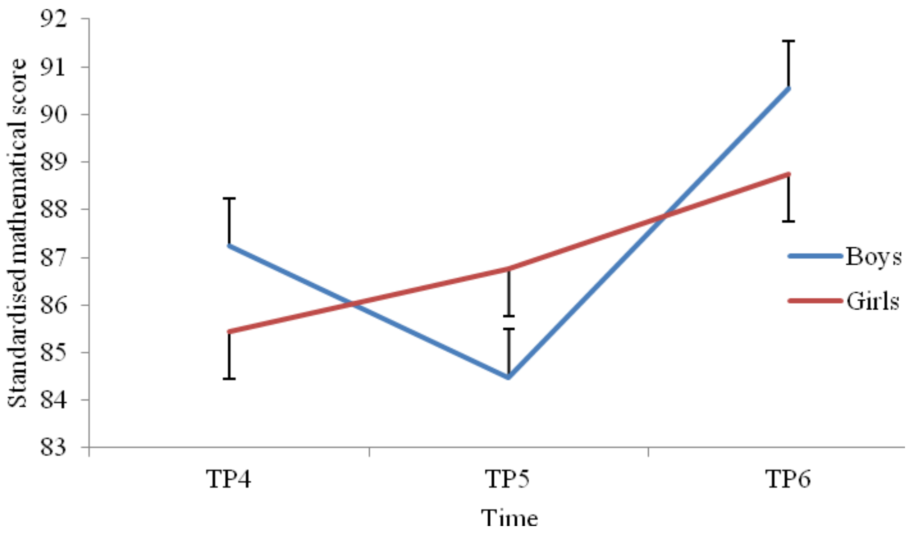

Figure 17: Experimental group's standardised mathematical scores

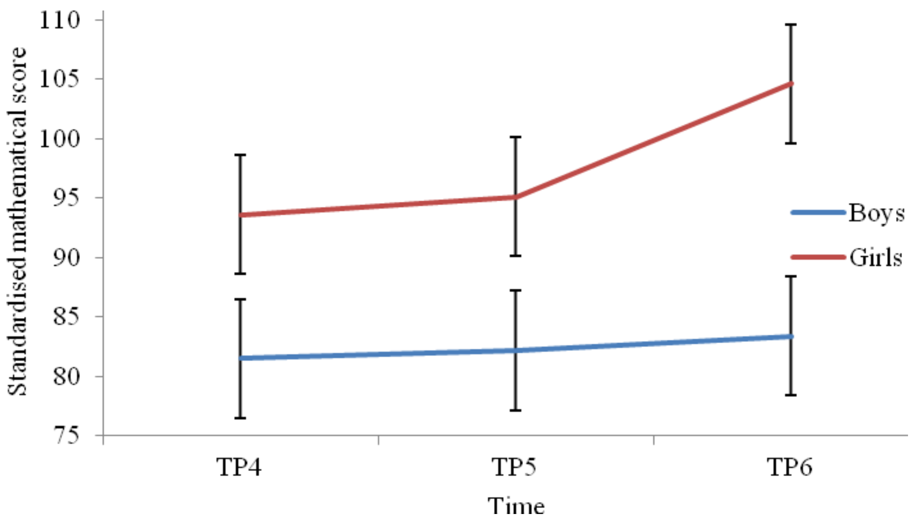

Figure 18: Control group's standardised mathematical scores

Control variables: Although BMI did not make any significant contributions to mathematical performance, tests showed a significant association between mathematical standardised scores and HPA, assessed across all three occasions post study cross-over. Results indicated that increased levels of physical activity were linked with higher mathematical scores (Table 4).

Table 4: Association between mathematical standardised scores and HPA (average step count)

Time point	β (beta value)	*p*	η_p^2 (partial eta-squared)
4	.001	.027	.19
5	.002	.017	.22
6	.002	.047	.16

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3.4 Results summary

Reading performance: For study one, mixed between-within subjects ANOVA, yielded no significant differences between the experimental and control group's reading performance, with both groups exhibiting an overall deterioration by study one's final assessment.

When covariates BMI and HPA were controlled for, a significant main effect for time in relation to reading performance was found. For reading age, an overall gain of approximately 2 months was reported for the control group, whilst no overall progress was experienced by the experimental group. In contrast, when performance was interpreted as standardised scores, deterioration in reading performance was observed: an overall decline of around one standardised mark for the control group, and 3.5 standardised marks for the experimental group.

For study two, statistical analysis showed the two study conditions did not differ significantly in terms of their impact on standardised reading scores, with or without adjusting for confounding variables. The control group experienced an overall gain in standardised scores whilst the new experimental group exhibited an overall decline in standardised scores.

For reading age a significant main effect for time was reported (yet failed to reach significance when covariates were controlled for), with both groups exhibiting significant gains between baseline and post-intervention (TP4 to TP5). However, at final assessment (TP6) these improvements in reading age were only sustained by the control group. Mixed between-within subjects ANOVA and ANCOVA also reported a significant gender effect in relation to reading age: the girls showed gains up to six times greater than their male peers when assessed post-intervention. Yet improvements in reading age were not sustained, as declines were exhibited by both genders when assessed two weeks post-intervention. After controlling for BMI and HPA, reading age was analysed separately for each sub-group: a significant main effect for time was found for the male controls, with an overall gain of nearly one month reported; and a main effect for time was reported for the female controls, with a more marked overall increase of approximately nine months.

Mathematical performance: Analysis using mixed between-within subjects ANOVA and ANCOVA reported a significant time by gender by group interaction, as well as a significant gender by group interaction, for mathematical performance over the course of study one. Performance measured post-intervention showed how the boys and girls in each group tended to respond in opposing directions: for the experimental group, a fall in the boys' performance compared to improved performance for the girls; and for the control group, a rise in the boys' scores compared to a decline in girls' scores. For study one, an overall assessment of mathematical attainment found performance had improved in relation to each subgroup with the exception of the male experimental group.

For study two, mixed between-within subjects ANOVA was only able to find a significant time by gender by group interaction and a gender by group interaction when covariates BMI and HPA were not controlled for. Post-hoc analysis using LSD, found significant differences in standardised scores were isolated to the female control group, with attainment levels at TP6 being significantly higher than their previous two assessments. After adjusting for covariates BMI and HPA, Bonferroni found that the aforementioned differences remained.

Throughout the study HPA was found to make a significant contribution to the participants' mathematical attainment, with increased levels of HPA associated with improvement mathematical performance.

Chapter 4

Discussion

4.1 The impact of the movement intervention on reading performance

The aim of this study was to explore the impact of a developmental movement intervention on the academic performance of Year 3 primary school children. In terms of reading performance, mixed between-within subjects ANCOVA yielded a significant main effect for time, following first delivery of the intervention. However, the direction of reading performance is presented differently dependent on the scoring used, i.e. reading age or standardisation, in that reading improved when expressed as reading age. Consideration needs to be given to whether reading age gains were partly due to maturation effects, given the fact that the children had increased in chronological age by the time post-intervention assessments were conducted. The educational significance of reading gains when expressed as reading age can be calculated using a ratio gain (RG) formula (Brooks, 2002). A RG allows for the time period over which an intervention has made its impact by dividing the readings age gain in months by the time passed from baseline to post-assessment in months (Brooks, 2002). As a guide, a RG of less than 1.4 denotes an impact which is not educationally significant whereas a RG greater than 1.4 is considered educationally significant (Brooks, 2002). The overall reading gains linked to reading age were more marked in the control group, however, in terms of its educational significance the RG of .7 represented a weak impact (Brooks, 2002). One viewpoint, with respect to the control groups' superior performance, is that these gains were partly down to a John Henry effect (Kocakaya, 2011). Certain educational studies have found that when students are aware that they are part of a control group, they demonstrate compensatory rivalry by working harder (Kocakaya, 2011). Future research would benefit from recommendations to isolate the control group and experimental group, in order to reduce the chance of such a reactive effect and, in turn, minimise the threat to the study's internal validity (Kocakaya, 2011). In terms of standardised scores, study participation appeared detrimental to both groups, though deterioration was three times worse for the experimental group. Following the first administration of the intervention, both groups started to demonstrate improvements in all measures of reading performance. These improvements continued until post-intervention of study two.

