Can Motor Skills Training Improve Academic Performance? A Structured Motor Skills Intervention for Young Children.

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ABSTRACT

The thesis explores the relationship between motor and academic skills. According to previous research, motor skills difficulties can affect academic outcomes. Furthermore, there is growing evidence supporting the relationship between the motor and academic areas. As part of this investigation a motor skills intervention was developed that aimed to make improvements in the performance of the reading, maths and motor skills of young children in mainstream education. The “Motor Skills Intervention for the Early Years” that was subsequently developed represented a new approach to intervention combining direct and indirect motor tasks resulting in a pragmatic, hybrid intervention.

The research involved 56 typically developing children (TDC) attending two English primary schools with a mean age of 58 months randomly assigned to either the experimental or control group. Children were assessed in their motor and academic skills both before and after the intervention. The intervention was delivered for a period of 11 weeks with two weekly sessions for each school.

Preliminary findings appear to be promising, showing a large effect size for motor skills, and medium to smaller effects for reading and maths. The motor skills of manual dexterity and ball skills were significantly improved in children within the experimental group. Improving motor skills in TDC is important in its own right, due to its strong preventative role. Based on these findings, it is concluded that a hybrid approach to motor skills intervention can improve specific motor skills and yield small effects to academic skills within TDC. Future research from this study might include follow-up assessments to identify possible benefits on the academic areas of reading and maths in the long term. In addition, these findings can be used to inform future research and, if replicated with a larger sample, to inform educational policies for school-based interventions.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Statement of Copyright

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This thesis is dedicated to my parents and my two brothers

CHAPTER 1

INTRODUCTION TO THE STUDY

"Νούς υγιής εν σώματι υγιεί" (Thales, 624BC-546BC)

"Anima sana in corpore sano" (Juvenal, 55AD-135AD)

A healthy mind, in a healthy body.

1.1. Introduction

Since ancient times, there have been numerous contradicting philosophical theories concerning the relationship between the mind and the body. Two of the main theories are dualism and monism, represented most famously by Plato and Descartes, and Thales and Spinoza respectively. Dualism claims that the mind and the body are separate, whereas monism supports the opposite view (Solms & Turnbull, 2002). Over the years, these philosophical enquiries have been transformed into scientific ones, with the result being the emergence of the "nature versus nurture" debate, which questions whether genes or environment have a more dominant role in human development. Up until now, the relationship has been considered to encompass many areas, both scientific and philosophical. In the present study, the scientific aspect of this debate is the main focus. A continuous investigation of the relationship between the mind and the body involves areas such as neuroscience, psychology, education and computer science. This thesis will focus on the interplay between education and psychology.

In recent times, the key question in the "nature versus nurture" debate has shifted from whether the mind and the body are interrelated to the basis of what is now assumed to be the causal relationship between them. In addition, there is also a long tradition suggesting that "a healthy body leads to a healthy mind" and that physical activity in general is beneficial for children's cognitive, mental and academic development. Furthermore the fact that this relationship appears to be reciprocal constitutes the need for continued investigation.

The present thesis explores the relationship between motor skills and cognitive functioning as indicated by academic performance. Historically, claims were made that motor skills developed automatically, but nowadays the idea that children should learn fundamental motor activities through organised patterns is dominant. Likewise, for many years, both motor and cognitive development were considered to act independently; however, more recent research has found evidence supporting a strong link between them. Physical exercise in particular has been associated with benefits in multiple cognitive areas including psychological health in both clinical and nonclinical populations (Etnier, et al., 1997; Taylor, Sallis & Needle, 1985; Taras, 2005). Understanding the relationship between motor skills, cognitive development and academic performance can, therefore, provide major insights into areas such as: human development, techniques for diagnosis, symptomatology, aetiology, treatment of developmental disorders and the educational system in general. Therefore, not only researchers, but also educators, parents and students can enrich their knowledge base by obtaining a better understanding of this relationship. The focus of the current research is in the area of cognitive functioning as expressed in specific areas of academic performance in typically developing children (TDC). To explore these links, the current research investigates the effect of a structured motor skills intervention; the “Motor Skills Intervention (MSI) for the Early Years” on motor skills, reading and maths.

From a theoretical perspective, the link between motor skills and cognitive ability has been much explored, with an abundance of recent research from the neuro-psychological perspective (Roby-Brami, Hermsdoffer, Roy & Jacobs, 2011; Wassenberg etal, 2005) However, far less has been written in terms of the impact of this theory in practice, particularly within the educational setting. Separate studies have shown that specific brain regions show similar patterns of activation when performing motor and cognitive tasks yet little has been published focusing on the influence of educational and social feedback or motivation on this link (Allen & Courchesne, 2003; Diamond, 2000). Another perspective named “embodied cognition” suggests that cognitive processes can be deeply rooted in the body’s interactions with the environment, granting the body a main role in shaping the mind (Wilson, 2002). For example, amongst the main key questions that arise from this existing literature are: How do we clearly define “motor” skills in relation to “cognitive” skills when there is so much overlap? What cognitive skills are required to perform specific motor skills, and vice versa? Are there any uniquely cognitive or motor skills? These are some of the issues that led to the design of the current research study, with the aim being to explore the area of motor and cognitive development by developing a well-designed intervention study.

Overall, research in this area is still limited with existing theories contradicting one another. Some theories support the notion that motor skills and cognitive processes are interrelated, whilst others suggest that there is no relationship between the two. An alternative view is that there seems to be a relationship, but that it cannot be documented with certainty and further research needs to be performed. Given the plethora of different views, research on this topic can become extremely complex. For this reason, and because many different research fields are involved, this study aims to harmonically combine information from these areas, analyse and explore it, reach conclusions and make further suggestions.

1.2. Origins of the Study

Previous research suggests that free play environments are not effective enough to produce significant changes in children’s motor development (as cited in Rutledge, 1993). Therefore, there is a high need for a structured intervention with specific motor instructions for children and the school setting offers an environment within which it can be efficiently and systematically delivered. Combining the theoretical and practical experience in related fields, it thus becomes obvious that the next step should be the development of an intervention aimed at improving children’s motor and academic skills.