In contrast to study one, when the second administration of the movement intervention had ceased, at two weeks follow-up a decline in both measures of reading performance was observed, with continued improvements restricted to the new control group's standardised reading scores. The most significant gains in reading age were experienced by the male and female controls.

On the whole, the results have reported variable performances; however, when the reading data was standardised in order to allow comparisons to be made against students of comparable chronological age, deterioration had occurred between study inception and study end. Standardised reading assessments take into account that students are getting older (Brooks, 2002). However, as certain studies (McPhillips, Hepper, and Mulhern, 2000) present their results in terms of reading age, the present study included this unit of reading measure also in order to facilitate cross-study comparisons. The failure to detect any significant group by time interactions along with the overall deterioration in standardised reading scores, suggests that the repetition of specific developmental movements did not benefit reading performance over and above conventional teaching methods, hence contrasting with previous research (Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, Wahlberg and Ireland, 2005). Conversely it is acknowledged that the use of standardised assessments, which have been based upon the norms of children who speak only one language, may not have been appropriate for the study's multiethnic sample (Mahon and Crutchley, 2006). In line with recommendations, it would profit future work to assess the reading performance of children with EAL who are not experiencing reading difficulties against monolingual children, to determine what is typical for children with EAL (Mahon and Crutchley, 2006). Issues surrounding the multiethnic nature of the current sample are examined further on in the discussion. Alternatively, there may have been insufficient time, given that an eight to nine month time frame is usually employed (Goddard Blythe, 2005), for any neurological improvements to have been firmly established by the time the original experimental group were assessed. As a result the testing was possibly conducted far too early for significant associated improvements to have been detected (Goddard Blythe, 2005). One may argue that the significant gains in reading age exhibited by the original experimental group (final control group) at the conclusion of study two were the delayed treatment effects. The final experimental group would need to undergo further assessments in order to investigate whether they too experienced a delay in reading age gains.

4.2 The impact of the movement intervention on mathematical performance

For study one a significant time by gender by group interaction, as well as a significant gender by group interaction were reported for mathematical performance. An observation of the results collected over this time period revealed many opposing responses. For instance, the results collected post-intervention indicated that the movement intervention appeared beneficial to the girls' mathematical achievement and detrimental to the boys' performance, whilst conventional teaching conditions appeared beneficial to the boys' attainment and detrimental to the girls'. The responses corresponding to the cessation (at TP3) of the initial intervention cannot be easily interpreted: one may partly attribute the decline in the girls' attainment levels and the improvement exhibited by the male experimental group, as further support for the earlier supposition that the impact of the movement intervention was gender specific, beneficial for the girls and unprofitable for the boys. Yet, this theory is challenged by the marked improvement exhibited by the female controls between post- and two weeks post-intervention under conventional teaching conditions. Although the mathematical performance measured over three time points (baseline, post- and two weeks post-intervention) involved many peaks and troughs during the course of study one, in summary the results contrasted with previous research (Jordan-Black, 2005), as the greatest progress was associated with conventional teaching conditions, a group gain of approximately four standardised marks for the controls compared to a group relapse of just over half a standardised mark for the experimental group.

Akin to study one, results (although not statistically significant) pertaining to the new experimental group, indicated that the boys' mathematical attainment did not respond well to the movement intervention. An average decline of approximately 2.5 standardised scores was observed between baseline (TP3) and post-intervention whilst cessation was linked with an increase in scores. The only sub-group associated with significant improvements during study two were the female controls. As briefly discussed in the previous sections, supporters of the developmental movement programme may argue that although these significant gains followed a period of conventional tuition, attainment may have been partly facilitated by delayed treatment effects (Goddard Blythe, 2005), which in this instance seemed to have been moderated by gender. Whether one attributes the aforementioned progress to carry-over effects or the result of returning back to conventional tuition, the greatest mathematical progress over the course of study two was associated with the control group.

4.3 Contrasting the present findings with prior movement interventions

The diversity in study design and methodology may to some extent explain why the present results contrast with earlier findings. Firstly, due to the time constraints of the academic timetable, the present intervention was delivered over a nine week period as opposed to the nine to 12 months time frame employed by previous studies (Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005). This disparity in delivery time prevents direct comparisons to be made with earlier findings, and may go some way to explain why significant evidence to support the efficacy of the movement intervention could not be clearly detected. For ethical reasons the current study wanted to allow every participant the opportunity to experience the intervention, which restricted the testing and administration time available.

Secondly, there is research to show that there are a number of confounding variables which may have influenced the strength of previous findings. For instance, boys have been associated with significantly higher levels of persistent primitive reflexes (Jordan-Black, 2005, and McPhillips and Sheehy, 2004), yet research into the efficacy of movement interventions has failed to investigate gender as a possible moderator (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005). In fact the gender ratio of recruited samples used has often been left undisclosed (Goddard Blythe, 2005, Jordan-Black, 2005, and Wahlberg and Ireland, 2005). The majority (58%) of the present study sample were from ethnic minority backgrounds and around half of the sample was entitled to free school meals. However, the number of interacting factors which have been found to influence academic and cognitive performance and which have not been controlled for in the previous research, such as PA levels (e.g. Hillman *et al.*, 2009), weight status (Taras and Potts-Datema, 2005), SES (Marchant and Hall, 2003, and McPhillips and Jordon-Black, 2007), and ethnicity (Connolly, 2006, and Sammons, 1995), demonstrate how the efficacy of the movement-intervention should not have been judged in isolation. This presents a problem when trying to generalise previous work with an ethnically diverse population who are largely from low socioeconomic backgrounds when free school meal entitlement is used as a measure of poor SES. The impact of how ethnicity and SES may have impacted upon the present findings is discussed in the following section.

Thirdly, the lack of transparency associated with previous work, such as the failure to describe intervention content (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005) prevents study replication and therefore the inability to compare and reach more informed decisions about reported findings. However, the limited information made available to the reader, illustrated a number of variations between the movement interventions. Jordan-Black (2005) administered the Primary Movement programme to whole class groups for one academic year with action songs and rhythms as accompaniments, whereas McPhillips, Hepper, and Mulhern (2000) sampled children with low reading ability and requested they complete the intervention at home for 12 months without teacher supervision and action songs. As a result McPhillips, Hepper, and Mulhern (2000) had limited insight into their participants' level of compliancy as they relied heavily on the children's motivation not only to complete their daily developmental exercises, but also in the manner intended. In contrast, research into the effects of PA such as treadmill walking (e.g. Hillman *et al.*, 2009) have demonstrated they have been able to manipulate the intensity of exercise performed by each participant and in doing so maintain a certain level of consistency in treatment being received. The Primary Movement programme and the INPP programme are both based upon the replication of primitive reflexes, yet unlike studies into the effectiveness of the Primary Movement programme (Jordan-Black, 2005, and McPhillips, Hepper, and Mulhern, 2000), a review of the INPP intervention found that its impact on educational progress was insignificant (Goddard Blythe, 2005). One may question why two very similar approaches have produced contrasting results. Variations in delivery may have contributed yet the lack of transparency highlights the difficulty in trying to answer such a question.

A fourth inconsistency between studies is demonstrated in the range of assessments used to evaluate the intervention's impact on literacy skills. Jordan-Black (2005), and Wahlberg and Ireland (2005) focused primarily on word decoding skills, whereas McPhillips, Hepper, and Mulhern (2000) measured both word decoding, components of phonological processing and comprehension skills. Goddard-Blythe (2005) did not show how reading ability was assessed, with progress sometimes presented via reading scores or reading ages. Previous research has tended to focus mainly on word decoding ability; however, the fundamental goal of reading is comprehension (Keenan, Betjemann and Olson, 2008). Reading competence relies on both word decoding skills and the ability to extract meaning (Keenan, Betjemann and Olson, 2008). An assessment tool should aim to measure the skills with which an intervention maintains to improve (Duff and Clarke, 2011) therefore, the present study regarded a test of reading comprehension (*The Group Reading Test II, 6-14,* NFER Nelson, 2005) to be more a appropriate test of reading.

The present study employed a group administered reading test (*The Group Reading Test II, 6-14,* NFER Nelson, 2005), which been employed in prior reading studies (Logan and Medford, 2011, Logan, Medford, and Hughes, 2011). The test required participants to solve 43 sentence completion questions from a multiple choice of 5 words. Unlike the Neale analysis of reading ability (employed by McPhillips, Hepper, and Mulhern, 2000), in which the assessor will interrupt to correct any mistakes in word reading, and potentially impair understanding as the available material is disjointed and unfocused (Spooner, Baddeley, Gathercole, 2004), the GRT requires the participant to decode silently to themselves without assistance. Following successful decoding, comprehension of the decoded words demands semantic (understanding word meanings) and morphosyntactic (grammatical) skills (Hulme and Snowling, 2009) for successful completion of the GRT. Although by utilising the GRT, demands associated with the NARA such as the need for expressive speech skills (see Spooner, Baddeley, Gathercole, 2004), were avoided, the group administration required the participants to possess enough motivation to continue with the assessment without the encouragement that may be offered in an individually administered test (Logan, Medford, and Hughes, 2011).

This brief look at some of the reading measures used show that each assessment demands a range of skills, for instance: Jordan-Black (2005) evidenced progress in decoding skills which would have relied heavily on phonological skills (Hulme and Snowling, 2009); conversely McPhillips, Hepper, and Mulhern (2000) and the present study evidenced the results of two very different tests of comprehension which both required skills beyond comprehension such as expressive language skills and intrinsic motivation. The tendency to employ reading tests interchangeably implies that researchers are under the impression that the same skill is being measured (Keenan, Betjemann, and Olson, 2008). However, a test of this unspoken assumption found that although measures of word reading correlated highly, modest intercorrelations between comprehension tests indicated different skills are sometimes being assessed (Keenan, Betjemann, and Olson, 2008). As different tests assess different aspects of language and different skills, this will influence the answers to research questions as we may not all be measuring the same skill (Keenan, Betjemann, and Olson, 2008). Future work should utilise a range of measurement tools when assessing reading performance given that one test cannot assess all aspects of language such as word recognition, spelling and comprehension. Furthermore, it has been underlined at the start of the chapter that reading tests which have been based upon the norms of monolingual children are not appropriate for children learning EAL, as assumptions cannot be made that their acquisition of English follows the same pattern (Mahon and Crutchley, 2006). In such situations, the Royal College of Speech and Language Therapists (2007) recommend an assessment of the child's competency in their native language and English.

Interest in how developmental movements impacted upon other academic areas besides reading ability was limited to the study conducted by Jordan-Black (2005). The current study was interested to explore whether the professed benefits associated with developmental movement interventions extended to arithmetic skills, as mathematical difficulties (MD) often coexist with reading difficulties (e.g. Geary, 2004, and Mazzocco and Myers, 2003). There have been fewer studies into MD compared to reading disabilities, potentially due to the fact that arithmetic development is far more complex and difficult to comprehend (Hulme and Snowling, 2009). The answer to a mathematical problem can usually be reached via a number of different strategies or procedures which as a result complicates the study of its development (Hulme and Snowling, 2009). However, children with mathematical difficulties often have problems with counting principles and use immature, effortful strategies to solve arithmetic problems (Geary, 2004). There is a lack of consensus regarding the classification of MD, hence variability in incidence rates may arise depending on the measurement tool used (Mazzocco and Myers, 2003). Geary (2004) has proposed that there are three subtypes of MD: procedural, semantic memory and visuospatial. However, standardised tests such as those employed by Jordan-Black (2005) and the current study, do not identify in which areas any deficits may lie (Geary, 2004, and Hulme and Snowling, 2009) and consequently which competencies have improved post-intervention. Therefore, it is difficult to make direct comparisons with previous findings (Jordan-Black, 2005) given the influence that different measurement tools can have on study outcomes.

Research into movement interventions have indicated that educational attainment can benefit significantly (Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005) or in some cases insignificantly (Goddard Blythe, 2005). However, in terms of neurological scores, this approach has been consistently associated with significant decreases in levels of retained reflexes (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005). Although observation of baseline levels in relation to ATNR persistence for children in primary school years 3, 5 and 7, has shown a steady decrease year on year (Jordan-Black, 2005). This elicits uncertainty regarding the degree of influence external factors such as movement interventions have in the inhibition of persistent reflexes, and the impact maturation may have on the intervention's effectiveness. Jordan-Black (2005) failed to provide the ATNR levels pre- and post-intervention for the control groups so this query could not be explored further. Based on the significant academic gains reported in association with a whole class approach (Jordan-Black, 2005), the present study focused on the efficacy of improving learning performance rather than the impact on retained reflexes. It is possible that the movement intervention is only beneficial for a specific population since previous findings have shown that those with low levels of retained reflexes have been less responsive (Goddard Blythe, 2005, and Jordan-Black, 2005). The participants sampled for this study may not have had a sufficient level of retained reflexes in order to benefit from the intervention. Further research is needed into whether the effectiveness of the intervention is specific to certain populations.

A review of prior work has underlined the inconsistencies in employed methodologies. At present there is a paucity of evidence to support the efficacy of movement interventions in relation to their impact on academic attainment. Furthermore different measurement tools which vary in what aspects of literacy and arithmetic they assess are being used to reach the same conclusion, that the rehearsal of specific movement patterns impacts positively on reading and mathematical difficulties. In addition, previous studies have failed to include the potential influence of confounding variables which may have provided alternative explanations for their findings. Variability in research design, measurement tools, populations, statistical analysis and lack of transparency have made it difficult to make direct comparisons and highlighted some of the reasons which may explain why the present results did not concur with prior research.

4.4 Detrimental effects of study participation on reading performance

The decline observed in overall standardised reading scores between inception and study conclusion conflict with previous work (Jordan-Black, 2005, McPhilips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005). Although evidence has shown that allocating more time for physical activities during the school timetable does not compromise school performance (Ahamed *et al.,* 2007) results indicated that study participation was detrimental to children's standardised reading scores. Possible explanations, including the influence of learning as EAL, socioeconomic status, motivation, self-handicapping behaviours and/or self-fulfilling prophecies will now be discussed in turn.

4.4.1 The influence of learning English as an Additional Language

The study sample under investigation was ethnically diverse with only 41.9% categorised as White. Although the study was unable to statistically measure the influence of different ethnic groups on academic performance given its categorical nature violated the chosen tests assumptions, it is still important to consider the well documented links with respect to attainment and ethnicity, in particular the influence of English as an Additional Language (EAL). The school records made available to the current study did not disclose whether any of the recruited participants had EAL, yet children from ethnic minority backgrounds tend to be learning EAL (Department for education and skills, 2007) and it is reported that on occasion English is recorded as the first language, although other languages are spoken in the home (Department for Children, Schools and Families, 2009). Consideration needs to be given to the possibility that the initial classification of having a reading age below that of the national average may have been a failure to differentiate between reading difficulties and language proficiency for a proportion of the sample from ethnic backgrounds. In order to reduce incidences of misdiagnosis the Royal College of Speech and Language Therapists

(2007) recommend an assessment of all languages children with EAL are exposed to. Unfortunately, a lack of standardised tests and qualified professionals available to assess the wide variety of languages spoken by UK students makes this problematic (Mahon and Crutchley, 2006). Therefore, as acknowledged earlier, using a standardised test based on the norms of monolingual children may not have been appropriate and the findings may have partly reflected the complexities of acquiring EAL, rather than learning difficulties.

A review of the literature has demonstrated that many factors influence the acquisition of a second language. As noted by earlier research (Hammer *et al.*, 2009) it may be the case that the families, of those from ethnic backgrounds, have been increasing the use of English in the home in an attempt to help their child's progression in society. This can impede the development of the child's native language and, as a result, a loss of proficiency in both the first and second language (Jitendra and Rohena-Diaz, 1996). Furthermore, the reported links between certain Asian and Black groups and poor quality home learning environments (Department for education and skills, 2007), may have compounded the disadvantage that a proportion of the sample (29% and 19.4% of the study sample were Asian or Black respectively) may have found themselves in at school commencement. Therefore, the findings may reflect the efforts of children who may have had stimulating experiences, such as support reciting the alphabet or access to books, omitted from development, rather than the opportunity to experience certain developmental movement patterns.