Another uncommon feature of the present study is that the focus of the research is on TDC within the mainstream, rather than on children with special needs or specific developmental difficulties. A wealth of research documents the benefits of early intervention in TDC by stressing the strong preventative role that it can play (e.g., Elbaum & Vaugh, 2001; Roberts, Freed & McCarthy, 2010). More specifically, children seem to benefit highly from participating in structured programmes which involve physical exercise and motor activities. The school environment has been identified as one of the most important settings for promoting physical activity and reducing the risk of a sedentary lifestyle (Stone, McKenzie, Welk & Booth, 1998). Schools provide a unique environment which serves a large number of children year round. Additionally, school staff and teachers can offer their expertise and teach children the benefits of physical activity. Hence, designing an intervention for the mainstream population serves as additional help and has a preventative role for children who have limited physical activity for a number of reasons, including: lack of opportunities, parenting styles, being overweight or having a sedentary lifestyle. There is much literature supporting the positive relationship between motor skill development and children's health through the prevention or decrease of conditions such as obesity (as cited in DiLorenzo, Stucky-Ropp, Vander-Wal & Gotham, 1998). Although the important role of physical exercise and early years' interventions in the school curriculum are gradually being identified there is the need for more research to be conducted using standardised measures. The current research addresses this need by testing the effectiveness of the MSI for the Early Years using standardised measures as well as applying an experimental design. Since the current research has identified this "gap" in the literature it aims to provide further evidence of the role of early motor intervention.

Further practice-based evidence on the relationship between cognitive and motor ability comes from the Centre for Evaluation and Monitoring (CEM). CEM is a non-profit organization which is part of Durham University. The Centre designs tests that are distributed to schools all around the United Kingdom, as well as internationally (see www.cem.org for more information). CEM securely stores data in a large database. As part of this research I analysed some of the data held within CEM. Data included both scores on motor development measures, as well as various academic measures. Findings supported the original thoughts connecting the motor to the academic, with this relationship seen to persist over the school years from nursery all the way to the end of primary school. These findings acted both as additional evidence of the link between the aforementioned areas as well as a basis for deciding upon the measures used in the intervention. More details on these measures will be provided in the Chapters to follow.

1.3. Research Problem

Many existing studies involve the use of different motor skills interventions, applied to children to test their effect in various cognitive and academic areas. Although in the main, these studies report a significant relationship between motor, cognitive and academic skills, the exact reasons behind this relationship are still to be investigated. Furthermore, the discovery of specific motor skills which directly relate to specific cognitive skills remain unexplored. Do motor skills relate with cognitive skills directly, or do we need to seek indirect factors influencing this connection? Is a theory based motor skills intervention able to improve performance in academic skills in young children? As a means to answer these queries, a hybrid motor skills intervention has been designed as part of the current research. The effects of this newly developed Motor Skills Intervention (MSI) for the Early Years were measured in the academic areas of reading and maths, as well as motor skills.

1.3.1. Aims and objectives of the research

The overall objective of this thesis is to provide further evidence to document the relationship between motor skills and academic performance in TDC. Specifically, it aimed to explore whether using a motor skill intervention as a supplement of conventional teaching will:

1. Improve children's motor abilities.
2. Improve children's reading performance.
3. Improve children's maths performance.

1.3.2. The significance of the thesis and potential impact

The majority of studies in this area involve the delivery of physical exercise programmes in the school setting. Others, meanwhile, are more specific to the child's difficulties and have focused on activities designed for non-typically developing populations. To date, there is no consensus on a generic approach to the development of motor skills interventions that yield significant positive effects in children's performance. Similarly, there is no specific motor/cognitive approach to intervention which has proved to help the majority of the population. Due to the complexity of the relationship between motor and academic skills and the inconclusive findings obtained thus far, each study that addresses this topic provides valuable information, since it adds to the existing knowledge.

An intervention study can offer a prospective view, building upon and testing current theory in order to establish the best methods of teaching cognitive or academic skills through their motor correlates. The current intervention study aims to investigate those areas currently under-explored in relation to motor ability and academic ability**.** The majority of existing studies suggest that future research should focus on an intervention that will maximize the positive effects that motor skills training has on academic achievement as well as physical benefits (see for example: Baranek, 2002; Erwin, Fedewa, Beighle & Ahn, 2012; Humphries, Wright, McDougall & Vertes, 1990; Losse et al., 1991; Majnemer, 1998). As such, the current research will investigate the newly designed motor skill intervention amongst young children, monitor its implementation, and evaluate its impact on a range of outcome measures. It is anticipated that findings from this study will assist educational and psychology researchers, as well as practitioners from various disciplines related to children's development, by providing evidence on the relationship between motor skills and academic skills, such as reading and maths. Moreover, if the intervention developed and evaluated for this thesis proves to be successful, teachers and other professionals might consider the inclusion of additional, structured motor activities in a typical school day and in other school settings. Additionally, this intervention has the practical benefit of being easily deliverable in a school setting by teachers in the future.

The potential impact of the present study is important for a further reason: not only will it provide insights on the relationship between the development of motor and academic skills, it will also test out a new motor skill intervention on TDC. Previous research suggests that there are three "weak" areas in the current development and investigation of motor skills interventions: namely, the lack of control groups, the use of non-standardised assessments, and the lack of research-based interventions (Baranek, 2002). This project will seek to address all of these limitations. Research also suggests that children with low levels of physical exercise tend to perform lower on academic measures (Roberts, et.al., 2010). In addition, there is a link between obesity and poverty, with overweight children often coming from low income families. Children who match this profile tend to have lower academic performance (Hollar et.al., 2010). Although the impact of obesity on school performance is high and has received increased attention, it was not the focus of this study and did not provide the rationale for the activities included in the current MSI for the Early Years.

Nevertheless, it is evident that a healthy mind in a healthy body has significant value which can be applied to many areas especially for the preventative role on TDC.

Overall, then, the current research provides an original contribution to the field of study by designing a newly developed, research-based hybrid intervention for TDC in order to investigate the relationship of motor skills with reading and maths.