Over time research has shown that the negative impact of EAL gradually reduces, in certain cases, as the school environment offers increased exposure to English (Mahon and Crutchley, 2006, Meirim *et* al., 2010, and Sylva *et al.*, 2004). In addition, it has been argued that students from certain ethnic backgrounds focus their efforts on the examinations which they believe will facilitate social mobility (Wilson, Burgess and Briggs, 2011). It is possible that certain children did not attach any worth to the study's assessments, as they may not have been deemed valuable for their future. Longitudinal research would provide further insight into whether reading performance improves through increased exposure to English and whether the assessment type (i.e. final exams) yields increased effort. In addition, in line with recommendations (Royal College of Speech and Language Therapists, 2007), future research needs to ensure that suitable assessments are being utilised with different populations in order to measure the fluency of both the native and English language. In doing so the chance of misdiagnosis may be reduced and the appropriateness of the support provided increased. Due to the small sample size, the current study was required to combine the different ethnic groups; therefore, a larger sample size would allow further investigation into the role of different cultural backgrounds.

It is apparent that a combination of reasons may explain the low standardised reading scores observed, including the drawbacks of using a standardised assessment on an ethnically diverse population (Mahon and Crutchley, 2006). Reflex inhibition interventions may work for a less diverse population however, previous work in this area of research has failed to investigate the role of ethnicity (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper and Mulhern, 2000 and Wahlberg and Ireland, 2005).

4.1.2 Socioeconomic status

Another factor which needs to be considered is the association between socioeconomic status and achievement. Being in receipt of free school meals (FSMs) was used as an indication of social disadvantage by the current study. The study does acknowledge however, that SES is a complex variable which is determined by a combination of factors including family income, parental education, and occupational status (Ardila *et al.*, 2005). It has been recommended that researchers use more than one aspect of SES in their analysis, as using a single component of SES will most likely overestimate its effect (Sirin, 2005). However, the study was limited to one component of SES due to data availability and resources. Furthermore, the influence of SES on the study results must be interpreted cautiously as this particular variable was categorical and could not included in the statistical analysis as it violated the test's assumptions.

Over half (n = 16) of the recruited sample were in receipt of FSMs, which is a crude indication that a large proportion of the children were from disadvantaged backgrounds (Marchant and Hall, 2003). It has been extensively documented that low SES is linked with underachievement (Akhtar and Niazi, 2011, Bradley and Corwyn, 2002, Dearing, McCartney and Taylor, 2009, Liu and Lu, 2008, McPhillips and Sheehy, 2004, Sastry and Pebley, 2010, and Sirin, 2005), albeit the strength of the correlation has been found to differ according to the measure of SES used (Sirin, 2005 and Yang, 2003). It is also clear from the literature that the association between SES and achievement is highly complex given the multiple factors which determine SES, along with the many conditions that can exacerbate its impact (Bradley and Corwyn, 2002).

Research linking parental education with achievement (McEwan, 2001, and Scott, 2004) and reading attainment (Myrberg and Rosén, 2008) may provide one explanation for the poor reading performance observed in the current study. Parents' years of schooling influences a child's academic performance indirectly through the parents' academic expectations and cognitively stimulating behaviours (Davis-Kean, 2005). As the current sample were categorised with a reading performance below that of the national average, the parents may have deemed it fruitless to invest in a cognitively stimulating home environment due to low expectations of academic success. The evidence that parental expectations can predict academic success (Davis-Kean, 2005) was potentially strengthened by low teacher expectations which are reportedly linked with children of low SES (McLoyd, 1998) and furthermore, children from ethnically diverse backgrounds (Bradley and Corwyn, 2002 and Department for children, schools and families, 2009). Alternatively, low educated parents may not have felt sufficiently educated themselves to support their child academically, with language barriers compounding this problem for certain ethnic minority families.

Another component of SES which needs to be taken into account, given FSM entitlement was used as an indication of SES, is the influence of income. Research has found that financial resources have a stronger impact upon attainment over the investment of parents' time (Altschul, 2011), occupation and education (Sirin, 2005). Hence, economic constraints may have restricted the quantity and quality of cognitively stimulating experiences, important for language development (Dearing and Taylor, 2007), that children eligible for FSMs had access to. As financial pressures are linked with unresponsive and less sensitive parenting behaviours (Barnett, 2008, and Bradley and Corwyn, 2002), the children experiencing difficulties with their reading may not have received the support they required at home.

It is clear that the relationship between SES and attainment is highly complex. The poor reading performance may have been influenced by a combination of interacting factors which cannot be fully understood without a greater understanding of the family background. As the family and school environment work together to influence academic performance (Liu and Lu, 2008), future research would benefit from examining the interventions effectiveness in relation to contextual variables such as parental education, parental occupation, and parental income.

4.4.3 The influence of motivation

Research has linked less skilled readers with low motivation (Morgan and Fuchs, 2007), with evidence that intrinsic motivation and self-referenced perceived competence predict reading performance (Park, 2011). Results from a study of 60 first-grade US students (Morgan *et al.,* 2008) found that less able readers reported lower reading self-concepts compared to the higher skilled students, and suggested that students classified as reading disabled enter first-grade ‘doubly disadvantaged’, given that they are both less skilled and less motivated to read from the onset. An investigation into the influence of intrinsic motivation on the reading comprehension skills of 111 children aged 9-11 years, found that verbal ability and decoding skill explained significant variance in the groups’ overall performance, whilst closer inspection showed that intrinsic motivation was a more significant factor in the progression of low ability readers (Logan, Medford, and Hughes, 2011). Based on prior research, it may be possible that the lack of progress observed in the current standardised scores was in part a reflection of poor intrinsic motivation given that all participants commenced and concluded with a reading performance classified below the national average. Previous work (Logan, Medford, and Hughes, 2011) in which the same reading measure was employed, proposed that poor readers may become exasperated with the lengthy process of trying to decode new words and as a result admit defeat. In addition, the GRT compels participants to self-motivate themselves to completion without the encouragement available during an individually administered test.

Gender differences in the relationship between motivation and reading ability have been reported. Primary school aged boys (Year 3 – 6) competency beliefs in reading and intrinsic motivation have been found to correlate more closely with their reading ability compared to their female peers (Logan and Medford, 2011). A number of possible explanations for this gender difference have been offered: being skilled at reading may be necessary for boys to feel motivated and have belief in their capabilities; boys may be more prone than girls to become disengaged due to a history of negative reading experiences; boys' intrinsic motivation and competency beliefs may influence the amount of effort they devote to reading; or conversely boys are possibly more aware of their actual competencies (Logan and Medford, 2011). Gender differences in reading performance have been observed in the present study with more marked reading gains associated with the girls. Higher levels of reading attainment from the onset may have motivated the girls to invest more effort in the subsequent reading assessments whilst past reading failures, coupled with a self-awareness regarding their capabilities, may have lead the boys to become disheartened and less engaged with the assessments.

4.4.4 The influence of self-handicapping

Self-handicapping signifies avoidance behaviours prior to a test of achievement, which allows failure or poor performance to be attributed to lack of studying rather than incompetence (Graham *et al.*, 2008). In a reading task boys were reported to use self-handicapping techniques more than their female peers: boys tended to donate less time reading the material they had no interest in, which as a result impacted negatively on their comprehension of the text (Graham *et al.*, 2008). The study proposed that as boys tend to approach reading tasks with a negative outlook from the onset, especially when the material is of no interest, this often leads to less time engaged in reading the material and therefore underperformance ensues. Oakhill and Petrides (2007), also found that boys' performance on a reading comprehension test was influenced by their level of interest in the text, whereas the girls' performance was unaffected by whether they were reading low or high interest topics. In accordance with the theory of self-sabotage, having a negative reading self-concept and being confronted with an achievement test may have induced self-handicapping behaviours in the present study (Urdan and Midgley, 2001). A noteworthy finding following study cross-over was the overall nine month gain in reading age exhibited by the female control group. In contrast the boy controls exhibited a one month gain in reading age. The aforementioned results correspond to the latter part of the study when interest in the assessments may have started to decrease. The higher reading gains observed in the girls' reading performance may be related to their ability to persist with text regardless of interest, whilst the boys' reading performance was partly due to lack of interest which may have also have served as a handicapping behaviour. It is also possible that differences in interest may not have stopped with the measures of academic achievement. Girls may have responded more favourably to the developmental exercises themselves, given that research has reported that preferences concerning types of physical activity involvement can differ according to gender (Wilson *et al.,* 2005). Research has shown that self-efficacy tends to influence boys' engagement, in that being skilful in a particular physical activity will tend to increase their motivation to participate (Wilson *et al.,* 2005). By exhibiting a lack of interest in the study assessments and perhaps the developmental exercises also, one can attribute poor achievements to disinterest and in doing so preserve one's self-respect.

4.4.5 Expectancy research

The interpersonal dynamics between the study participants and their corresponding teachers is unknown. However, the school were not instructed to blind the students or teachers from the study's aims and objectives, and in doing so the sampling method may have facilitated the rise of negative self-fulfilling prophecies. Expectancy research has shown that the recipients of positive teacher expectations do well, whilst negative expectations, also termed the Golem effect, impact negatively on student performance (Reynolds, 2007). However, as ethical restrictions associated with the administration of negative expectations in the classroom have led to a shortage of conclusive evidence, further research is necessary (Jussim and Harber, 2005, and Reynolds, 2007). Based on prior research (Reynolds, 2007), one may question whether negative self-fulfilling prophecies were partly in operation during the present 'Fit to Read study. Although the sample's low ability may not have been overtly verbalised by the teaching staff, the participants may have interpreted the act of being singled out for additional help as an expression of the school's low expectations in their present ability. On the other hand, school children are largely familiar with being singled out and assigned to teaching groups according to their ability (Department for Education, 2012), which underlines how their abilities compare in relation to their peers. However, a review into the past 30 years of expectancy research reported that the effects of self-fulfilling prophecies are usually small, weak and short lived, and although there is evidence that negative self-fulfilling prophecies operate, it occurs more widely in certain stigmatised groups where the effects are unfortunately more powerful (Jussim and Harper, 2005). The review concluded that the main reason a student's performance is often predicted by teacher expectations is down to a teacher's accurate assessment of ability rather than self-fulfilling prophecy.

4.5 Interpreting the gender differences observed in reading performance

Gender differences in academic performance are often reported (e.g. Chui and McBride-Chang, 2006, Marchant and Hall, 2003, and McPhillips and Jordan-Black, 2009) around the world, with enhanced performance more prevalent in girls and reading disabilities more common in boys (Liederman, Kantrowitz, and Flannery, 2005, Skårbrevick, 2002, and Wheldall and Limbrick, 2010). Furthermore, longitudinal analysis has found that this disparity in academic and reading achievement increases throughout a student's academic career (Lynn and Mikk, 2009, and Sammons, 1995), although longitudinal research has reported that the gender ratio is more modest than previously thought (Wheldall and Limbrick, 2010). It has been purported that the dominance of boys identified with reading difficulties is possibly influenced by the attention they attract through more frequent displays of disruptive behaviour (Beaman, Wheldall, and Kemp, 2006, and Skårbrevick, 2002).

Gender differences have been contested by certain authors (Canning, Orr, and Rourke, 1980) with some raising concerns with inconsistencies in the criteria used by researchers to define reading difficulties (Siegal and Smythe, 2005). In their analysis of Canadian longitudinal data (n = 984), Siegal and Smythe (2005) found that significant gender differences were limited to Kindergarten and Grade one students, with no differences detected from this point to Grade five. They suggest that a lag in maturity may have explained these results: girls mature sooner than boys and are equipped with these skills at the early stages of reading development, yet by Grade two boys appear to have caught up. The study concluded that their data analysis yielded no significant gender differences in reading achievement and stated that whilst inconsistent definitions continue to be employed in reading research, inaccurate conclusions regarding disabilities will persist.

Concerns that study conclusions may differ depending on the measures of reading ability used was demonstrated by the present study's reading results. Data collected during the second stage of the study showed a main gender effect for reading achievement when performance was construed as reading age, yet gender differences could not be found once scores were translated as standardised marks. Classrooms normally consist of a spread of ages, with older pupils having the potential to achieve higher test scores than their younger peers (McPhillips and Jordan-Black, 2009). This may have been the case in the present study, because when reading progress was converted into reading ages, older participants had the advantage of being measured against younger participants. However, when reading progress was presented in terms of standardised scores, participants were measured against pupils of comparable age, which may explain why analysis failed to detect any significant differences. Therefore, this should be taken into account when interpreting the main effect, reported in study two, for gender in relation to reading age.

Baseline results followed a similar pattern to former research (Jordan-Black, 2005), in that whilst the girls' initial mean reading ability surpassed the boys', no significant gender differences were observed in relation to mathematical performance (Figure 2). When reading performance was revisited post cross-over, results suggested that a change in reading age was significantly influenced by gender. Further analysis showed that being male or female and not a participant of the movement intervention during study two was associated with significant gains in reading age, however, the gains achieved by the girls were approximately nine times greater. As proposed earlier in the chapter, the control group's enhanced performance may have been partly attributable to a John Henry effect (Kocakaya, 2011). In line with previous work ((Kocakaya, 2011) being conscious that they were part of a control group may have induced compensatory rivalry by working harder. This effect may have been strengthened further for the girl controls as gender differences have been reported with respect to motivation (Logan and Medford, 2011). Earlier investigations (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005) into the impact of developmental exercises have failed to conduct separate analysis based on the effect of gender so comparisons could not be made. Research in support of academic gender differences has offered numerous theoretical explanations including gender differences in attitude towards reading (Graham *et al.*, 2008, Logan and Johnston, 2009, Oakhill and Petrides, 2007, and Tse *et al.*, 2006), motivation (Logan and Medford, 2011), handwriting proficiency (Berninger *et al.,* 2008), teaching strategy (Johnston and Watson, 2005), genetic factors (Harlaar *et al.,* 2005), maturation differences in vestibular function (Hirabayashi and Iwasaki, 1995) and neurological processing (Burman, Bitan, and Booth, 2008, and Spironelli, Penolazzi, and Angrilli, 2010).

It appears that a combination of different factors may have contributed to the significant progress in reading age observed in the female controls and to a lesser degree in the male controls. Based on reading ability at inception and earlier theoretical explanations, inferior reading scores for the boys may have led to literacy being associated with negative experiences which in turn may have led to low self-competency beliefs (Logan and Medford, 2011), and reinforced by being selected for study participation. The consequential impact on test performance may have been more influential due to the ethnic make-up and low socio-economic status of the sample, as the influence of self-fulfilling prophecies is reported to be more powerful in certain stigmatised populations (Jussim and Harper, 2005). In addition, sporadic displays of disruptive behaviour observed by the assessor may have been an attempt to manipulate the perceptions of those present. A self-preservation strategy which hopes poor test results will be blamed on lack of task engagement rather than incompetence (Urdan and Midgley, 2001). Although statistical analysis reported significant progress in the male controls' reading age, the overall achievement during study two amounted to a ninth of the gains made by the female controls. In view of the reading research, it is possible that the boys approached the reading assessment with a negative attitude and as a result the test scores may not have reflected of their true potential.

Neuroimaging studies provide a possible neurological explanation for the differences observed in reading performance. A study which utilised functional magnetic resonance imaging (fMRI), a technique used to measure brain activity, found that word modality influenced the brain regions boys utilised for accurate completion of language tasks: printed words activated visual association cortex and posterior parietal areas, whilst auditory stimuli activated regions involved in auditory and phonological processing (Burman, Bitan, and Booth, 2008). However, fMRI images for girls showed evidence of greater bilateral activation in the inferior frontal and superior temporal gyri and activation in the left fusiform gyrus compared to boys. For girls greater fusiform and inferior frontal activation was correlated with increased performance accuracy regardless of word modality, indicating that girls have the advantage of employing a multimodal language processes (Burman, Bitan, and Booth, 2008). The accuracy of boys' linguistic judgements appeared dependent upon modality-specific processes, thus pointing towards a poor ability to integrate phonological and visual information. Research seems to indicate that the greater achievements observed in the female control's reading age may be attributed to more effective sensory processing skills (Burman, Bitan, and Booth, 2008). Consequently reading may be perceived as a more enjoyable activity, perhaps explaining why girls tend to read more frequently than boys (Coles and Hall, 2002). It is possible that the girls approached the GRT with a more positive attitude, a variable reported to positively influence reading achievement (Tse *et al.,* 206), due to more positive past literacy experiences. In addition, an ability to persist with text regardless of interest (Graham *et al.,* 2008), indicate that girls had potentially far fewer barriers to overcome compared to their male peers.