1.4. Research Questions

The current thesis is based on three research questions and one related hypothesis; these are outlined below.

Research Questions

1. To what extent is motor skills proficiency associated with reading and maths performance?
2. What will be the effect of the MSI for the Early Years on the motor skills of young children?
3. What will be the effect of the MSI for the Early Years with regards to the reading and maths attainment of young children?

Hypothesis

1. Children who receive the MSI for the Early Years are expected to show improvements in their motor skills, reading and maths scores.

1.5. Rationale for the Structure of the Thesis

This introductory Chapter has briefly described the origins, empirical research, main aims and objectives of the present study, as well as stating the potential significance and impact of this research. Chapter 2 is the literature review which was written from a psychological standpoint and emphasises the psychological perspectives of the research under investigation. Moreover, since the main areas of this investigation comprise the motor, cognitive development and academic skills of young children it was deemed beneficial for the review to include some influential developmental approaches, as well as a discussion of the “nature versus nurture” debate that was, and still is, responsible for initiating research in many fields. Chapter 3 is the Methodology Chapter, which gives a detailed account of all the stages of the research, providing a rationale of the various processes involved for the research to progress from a theoretical construct to a real-world experience. Chapter 4 gives an overview of the data analysis so as to introduce the reader to the statistical processes involved. Chapter 5 then concentrates on the findings from the research. The main focus of this Chapter is the presentation of the findings in a simple and systematic way. As such, it is structured according to the different data analyses used and also includes some initial interpretations of the outcome measures, which are then more fully discussed in Chapter 6. Chapter 6 provides a discussion of the findings along with interpretations, relationship of the findings with previous research, presentation of possible benefits of the current research along with strengths and limitations of the study and suggestions for future suggestions. Finally, Chapter 7 provides a conclusion to the study by outlining the implications of the findings and the contributions they make to the field, as well as discussing issues beyond the scope of the current study. This Chapter also includes the author’s concluding discussion, with some final thoughts on completing the thesis.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1. Introduction

The purpose of this Chapter is to review and analyse the theoretical framework that underpins the current study. First, it provides a background of the main ideas concerning the relationship between genes, environment and human development. Second, it offers an introduction to the area of motor development along with the basic principles surrounding this area. Third, follows a discussion of the literature on cognitive development in relation with the interaction between motor, cognitive development and academic skills, as well as evidence supporting this relationship. Following this, a review of a selection of current motor skill interventions and trends in the area will be presented, followed by an analysis of the theoretical framework and principles that have been selected for the design of the MSI for the Early Years. Finally, a summary of the Chapter is offered.

2.2. GENES-ENVIRONMENT AND DEVELOPMENT

Behaviour is a complex topic because it reflects the functioning of the whole organism and because it can easily change in response to a variety of environmental stimuli. An environmental stimulus could be an intervention aimed at purposely changing behaviour—such as a MSI delivered in the early years of a child's life (like the one that has been developed as part of this thesis). The two main areas that influence human behaviour and have an effect on development are nature (which is associated with genes) and nurture (which is associated with environmental conditions). Both areas have been widely studied over the years, with research being in favour of either nature's or nurture's dominant role on development (see for example: Bronfenbrenner & Ceci, 1994; Plomin & Asbury 2005;

Sherry, 2004). The inception of this debate can be traced back to 1863 and the attempt to identify the mechanisms through which genotypes are transformed into phenotypes (Bronfenbrenner & Ceci, 1994). Research in this then began with Galton and Watson and flourished after the DNA code was cracked (Plomin & Asbury, 2005).

In recent years, however, the common consensus has been that both nature *and* nurture are both important for the human development and later behaviour (Plomin, DeFries & Fulker, 1988). This consensus has provided the primary rationale underpinning intervention studies, since if we do not accept that behaviour is the result of nature and nurture, then research in the area of developing intervention studies that seek to alter behaviour cannot evolve. Therefore, it is very important to have information about the foundation of behaviour before designing a motor skills intervention. Additionally, we also need to explore the different approaches to motor development for a full understanding of where interventions originate. Furthermore, the importance of historical research to the topic under investigation is acknowledged especially since motor development has been in and out of favour. Thus some older research is being presented which cannot be viewed as dated as recent work has either not been done or it is still under investigation. The following sections review the relevant research on nature and nurture, the debate between the two, as well as the significant role that early intervention has on development.

2.2.1. Nature and Nurture

Is a child's athletic ability inherited, a product of training, or a combination of both? Questions of this sort, which stand at the centre of the "nature versus nurture" debate, have, over the years, engaged researchers in many different fields. For the purpose of this thesis, questions of this sort are also important because if there is an interaction between nature and nurture and one affects the other, it follows that an intervention could influence a child's development in many ways. Thus, the decision of developing an intervention for young children could potentially positively impact the targeted areas of development.

An influential figure in the "nature versus nurture" debate was Charles Darwin (1873), who proposed that "human development is the result of a chain of adaptations through time to environmental demands" (as cited in Sherry, 2004, p.86). The result of the aforementioned process is the "survival of the fittest", by which the most dominant and adaptive characteristics prevail against the maladaptive ones while in the genetic pool. Darwin believed that those adaptations also included an array of different behaviours and emotions (as cited in Sherry, 2004). Many research areas have been influenced by Darwin's evolutionary work. One of these areas is developmental psychology. Gesell (1929) was the first to emphasise that maturational changes are responsible for physical and mental development rather than the process of learning. By stating that maturation rather than learning is the source of human development, Gesell supported a nature over nurture stance (as cited in Marchese, 1995). Furthermore, other psychologists in the early twentieth century, such as Freud, Erickson and Piaget, were strongly influenced by, and therefore focused their interest on, the description of human development, rather than the causes. As a result, an abundance of developmental stage theories were created that predominantly emphasised the role of biology on development, but without disregarding the role of environment.

Research on nature's influence over development was halted by World War II, but after the genetic code was cracked by Nirenberg, Mathaei and Ochoa in 1966, interest in genetic research grew again (as cited in Khorana, 1968). Genetic research has shown heritable influence in many areas of behaviour and development such as mental illnesses and cognitive disabilities. Research in this field is ongoing and has provided the scientific society and the general public with numerous influential studies (for example: Plomin 1989; Plomin &

Asbury 2005; Thompson et al., 2001). Appendix 1 provides a more detailed description of these various studies.