As far as group influence is concerned, this may be interpreted in one of two ways: the significant gains exhibited by the control group in terms of reading age was the result of delayed treatment effects, as animal studies have found brain plasticity continues even after the conclusion of exercise (Berchtold, Castello, and Cotman, 2010); or the movement intervention did not optimise learning, given that reading achievement only reached statistical significance when attainment was presented in reading age rather than standardised scores. Although animal research and neuroimaging studies involving humans have found that as little as one weeks voluntary exercise (Vaynman, Ying, and Gomez-Pinilla, 2004), or even as little as a single bout of moderately-intense exercise (Hillman *et al.,* 2009) can improve cognitive functioning, there is uncertainty regarding the dosage of developmental exercises claimed to promote new neural connections and enhanced learning. Future neuroimaging studies are necessary to measure the impact of developmental exercises compared to variable intensities of physical activity on brain activation and cognitive functioning.

4.6 Interpreting the gender differences observed in mathematical performance

Research investigating gender differences in mathematical performance is complex and inconsistent. The gender stereotypical view that males are better at arithmetic compared to girls is mixed: some studies report a male advantage (Manger and Eikeland, 1998, and Royer, Tronsky, and Chan, 1999), with its emergence ranging from the very start of formal education (Penner and Paret, 2008) to as late as adolescence (Rosselli *et al.,* 2009). In contrast, recent studies have reported a female advantage (Grimm, 2008) or maintained male and female mathematical achievements are comparable (Ding, Song, and Richardson, 2006, Imbo and Vandierendonck, 2007, Lachance and Mazzocco, 2006, Marks, 2008, and Scafidi and Bui, 2010).

The grounds for reported gender differences are many and include, variations in strategy use (Carr *et al.,* 2008, and Gallagher *et al.,* 2000), test item difficulty interactions (Kyriakides and Antoniou, 2009), efficiency in retrieval of math facts (Royer *et al.,* 1999), spatial ability (Roselli *et al.,* 2009), social and cultural factors (Frenzel, Pekrun and Goetz, 2007, Keller, 2007, and Penner and Paret, 2008), and variations in neural processing (Keller and Menon, 2009).

Baseline scores in the present study agree with previous findings (Ding, Song, and Richardson, 2006, Imbo and Vandierendonck, 2007, Lachance and Mazzocco, 2006, Marks, 2008, and Scafidi and Bui, 2010) in that overall, girls and boys exhibited comparable general mathematical ability prior to study commencement. Mixed between-within subjects ANOVA reported a significant time by gender by group interaction and gender by group interaction for mathematical performance measured in both study one and study two. For study one, these interactions remained significant when control variables BMI and HPA were adjusted for, however, for study two the aforementioned interactions failed to reach significance in the presence of covariates BMI and HPA. The data indicated that participation in the movement intervention was detrimental to the boys' mathematical achievements. The male experimental groups in study one and study two exhibited similar trends in mathematical performance: deterioration was observed immediately post-intervention, followed by an upward turn in standardised scores two weeks after participation in the intervention had ended. In contrast, participation in the movement intervention was associated with mathematical gains at each time point for both female experimental groups, apart from a slight decline of approximately one standardised mark at time point three. As Jordan-Black (2005) failed to include gender as a potential mediating factor when exploring the impact of developmental exercises on mathematical performance, further study is needed to determine whether the gender specific responses observed in the present study will be replicated using a larger representative sample size. The greatest mathematical gains were observed in both control groups which is inconsistent with prior investigations (Jordan-Black, 2005). However, as discussed earlier, without further longitudinal research it is unknown whether the achievements exhibited by the control group post study cross-over, are the result of delayed treatment effects or additional classroom tuition.

In contrast with the decline observed in the sample's overall reading achievements, gains were achieved in the sample's overall mathematical performance, although the girls' rate of progress amounted to almost twice that of the boys'. Research focused upon the associations between motivation and academic progress provides some variables which may have contributed to this study's findings. It has been reported that students who possess low reading motivation tend to show high levels of mathematical motivation (Nurmi and Aunola, 2005). Based on prior research (Nurmi and Aunola, 2005), study participants may have directed their motivation and efforts towards a subject area that they perceived themselves to be more capable of, which in this case appeared to be arithmetic over reading skills. In addition, the sub-groups, namely the female experimental group and male control group, associated with higher mathematical baseline scores experienced the greatest gains. Aunola, Leskinen, and Nurmi (2006) found that high arithmetic performance measured at the start of grade one predicted successive task motivation, which in turn predicted a high performance measured at grade two. In addition, a reciprocal relationship between mathematical achievement and mathematical self-concept has been reported by Marsh *et al* (2005); with evidence that math self-concept predicted mathematical interest, although this was not found to be a reciprocal relationship. The theory of self-efficacy assumes that a belief in one's capabilities is correlated with achievement related behaviours (Seifert, 2004). Therefore in line with the behaviours associated with high levels self-efficacy (Seifert, 2004), self-competence beliefs in their arithmetic abilities may have motivated the sample, particularly those with higher mean scores, to persevere with the mathematical tests. Self-competence may explain why boys are reported to enjoy mathematics more than reading (Burnett, 1996). Evidence that intrinsic motivation, competency beliefs (Logan and Medford, 2010) and interest (Graham *et al.*, 2008) play an important role in boys' academic achievements, may explain to some extent why out of the two domains, improvements were limited to mathematical performance for the boys.

Literature has tended to report gender differences in favour of boys (Manger and Eikeland, 1998, Penner and Paret, 2008, Rosselli *et al.,* 2009, and Royer *et al.,* 1999); however, the current results showed girls experienced a faster growth in mathematical progression. As the reasons behind mathematical gender differences are not fully understood (Imbo and Vandierendonck, 2007), the explanations offered by the current study are based on a number theories and further study is needed before firmer conclusions can be drawn. Although the female advantage demonstrated by these results appeared to contradict much of the research, the male advantage is reported to be more apparent in higher achieving populations (Royer *et al.,* 1999). Research employing normal achieving students has suggested a male advantage can be explained by their ability to retrieve mathematical facts more efficiently than females (Royer *et al.,* 1999). Practically, efficient mathematical-fact retrieval allows a student to complete an achievement test within the time limit, whereas a slower retriever may struggle to use their time effectively and fail to complete the test as a result (Royer *et al.,* 1999). However, Royer *et al* (1999) states that the removal of time constraints will not remove the gender differences. Fast mathematical-fact retrieval is described as having automatic skill properties and utilising minimal cognitive capacity: minimum capacity is spent on less complex arithmetic tasks so that surplus cognitive capacity can be dedicated to more complex operations (Royer *et al.,* 1999). Royer *et al* (1999) discovered gender differences became evident when performance was investigated according to retrieval speed: the fast males performed faster than the fast females, whilst the slow females performed faster than the slow males.

The source of gender differences is explained by means of the practice and engagement hypothesis. Royer *et al* (1999) maintain that gender differences are the result of practice effects: boys tend to engage in after school activities which enhance their arithmetic skills, and when united with classroom tuition, increase the available opportunities to practice manipulation of arithmetic information. Conversely, girls' after school activities tend to offer practice in verbal skills. According to Royer *et al* (1999) some boys disengage from classroom activities whilst the female as a population are likely to remain engaged. As a result, the female advantage often observed at the bottom end of the mathematical distribution, is due to their continued academic interest, whereas the practice boys gain from mathematical related out-of-school activities is degraded by their reduced interest in classroom based studies. Therefore, as this study's participants commenced below the national average, the superior mathematical gains exhibited by the girls in these results may be explained by their enhanced academic engagement. Even though boys have been reported to enjoy mathematics and feel more confident in this particular domain compared to girls (Burnett, 1996), domain related practice may have been limited to after school activities for this particular male sample, and as a result, reduced their opportunities to develop a range of automatic skills required for efficient mathematical problem solving skills (Royer *et al.,* 1999).