In addition to the study of genes and heritability, which is highly associated with human development, the role of nurture on development has been studied for a long time. Nurture seems to be at the opposite end to genetically inherited traits on the continuum of human development. Watson (1924) was one of the pioneer behaviourists in this field and was responsible for introducing the stimulus-response (S-R) learning model. According to this model, the human developmental stages arise from societal learning. Although Watson did not deny the influence of biology on human development, he argued that the environment changes biology, and not the other way around. Watson's environmental determinism theory inspired others and additional theories emerged in the following years (Watson, 1924), including those by Pavlov (1927) (as cited in Ashby, 1947), Skinner (1938), and Bandura (1977) (as cited in Bandura, Adams & Beyer, 1977). All these theories have as a common ground the principle that behaviour is the result of external stimuli, imitation and reinforcement-punishment based model. Based on these principles, early researchers mainly focused on the role of society on learning and development, supporting the modification of behaviour through environment and not biological influences. From the perspective of this thesis, these theories provide a rationale for the effectiveness of an intervention on children's development and learning in various areas.

So, how can nurture be defined? Originally, nurture was related to family upbringing, with the mother's role being of major importance (Plomin et.al 1988); now, nurture's definition has extended and is regarded as "any environmental influence upon development including, peer experiences, media and socio-economic status" (Sherry, 2004). Today, the importance of both nature and nurture in human development and behaviour has been widely accepted (Belsky & Pluess, 2009). This shift in emphasis has come about because of a series of experiments involving twin, adoption and family studies. A description of some of the most influential experiments follows.

The study of nature and nurture and their effect on development was first documented back in 1859 by Francis Galton (cited in Bulmer, 2003). Following the work of Galton, Merriman (1924) performed the first twin study, examining the Intelligence Quotient (IQ) so as to compare mental against chronological age (Neisser et al., 1996). Twin studies are widely seen as the best natural experiment to differentiate between the effects of environment and genetic influence. In Merriman's study, comparisons between total twin populations revealed that identical twins appear to have a much higher correlation in their IQ scores than non-identical twins: "The duplicate of the one egg origin should show a very much higher degree of resemblance than the fraternal because each member of the pair develops from substantially the same arrangement of the factors for heredity in the germ cells" (Merriman, 1924). Subsequent twin studies that have tested academic achievement have also reported considerable genetic influences on academic scores, as well as specific cognitive abilities (Liew, Elsner, Spector & Hammond, 2005).

On the other hand, the findings from these studies also reveal the equivalent importance of the environment, since environmental factors are responsible for more than half of the variance for more complex behaviours (Collins, Maccoby, Steinberg, Hetherington & Bornstein, 2000; Plomin, 1989; Sherry 2004). It is clear, therefore, that both genetic and environmental influences play a significant role in the child's development.

As mentioned above, the current common consensus is that development is the result of the interaction between genes and environment. Understanding the ways in which genes and environment interact can therefore help researchers to identify and assist those who are not developing as expected. For example, children with several developmental disorders can be diagnosed at an earlier stage. Additionally, important information regarding their symptomatology can be retrieved and help with various therapeutic programmes, allowing interventions to be provided. Understanding the way that genes and environment interact, and how this interaction produces different behavioural and cognitive outcomes, is one of the key factors influencing and advancing developmental research. Indeed, development can no longer be viewed as a product of only nature or nurture. On the contrary, human development is now perceived as a continuum which is affected by both genetic and environmental changes during the whole lifespan. Further evidence from different areas that support the link between the mind and the body will be discussed in later sections.

Alongside the ongoing "nature versus nurture" debate and the years of research into human development, has been the creation of various stage-developmental theories. Several of these stage development theories arose from the need to further explain the interaction between nature and nurture and how it influenced the developmental process; with some theories emphasising the role of nature and others emphasising the role of nurture. Another factor which influenced the creation of stage theories was the need to match specific developmental milestones with different ages, since the nature-nurture debate did not provide specific stages in which changes occur.

For developmental theorists such as Erikson and Piaget, one of the major aims of research in stage development was the establishment of universal laws about human development (as cited in Miller, 2002; Watts et.al., 2009). By establishing universal laws, it was believed that it would be possible to easily identify and "treat" areas of development that appeared to differ from the norm. More specifically, stage developmental theorists suggested that, during learning, an individual moves from novice to expert to master level where she/he performs tasks not only better, but in a different way as well (Sameroff, 2010). They therefore suggested that development should not be viewed and studied in restrictive terms, but should instead be studied as a process that evolves while the individual is growing and is affected by various environmental and biological factors, resulting in a model of development as age-related rather than age-dependent.

2.3. Current Research & Trends

The above section has provided an overview of the relationship between genes and environment in the developmental process, incorporating perspectives from the "nature versus nurture" debate. This following section offers a critique of these traditional views.

First, development cannot be easily predetermined because it can take different routes depending on the nature-nurture interaction evidenced through twin studies. Alongside the provision of experimental and observational evidence, theorists have attempted to model this interaction. Some have focused on genetic or biological factors, whilst others have emphasised the importance of societal and environmental factors. The importance and the contribution of these theorists and the models they have developed is significant. Starting with Darwin, his "survival of the fittest" theory offered a theoretical framework upon which later theories were based on, especially those produced by developmental psychologists (Dixon & Lerner, 1988). Following the publication of his research, theories on maturation and the effects on human development flourished and there was a significant development of theories describing the processes involved in development. Maturation influences development and can also account for individual differences that are observed among children. Additionally, theories emphasising the role of environment on development were created, providing valuable knowledge on how various stimuli shape or even alter the developmental process (Lerner, 1978). A significant contribution from this period was the twin and adoption studies, which provided major insights on human development, both in terms of observed similarities and individual differences (Plomin, DeFries & Fulker, 1988). Subsequent theories were inevitably influenced by this early research on genes and the environment. This period is also of major significance since it witnessed a shift towards a more scientific, evidence-based view of human development. Nevertheless, these early theories were mainly of a descriptive rather than an explanatory character. Therefore, subsequent theories on development have attempted to establish the importance of the interaction between nature and nurture and have tried to provide explanations as to how the different processes take place. These theories, which will be discussed in later sections, form part of the theoretical framework of the current thesis, with the premise being that both nature and nurture shape development by interacting with one another.