Alternatively, Geist and King (2008) believe that educators need to accept that boys and girls develop mathematical skills differently, which should not be interpreted as one gender being more superior to the other. In their review they provide suggestions on how the education system might support the mathematical learning styles for each gender. Hence, the gender gap reported in the present study may be a response to a learning environment which does not meet individual learning needs. Research demonstrates that various gender approaches to learning may be in operation: for instance Rosselli *et al* (2009) found that boys have better visual spatial perception which served as an explanation for reported gender differences; Imbo and Vandierendonck (2007) found that girls were skilled in transformation use whilst boys were more inclined to opt for retrieval strategies; Carr *et al* (2008) found that girls favoured manipulative strategies (e.g. using finger counting or hatch marks on the paper), whereas boys had superior three-dimensional spatial ability, were more likely to demonstrate accurate cognitive strategies (e.g. counting mentally), and fluent information processing compared to their female peers; and Royer *et al* (1999) found girls were faster than boys at verbal processing tasks. However, the aforementioned list and opposing findings (e.g. Imbo and Vandierendonck, (2007) do not support gender differences in retrieval efficiency, and Manger and Eikeland (1998) found no gender differences in spatial visualisation) demonstrate the complexity in attempting to draw conclusions regarding observed gender differences in mathematical performance, given this area of research is not fully understood.

It has been discussed that the greatest mathematical progress was ultimately experienced by the girls. Furthermore the most significant mathematical and reading gains throughout the study were exhibited by the female controls (original experimental group) post study cross-over. Results indicate that being female, and in the second control group had a significant positive impact on reading and mathematical performance. However, further research is needed to determine whether these gender and order of treatment effects were specific to this particular sample or whether these observations can be replicated by the second experimental group. The gender specific response to the developmental movement intervention may be a reflection of the reported sex differences in brain development. There is evidence that the progression of brain development is different for girls and boys (Mahone and Wodka, 2008). For instance, a comparison of brain developmental trajectories using MRI data found that compared to boys, girls' total cerebral volume peaked at an earlier age, 10.5 years compared to 14.5 years respectively (Lenroot *et al.*, 2007). In a standardised assessment of basic motor functions in normally developing children (72 boys, 72 girls, aged 7-14 years), girls were found to exhibit fewer subtle signs (i.e. involuntary movements such as limb tremor and odd posturing) and showed better performance on the gaits and stations tasks, and timed patterned movements (Gidley Larson, 2007). Reported gender differences in motor development suggest that the neural systems supporting certain motor functions mature differently in boys and girls (Gidley Larson, 2007). Developmental differences may partly explain the differences in academic growth rates. As for the significant gains associated with control conditions, the study can only present potential theories: learning was optimised by additional classroom based activities rather than the movement intervention; delayed treatment effects were in operation given brain plasticity has been found to continue post exercise (Berchtold, Castello, and Cotman, 2010), and/or the movement intervention had a priming effect, in that the specific developmental exercises potentiated the impact of exercises and physical activity post-intervention (see Berchtold *et al.,* 2005, and Hill *et al.,* 2011). Of course these factors should not be judged in isolation of mediator variables such as task motivation, strategy choice, and developmental differences.

4.7 Conclusion

The study results support the alternative hypothesis in that participation in a nine week movement intervention yielded significant differences in reading and mathematical performance, however, the present findings do not concur with earlier research (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005). For standardised reading scores the first study reported deterioration in both the groups' standardised scores, whilst the second study found no significant differences between the two conditions. Possible explanations include: a reflection of performance of children from different backgrounds given the interacting influence of SES (Akhtar and Niazi, 2011, Bradley and Corwyn, 2002, Liu and Lu, 2008 and Sirin, 2005) and ethnicity (Department for education and skills, 2007) on academic performance; student disengagement rather than ability, as low ability readers have been linked with lower intrinsic reading motivation (Logan, Medford, and Hughes, 2011); negative self-fulfilling prophecy (Reynolds, 2007); and self-handicapping behaviours (Urdan and Midgley, 2001). A review of prior research (Goddard Blythe, 2005, Jordan-Black, 2005, McPhillips, Hepper, and Mulhern, 2000, and Wahlberg and Ireland, 2005) highlighted many inconsistencies in research design, measurement tools, populations and statistical analysis which may explain why the present results did not confirm earlier findings. Concerns regarding the risk of reaching inaccurate conclusions due to inconsistent measurement tools/criteria (Keenan, Betjemann, and Olson, 2008, and Siegal and Smythe, 2005) often reported by researchers, was demonstrated by the present study's reading results. A plausible explanation for the poor reading performance may relate to the appropriateness of the reading tests employed. The standardised tests based upon the norms of monolingual children not appropriate for children learning EAL, as assumptions cannot be made that their acquisition of English follows the same pattern (Mahon and Crutchley, 2006). Although the school records did not disclose whether any of the recruited participants had EAL, children from ethnic minority backgrounds tend to be learning EAL (Department for education and skills, 2007) and it is reported that English is often recorded as the first language, even though other languages are spoken in the home (Department for Children, Schools and Families, 2009).

During study two, significant improvements observed in the control group's reading age (girls experienced gains up to nine times greater than the boys) need to be judged tentatively as once their achievements were measured against pupils of a comparable age the changes failed to reach statistical significance.

In terms of mathematical progress, the intervention was not equally effective, as the female experimental sample appeared to benefit from the movements whilst participation appeared detrimental for male participants. For study two, significant mathematical improvements were confined to the female controls. The results for arithmetic performance do not support earlier findings (Jordan-Black, 2005).

Throughout the study significant gains were associated with control conditions. One viewpoint which has been considered is that these gains were partly down to a John Henry effect (Kocakaya, 2011). It is reported in certain circumstances that students who are aware that they are part of a control group demonstrate compensatory rivalry by working harder (Kocakaya, 2011). However, in order to refute or confirm the interventions efficacy in improving academic performance, further research would be needed to determine whether these gains were the result of delayed treatment effects, given that brain plasticity has been found to continue post exercise (Berchtold, Castello, and Cotman, 2010), and/or whether the movement intervention had a priming effect, in that the specific developmental exercises potentiated the impact of exercises and PA post-intervention (see Berchtold *et al.,* 2005, and Hill *et al.,* 2011). It appears that although there is evidence to show that acute bouts of physical activity can positively impact upon cognitive and academic performance (Hillman *et al.,* 2009, and Tomporowski's, 2003), developmental exercises may require a much longer commitment from its participants before firm conclusions regarding its effectiveness can be made.

As for the gender differences reported, although there is evidence that boys and girls differ in brain development (Gidley Larson, 2007, and Mahone and Wodka, 2008) with sex differences having been found in the neural processing of language (Burman, Bitan, and Booth, 2008, and Spironelli, Penolazzi, and Angrilli, 2010) and arithmetic (Keller and Menon, 2009), neuroimaging research is needed to detect a) whether movement interventions yield any measurable effects in the neural systems supporting motor functions, reading and arithmetic, and b) why there may be a gender and academic specific response to developmental exercises. Alternatively, may have responded more favourably to the intervention given that research has reported that preferences concerning types of physical activity involvement can differ according to gender (Wilson *et al.,* 2005).

In conclusion the findings show that the developmental movement intervention was not effective in improving reading and mathematical performance. Reflex inhibition interventions may work for a less diverse population with different background characteristics.

4.8 Study limitations and suggestions for future work

This study is not without its limitations and should be considered when interpreting the study's findings.

Covariates collected by the study, due to their reported links with educational outcomes, namely SES via FSM entitlement (e.g. Dollman, Boshoff, and Dodd, 2006, Marchant and Hall, 2003, and McPhillips and Sheehy, 2004) and ethnicity (e.g. Davis-Kean, 2009, and Kingdon and Cassen, 2010)**,** could not be included in the study's statistical analysis, as these particular variables were categorical in nature and violated the test's assumptions (Pallant, 2007).

This was an evaluation of a movement programme conducted on behalf of Coventry City Council; hence it was necessary for the study to work within certain parameters. For instance, recruitment was restricted to a small sample of year 3 primary school children which may have reduced the power of the statistical tests, and increased the chance of a type II error (Pallant, 2007). The present study had a power of .08, and post-hoc effect size indicated data reported had a small effect of .01. A power analysis to detect a difference, p = .05, at a medium effect size and power of 80%, indicated that a sample of 269 per group would be needed to detect a meaningful effect. However, this was beyond the remit that was achievable for the researcher and school setting. Furthermore, the cross-over design, employed for ethical reasons in order to allow every participant the opportunity to experience the intervention, limited the testing and administration time available.