As mentioned previously, it is now commonly accepted that both biology and the environment are important in shaping the developmental process. Therefore, opportunities to shape and enrich the environment while children develop are of major significance. The environment matters and providing enriching opportunities in the early years can significantly benefit children. Evidence to support this can be derived from several meta-analyses which have investigated the role of early years interventions on attainment and have found a moderate to large effect (see for example: Anderson et.al., 2003; Gorey, 2001 & LaParo & Pianta, 2000).

Many diverse theories have contributed to the current view of child development. Some of the basic assumptions at the present time are that: both humans and their environment are active in the developmental process; development is both continuous and discontinuous; and that development can have both universal aspects and aspects that are influenced by more specific factors such as cultural, socioeconomic and individual factors. Given that there is currently no universal theory that can solely account for explaining human development, a more desirable approach may be to use principles and concepts from different theories which best represent the phenomena under investigation. New research is mainly guided by existing theories, so the fact that the area of human development has such a rich research background means there is plenty of scope for innovation. Indeed, nowadays, most researchers tend to endorse a combination of theories, rather than focusing on one, because they understand the multidimensional nature of human development (Sherry, 2004). Finally, because there is such a wide variety of developmental theories — largely due to the complexity that characterises this area — new research is always needed.

A careful examination of all the factors that may influence development and the degree of this influence would benefit future research. It is now widely accepted (although there are clear supporters of one or the other view) that both nature and nurture are important to human development. Thus, improving knowledge in either area is important (Sameroff, 2010). Future advances will help disciplines such as psychology, medicine and education to further expand their knowledge and also develop new strategies to treat the various developmental problems that children may exhibit. Additionally, in order to develop an intervention for the early years it is central to understand that development is a holistic process.

The present research seeks to explore the relationship between motor skills and cognitive functioning in young children. During development, multiple changes take place both in the motor and the cognitive area. In this study, a motor skills intervention has been designed to test this relationship. Given the above theoretical background, it can be surmised that the role that environment plays in development can be hugely important and can influence a person's performance on various skills. More specifically, in the current research it is hypothesised that the MSI for the Early Years will change children's performance on motor and academic skills. An additional interest of the present study was the various comorbid cases of developmental disorders and, more specifically, the ones where children seem to have difficulties in both the cognitive and motor areas. This observed comorbidity between the motor and cognitive areas provides supporting evidence of the relationship between the two areas under investigation and will be discussed later in this Chapter.

It is not advisable to design an intervention and explore an area that is based on human development without knowing some of the dominant theories surrounding this area. A detailed knowledge of growth and development theories provides a foundation for such intervention. The following sections provide an in-depth discussion of some of the most relevant theories in the field.

2.4. MOTOR DEVELOPMENT

Because all the different and countless movement skills gradually become automatic, their importance has often been overlooked. Historically, motor development has been studied for the purposes of examining the relationship between behaviour and neural maturation. Two of the first people to study motor development in infants were McGraw and Gesell, in the 1930s and 1940s believed that the driving force of motor development was the maturation of the nervous system and morphological maturation respectively (as cited in Kamm, Thelen & Jensen, 1990). Subsequent investigations have studied movement from many different perspectives including: physical education, dance, sport science, sport sociology and motor learning. Since human movement incorporates numerous fields, there should be caution when studying motor development, since clear boundaries need to be set. In this study, motor development is defined as "the process through which a child acquires movement patterns and skills through change" (Malina, 2004). The sections that will follow will present different approaches to motor development. One of the main aims of the current thesis was to design a motor skills intervention for the early years. If the different approaches to motor development remain unexplored it is not possible to fully understand where the different approaches to motor skills intervention arise from. Therefore, a critical overview of different approaches is discussed along with their main limitations and strengths.

Motor development is a complex process that according to Malina in 2004 involves the interaction of a variety of factors, including: (1) neural and muscular maturation; (2) physical growth and the child's behavioural traits; (3) the speed of physical growth which includes biological and behavioural maturation; (4) the residual effects of prior movement experiences; and (5) "the new movement experiences". Motor development also involves a wide array of different skills, including movement behaviour, motor skills, motor performance, motor learning, motor fitness, and motor educability. All these different categories fall under the wider category of movement development and, by developing each of these categories, movement development improves as well.

Before analysing in more depth the area of motor development, it is important to define the aforementioned terms. “First, movement behaviour can be defined as the observable movement of the body such as reflex actions. Second, motor performance can be defined as a short-term movement oriented toward the execution of a specific task. Third, motor skill is a complex motor performance that requires some degree of learning. Fourth, motor learning is a permanent change in motor performance through practice. Fifth, motor fitness is the individual’s capacity to perform a motor task. Sixth, motor educability is the capacity to learn several motor skills” (Gallahue & Ozmun, 1995). All of these skills are active and each contributes to the process of motor development. Motor development is an important part of human development and, as the current study suggests, it might be correlated with other aspects of development such as cognition or academic performance. In the sections to follow a detailed description of the following areas is provided: (1) motor development in the early stages; (2) different approaches to motor development; (3) theories of motor control; and (4) a summary of the motor development section.

2.4.1. Motor Development in Infancy

Infancy is the first period during which a person is “exposed” to the external world. As a result, rapid changes tend to occur in the motor development of the child. In the following section, a description and analysis of the motor development process during the infant years, as well as a presentation of the prevalent theories of the area, will be discussed.

The first movements that have been documented by researchers are the primitive reflexes that first appear in the foetus and continue after birth. Campbell (2004), introduced a new ultrasound scan which shows foetuses as early as 12 weeks old that can stretch, kick and leap around the womb (Campbell, 2004). Primitive reflexes are involuntary movements that are triggered by external stimuli and are characterised by a short reaction time between the stimulus and the response. Reflexes cannot be habituated and continue to appear independently of the number of times that the same stimulus is presented (Piek, 2006). Some of the primitive reflexes include sucking, symmetric tonic neck and rooting/search and they are usually found from prenatal to six or seven months of age. The role that the primitive reflexes serve is to protect the (vulnerable) child during the first crucial years of life. Other than the primitive, there are two more types of reflexes: postural and locomotor. Postural reflexes include, among others, pull-up and neck righting, and are found in babies from two to 12 months of age. The role of postural reflexes is to help the infant maintain posture in the changing environment after birth. Locomotor reflexes, on the other hand, include crawling and stepping and appear around birth to five months of age; they are also connected with the voluntary movements that they resemble (Piek, 2006). Reflexes comprise a central part of the infant's early movement repertoire and they have a strong influence on the study and understanding of later motor development. Indeed, failure to inhibit primary reflexes has been associated with later developmental difficulties such as dyslexia (McPhillips, Hepper & Mulhem, 2000).

Another set of movements that have been studied during infancy are spontaneous movements. These occur in infants without a specific stimulation and they disappear around 12 months of age (Haywood & Getchell, 2009). Research in the area of spontaneous movements has largely focused on general movements. Normal general movements are defined as gross movements that involve the whole body. More specifically, they follow a specific pattern of arm, leg, neck and trunk movements and they seem to emerge at nine weeks of age and remain until the infant is two to three months of age. Infants appear to have a different range of movements that can be changed with the interaction of their caregivers and shaped in a different way (Piek, 2006). The above patterns of development suggest that intervention techniques at an early age can possibly change early problematic behaviours and prevent later difficulties.

Furthermore, since early movements have been associated with later motor development, the importance of these early movements has been recognised by many researchers (Piek, Dawson, Smith & Gasson, 2008; Thelen, 2000). In the early infant stage, the range of movements is limited, but, as the infant approaches the first year of life, his/her movement capabilities evolve dramatically. Although it is possible to deliver an intervention to enhance motor skills at infancy, it is not common for researchers to intervene in a systematic way at this early age. One of the possible reasons for this is that the difficulties that the infants will develop later in life will not yet be clear; hence, intervention in children with developmental difficulties tends to start later in life once the condition has been expressed (Fenske, Zalenski, Krantz & McClannahan, 1985; Howlin & Asgharian, 1999). Additionally, it is possible that some of the at-risk-infants might not develop a disorder later in life (Blauw-Hospers & Hadders-Algra, 2005).

Without doubt, the first months of the infant's life are of major importance for his/her future life. During the first months after birth the infant experiences both reflexive and spontaneous movements which are vital for his/her survival. As the infant grows older the reflexive movements tend to fade away and give way to new voluntary movements. One of the most important points to emerge from this section is that, during this stage of development, skills can change and are shaped through the interaction with the environment. In the section that follows, the most important theories of early motor development will be presented. More specifically, three theoretical perspectives will be discussed: first, the maturational approach; then, the information processing approach; and, finally, the dynamic systems approach. Each approach has made its individual contribution to the area of motor development and has also shaped the background of the current thesis.

2.4.1.1. Theories of Early Motor Development

Historically, there have been a number of different theories of motor development, which have, in turn, influenced a number of different theoretical and therapeutic approaches. As Adolph and colleagues suggest up until today there is the following prevalent view of motor development: “In standardising the course of motor development, researchers focused on the typical child (who is, of course, no child), rather than on within individual variability and individual differences. The idea of age appropriate activities as an index of intrinsic biological functioning is the received legacy of early work on motor skill acquisition” (Adolph, Keramik & Tamis-LeMonda, 2009, p. 1). Although, later theories have suggested an alternative approach to motor development and learning (such as dynamic systems approach) the above ideas are still prevalent.

In the sections to follow, three theories will be discussed on the basis of the chronological order in which they were generated: maturation, information processing and dynamic systems. The first body of literature to be discussed relates to the maturational period, which is considered to be significant for the following reasons: (1) during this period developmental psychology emerged as a science in its own right; (2) motor development had a rapid growth as single-subject biography; and (3) major insights into changes in motor behaviour and development have been documented (Clark & Whitall, 1989). In the section that follows a detailed description of the maturational period is provided.

2.4.1.2. Maturational Period

According to the maturational approach, development is perceived as a result of the maturational changes of the central nervous system that shape motor development (Haywood & Getchell, 2009). The effect that nature has upon development plays a dominant role in this approach, with the science of biology deeply rooted at the core of the theory (Clark & Whitall, 1989). More specifically, motor development has been seen to be driven by internal rather external factors, with internal factors usually associated with genes, whereas external are usually associated with the environment.

The most influential theories in this field were the ones introduced by Gessell in 1945 and by McGraw in 1963 (Piek, 2006). Both theorists observed the developmental changes in infants and tried to associate them with biological changes; however, they both approached the subject with a different perspective on the maturational process.

For Gessell, maturation was perceived as morphological in nature, whilst, for McGraw, maturation was perceived as neural in nature (Piek, 2006). More specifically, Gessell argued that motor development follows a specific hierarchical pattern that is mainly influenced by biological factors (Piek, 2006). Furthermore, Gessell provided a detailed description of the different levels of maturity of motor development of the child from infancy until five years of age, as well as the different principles that characterise development based on a cephalocaudal direction[1] (Piek, 2006). Both the levels of maturity described by Gessell and the different principles he outlined have been accepted by the general research community. However, it has been pointed out that there are many constraints involved. For example, infants may use their feet to interact with toys before they can use their hands, implying that the strict cephalocaudal perspective cannot be applicable in all cases (Piek, 2006).

As the above example illustrates, there is an argument that Gessell's ideas, although highly influential, can be too restrictive in some aspects and may place additional constraints to children's abilities. In response to these claims, Gessell created a dynamic map that depicted the non-linear evolution of development through the interaction of various morphological events as the infant matures (Piek, 2006). A significant contribution of Gesell's work was the fact that he offered an alternative explanation to that of behaviourism which was a popular approach for development at that time (Thelen, 2000). In addition, his non-linear approach to

[1] Cephalocaudal direction= Direction from head to feet and development from upper to lower limbs (Piek, 2006).

development proved to be very influential to later theorists, especially dynamic systems theorists.