The study was conducted in an ecologically valid way by working within the parameters of a school setting. Therefore factors outside of the study's control, such as the academic calendar, limited the number of opportunities available for uninterrupted delivery of the intervention as well as post testing. Hence the length of time between post intervention and follow-up tests was relatively short and scores may have been influenced to a certain degree by fatigue effects and low levels of motivation, which has been associated with pupils of low ability (Logan and Medford, 2011, and Logan, Medford, and Hughes, 2011). The study also appreciates that the quasi-experimental design may have introduced a certain degree of sampling bias, as low performing participants were selected by the primary school's teaching staff, before they were randomly assigned to an experimental or control group.

The study acknowledges that it may have been subject to a reactive effect and in turn introduced compensatory rivalry (Kocakaya, 2011).

The study recognises that SES is a complex variable determined by a combination of factors including family income, parental education, occupational status and habitation (Ardila *et al.,* 2005). Due the availability of data the study relied upon a crude measure of SES, namely FSM entitlement, therefore this may not be an accurate reflection of the children's home background.

Further research in this area would benefit from:

a) Employing a larger sample size in order to increase the study's representativeness and statistical power
b) Conducting the study over a longer period (i.e. 2 academic years) as it appears that 9 weeks is in sufficient time to draw firm conclusions regarding the movement interventions effectiveness, and also to provide all participants the opportunity to partake in the study
c) Using a randomly controlled trial in order to minimise selection bias, and increase the likelihood that participant differences are down to chance
d) Utilising a range of measurement tools when assessing reading performance given that one test cannot assess all aspects of language such as word recognition, spelling and comprehension

e) Employing tests which measure specific arithmetic skills given mathematics is multi-faceted like reading. Standardised tests only provide a general measure of ability and do not identify where a participant's deficits may lie or even where improvements may have been made

f) Employing neuroimaging techniques research is needed to detect a) whether movement interventions yield any measurable effects in the neural systems supporting motor functions, reading and arithmetic, and b) why there may be a gender and academic specific response to developmental exercises.

g) Reducing the chance of misdiagnosis by using assessments appropriate for the native language spoken

h) Gaining a better understanding of the home learning environment

i) Tailoring interventions to meet the needs of different subpopulations, as research has shown girls and boys differ in their preferences concerning types of physical activity involvement (Wilson *et al.*, 2005)

j) Isolating control and experimental groups in order to reduce the chance of introducing a reactive effect (Kocakaya, 2011).

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Appendix 1: First cycle

Co-ordination, concentration and balance exercise

Exercise	Progression	Frequency	
Standing balance Stand on one leg	Commence with eyes open & progress to closed eyes. Balance time increased.	**Week 1**	5 seconds per leg, 5 days p/w
		Week 2	5 seconds per leg, 5 days p/w
		Week 3	10 seconds per leg, 5 days p/w
Leaning balance Stand with feet together, reach out as far as possible without falling.	Aim to increase reach. Participants face opposite one another, passing bean bags between them. Aim to increase distance between participants.	**Week 1**	1 day p/w
		Week 2	1 day p/w passing bean bags
		Week 3	1 day p/w passing bean bags
Squat balance Stand in a hoop or on a marker spot. Squat 3 times, stand, turn around 3 times, squat 3 times and turn in the opposite direction 3 times. Then throw bean bag just above eye level 10-30 times, catching with both hands, one hand or from left to right. Eyes follow bean bag at all times.	Squats with eyes closed. Repetitions and frequency increased.	**Week 1**	Repeat 3 times, 1 day p/w
		Week 2	Repeat 4 times 1 day p/w Repeat 5 times 1 day p/w
		Week 3	Repeat 5 times 2 days p/w
Balance throw Stand on one leg in a hoop or on a marker spot, whilst catching a bean bag thrown by helping participant. Alternate legs.	Progress to one handed catches. Frequency increased.	**Week 1**	Repeat 4 times 1 day p/w
		Week 2	Repeat 4 times 2 days p/w
		Week 3	Repeat 4 times 2 days p/w
Figure of 8s Whilst standing, pass a bean bag between legs in a figure of 8	Commence circling one leg if circling both too difficult.	Include in one session during week 1	
Pendulum Stand and reach up high. Then with arms by side perform a pendulum movement for 10 seconds, 4 times. Throw bean bag from left to right 10 times, whilst eyes track the object. Stretch arms up high and whilst keeping arms above the head, repeat the pendulum movement with eyes closed.	Number of repetitions increased.	**Week 1**	Repeat 4 times 1 day p/w
		Week 2	Repeat 5 times 1 day p/w
		Week 3	Repeat 6 times 1 day p/w
Close eye walk Begin with eyes open. Stand on a marker spot, walk forwards 4 steps and then backwards to the same spot. With eyes open turn clockwise, then anti-clockwise with feet together. All movements repeated with closed eyes.	Progress to eyes closed and walking sideways.	**Week 1**	1 day p/w
		Week 2	1 day p/w with turns
		Week 3	1 day p/w with turns

Appendix 2: Second cycle

Co-ordination, concentration and balance exercise

Exercise	Progression	Frequency	
Spirals Sit forward on a chair, resting hands on knees. Spiral the body, from small to larger motion, returning to small. Repeat in a clockwise and anticlockwise direction.	N/A	**Week 4**	2 days p/w
		Week 5	2 days p/w
		Week 6	Nil
One legged bean bag catch Standing on one leg, throw and catch a bean bag 15-30 times.	Alternating legs. Utilising a balance disc	**Week 4**	3 days p/w
		Week 5	2 days p/w
		Week 6	4 days p/w utilising a balance disc
Bean bag drop Stand in a 'T' position (arms outstretched each side) with a bean bag in one hand. Drop the bean bag and pick it up without moving feet. Repeat 10 times.	Progress to standing on one leg. Utilising a balance disc.	**Week 4**	2 days p/w without balance disc 1 day p/w with disc
		Week 5	3 days p/w wit balance disc
		Week 6	Nil
Balance disc sit/stand Walk/jog around a balance disc 3-6 times. Attempt to sit (feet raised off the floor) or stand on the balance disc.	Progress to sitting and standing on disc with eyes closed.	**Week 4**	2 days p/w – sitting exercise
		Week 5	3 days p/w – standing exercise
		Week 6	Nil
Partner bean bag throw Participants stand facing each other. A bean bag is passed between participants, from hand to hand in a clockwise direction, followed by an anticlockwise direction.	Progressing from passing to throwing the bean bags. Utilising a balance disc.	**Week 4**	Nil
		Week 5	Nil
		Week 6	4 days p/w with balance disc.
Revisit first cycle Participants revisit an exercise(s) from the first programme cycle, which may require additional practice.		**Week 6**	5 days p/w

Appendix 3: Third cycle

Co-ordination, concentration and balance exercise

Exercise	Progression	Frequency	
Spinning side step Spin around on the spot 3 times, followed by 4 steps left, then 4 steps right. Spin again 3 times, followed by 4 cross steps to the left, and 4 to the right. On each occasion aim to return to original starting position.	Perform with eyes closed.	**Week 7**	3 days p/w
		Week 8	3 days p/w
		Week 9	3 days p/w
High low throw In partnership, bean bag is thrown and caught at chest, waist, and knee and ankle height 5 times.	Perform on a balance disc.	**Week 7**	2 days p/w
		Week 8	2 days p/w
		Week 9	2 days p/w
Jumping twist Jump and turn 180° 10 times. Bounce and catch a soft ball 20 times.	Progress to throwing the ball into air (head height) and catching 20 times.	**Week 7**	3 days p/w
		Week 8	3 days p/w
		Week 9	3 days p/w
Standing balance Stand on one leg for 20 seconds. Repeat exercise with alternate leg. Aim to repeat again whilst keeping eyes closed	Perform with eyes closed	**Week 7**	2 days p/w
		Week 8	2 days p/w
		Week 9	2 days p/w
Bean bag drop Stand upright and hold a bean bag high above head height. Allow the bean bag to drop as low as possible, catching it before it reaches the floor. Repeat 10 times.	To extend the time between drop and catch.	**Week 7**	3 days p/w
		Week 8	3 days p/w
		Week 9	3 days p/w
Hop to it Hop in circle around a marker spot 4 times. Take 4 steps to the right and repeat hopping exercise in opposite direction with alternate leg. Then take 4 steps to the left, and aim to return to the starting position.	Perform with eyes closed	**Week 7**	2 days p/w
		Week 8	2 days p/w
		Week 9	2 days p/w