By contrast, McGraw introduced a neural maturational approach to motor development. According to McGraw, the cerebral cortex is responsible for the maturation of the motor system, rather than the muscular system (Piek, 2006). For example, the infant’s ability to lift his/her head was considered to be the result of cortical control of the cervical region (Kamm et.al., 1990). Additionally, McGraw viewed the development of motor behaviours as the end product of the interaction between the maturing nervous system and the child’s experiences. She also proposed that there might be critical periods in which behavioural functions could be better advanced by intervention (Clark & Whitall, 1989). This early example can be viewed as one of the first ideas produced by maturational theorists supporting the argument that early intervention can positively influence behavioural change.

Both Gessell and McGraw fall under the maturationist label, although their views on development have differences. Both theorists were influenced by embryologists, but Gessell focused on morphology whereas McGraw focussed on neural maturation. More specifically, Gessell formulated the concept of developmental morphology. Developmental morphology is based in the study of form and its change through ontogeny (Clark & Whitall, 1989). McGraw’s approach was based on neural maturation, stating that maturation is achieved once primitive reflexes are inhibited by the cortical control over the lower brain and spinal cord.

Although this approach has lost support over the years, it continues to influence the creation of many interventions for children and serves as the basis for the creation of future approaches to development (Piek, 2006). For example, a recent intervention by McPhillips called the “Primary Movement Programme”, which is currently being used and is gaining support, is based on the inhibition of primary reflexes that persist on a later age in children (McPhillips & Sheeny, 2004). Furthermore, many researchers and practitioners continue to believe that basic motor skills will automatically materialise and, hence, that there is no need to facilitate the development of these skills (Haywood & Getchell, 2009). Indeed, maturational theories seem to oversimplify the developmental process by suggesting that genes and nervous structures are mainly responsible for the behaviours exhibited by an individual, without considering the role of the environment. Therefore, maturation may be necessary, but not sufficient, for the development of motor skills. On the other hand, both Gesell and McGraw believed that a level of readiness is necessary for the development of motor skills and they both claimed that maturation may be a critical period for advancement of those skills.

Some of the strengths and limitations of the maturational approach are outlined on Table 2.1 below.

Table 2.1.

Strengths & Limitations of Maturational Approach

STRENGTHS	LIMITATIONS
1. First ideas of non-linear nature of development.	1. Focus on CNS.
2. Alternative to Behavioural theories.	2. Limiting the role of the environment.
3. Co-twin studies offering rich information.	3. No explanation for bottom-up movements.
4. Development of assessment tests.	4. Limited contemporary evidence.
5. Information of the underlying developmental processes.	

As the table summarises the maturational approach encompasses both strengths and limitations. During the maturational period the first ideas of a non-linear nature of development were introduced. More specifically, based on Gesell's reciprocal interweaving principle, growth is seen as a "non-linear but rather spiral process where structure and function mature leading to regressions, asymmetries and re-organisation" (Heriza, 1991, p.102). Early ideas on the non-linearity of growth inspired later theories (dynamic systems theory). This theory suggested an alternative explanation to development compared with early behavioural theories explaining the different genetic influences upon the individual. Both Gesell and McGraw can be characterised as pioneers in the co-twin research providing important information on the influence of maturation versus training on development and assisting in the development of new assessment tests for the early years such as the "Denver Developmental Screening Test" (Thelen & Adolph, 1992). On the other hand, the maturational perspective encompasses limitations. The increased emphasis on the CNS can be viewed as a limitation since the role of other systems which are involved in motor development such as muscular systems is not taken into consideration. Another main limitation is the theory's views on the limited role of the environment. According to the maturational approach the environment can produce minor changes in development but these changes will not be able to cause permanent changes since motor development is genetically pre-determined. This view along with the theory's inability to explain bottom-up movements restrict the true potentials of the individual and additionally it fails to explain variability. Finally, there is no contemporary evidence to support the notion that the brain matures in an autonomous way causing the body to "follow instructions".

Overall, the maturational approach offered major insights to the area of motor development, providing one of the first scientific descriptions of the developmental process. Additionally, it served as the basis for the establishment of several standardised tests of motor skills (Heriza, 1991). On the other hand maturational theories of development had various drawbacks which resulted in the development of alternative theories (such as dynamic systems theory). As a result, the theories that followed sought to address the limitations of the maturational approach by moving from a descriptive/biologically deterministic approach to an explanatory approach, suggesting that neural maturation alone cannon sufficiently explain developmental change.

Although the maturational approach is not directly related to the current research project, it is nonetheless significant because it informed so much later research on motor development (Clark & Whitall, 1989). One such subsequent approach was the Information Processing approach, which the next section will now discuss in more detail.

2.4.1.3. Information Processing Period

During the 1970s, both developmental and experimental psychologists explored behaviour and tried to provide explanations for human development (Clark & Whitall, 1989). The model most often associated with motor behaviours during this period was called 'information processing'. This theory argued that the brain can be perceived as a computer system which receives information, processes it, and then produces an output such as a movement (Haywood & Getchell, 2009). Hence this model suggests a three step approach to motor learning and development: input, processing, and output.

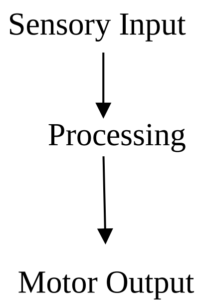


Figure 2.1: Basic Model of the Information-Processing Approach

The origins of this approach can be identified in the early stimulus-response (S-R) learning model of behaviourists such as Watson and Skinner (Watson, 1924). Two main cognitive skills involved in this basic model are memory and perception, which, as suggested, are important variables for processing and producing the output. Some of the central assumptions of this approach are outlined below:

- Numerous processing stages are involved between the stimulus and response.
- The stimulus presentation initiates the start of the processing stages.
- Each stage uses information only available to it.
- Each stage transforms the information received.
- After completion of each stage the transformed information is made available to the next stage of processing.
- Each stimulus needs a specific time from the onset until the response.

These assumptions have been summarised by Kelso (1982), who provided detailed descriptions of the information processing approach.

Following Skinner and Watson, Schmidt and Lee (2005) outlined a more generalised motor programme (GMP), which consisted of a stored pattern of movements. Also, its application covered a wider array of movements that could be modified in response to environmental conditions (Schmidt & Lee, 2005). Another characteristic of their approach was the introduction of certain parameters. These parameters can specify the movement's duration, overall force and spatial order, as well as the temporal phasing by which the movement is executed. According to the aforementioned principles, different parameters reduce the memory load from the motor programmes by simply adding parameters to movements that are recognised as similar (Rose, 1997). This new approach was highly favoured.

Contrary to the maturational approach presented earlier, information processing highlighted the importance of external or environmental factors on shaping behaviours. Therefore, it encouraged a shift of focus from genes to environment, whilst still maintaining the important role of the brain and nervous systems as the "machine" needed to process external information. The main drawback of this approach for explaining developmental changes is the physical limitations that the main system has on processing, maintaining and deciding upon the motor output. Indeed, since there is only one executive system responsible for unlimited commands and processes, the system could, in theory, be easily overwhelmed by any task. An additional limitation is the fact that — just as with the maturational approach — the theory disregards the role of other important systems involved in movement, such as the muscle and skeletal system. Thus, information processing cannot provide explanations for the flexibility that the organism exhibits when performing a motor task or the continuous adaptations required for completing a task such as walking (Schmidt & Lee, 2005).

The strengths and limitations of the information processing approach are summarised on Table 2.2 below.

Table 2.2.

Strengths & Limitations of Information Processing Approach

STRENGTHS	LIMITATIONS
1. Acknowledgment of the environment's role.	1. Brain's storage limitations.
2. Schmidt's schema theory.	2. No explanations for flexibility & variability of MD.
3. Information regarding reactions to environmental stimuli.	3. Restrictive S-R model.
4. Individual as active learner.	4. Disregard the influence of several systems in movement production.
5. Introduction of Reaction Time.	5. Lack of a broad perspective of development.

As outlined in Table 2.2 a significant strength of the information processing approach compared with the earlier theories was the acknowledgement of the important role of the environment on motor development. Another strong point was the development of Schmidt's schema theory explaining the production of movement and the relevant alternations. Although Schmidt's schema theory has received major criticism over the years, its contribution on providing insights into different aspects of motor skills learning cannot be underestimated. Another contribution of the theory was the processes involved during the execution of a movement giving details on how the individual responds to various environmental stimuli. Furthermore, the person is now viewed as an active learner who learns through his/her interaction with the environment. This comes in contrast with the maturational perspective which views the person as a passive learner. Finally, the introduction of “reaction time” was an important contribution to motor development research which is extensively used in experimental research.

Some of the limitations are also summarised in Table 2.2. Mainly having the brain as the main system receiving information can be overwhelming, therefore the suggestion of other systems should be considered. Additionally, the approach did not explain the observed flexibility and variability of motor development. This is a gap in the theory. Furthermore, the notion of the individual who is driven by a S-R model appears to be restrictive, whereas the influence of other systems involved in the production of movement need to be acknowledged. Finally, a broader perspective addressing both biological and psychological determinants of behaviour would enrich the theory.

As the above discussion highlights, the information processing approach is different from the maturational approach to development since there is an obvious shift of focus from genes to environment. More specifically, the role of various external stimuli to behavioural change is believed to play the major role in the developmental process, while the brain receives the information and produces an output. Moreover, whereas the maturational theories offered a more descriptive explanation, this approach provided an explanation of the steps and processes involved to produce a motor output. Based on the information processing approach the learning of a motor skill takes place while the child becomes more proficient in the elements that are considered to be the building blocks of motor skill acquisition (Sugden, 2007).

Some of the principles of the information-processing approach have informed the process-oriented approaches to motor skills intervention used in this study. In fact, the MSI for the Early Years was developed based on both process and task-oriented approaches to intervention. For example, during the information processing period, the important role of the environment on development was addressed. Likewise, the current intervention was developed based on the principle that environmental stimuli can alter behaviour.

Nevertheless, although information processing added to the area of motor development theories, there remained many processes to be explored, such as the observed variabilities among individuals. Consequently, subsequent approaches to motor development sought to fill-in some of the vaguer areas of the information processing approach, whilst also offering a new perspective to the study of movement. One such new approach was the ecological approach, which emerged as a serious alternative to information processing in the 1980s (Payne, Isaacs & Pohlman, 2002). Unlike information processing, this new approach emphasised the role that other systems (such as the muscular system) played in receiving, processing and producing an output. In addition, this new approach also advocated the use of non-linear models instead of the aforementioned S-R models (which were perceived to be too restrictive) (Kamm, Thelen & Jensen, 1990; Thelen, 2000). Methodologically, the ecological approach was characterised by two distinct approaches: the dynamic systems approach and the perception-action approach. These two approaches provide the subject matter for the following two sections of this literature review.

2.4.1.4 Dynamic Systems Approach

During the 1980s, the dynamic system approach emerged as an alternative approach for explaining motor control and coordination (Thelen, 2000). This theory was rooted in the revolutionary ideas of Bernstein who perceived movement as function specific rather than muscle specific (Thelen, 2000). Hence, there was a shift from the central nervous system to the biomechanics of moving limbs as contributors to motor development. Bernstein suggested that, due to the complexity of the human organism, there is a need for different systems (such as body segments and joints) to make the organism able to perform. This approach was named “degrees of freedom” (Thelen (a), 1995). Although influential, one problem with the “degrees of freedom” approach was that, whilst it recognised the flexibility and adaptability of several body movements, it offered little information as to how the individual was able to exercise control over the enormous number of components that were, seemingly, involved in the production and execution of a movement (Berthouze & Lungarela, 2004).

According to Bernstein, movements can be organised into “functional groupings or synergies, flexibly adapted by people to meet specific tasks”, thereby lightening the computational load of each individual movement (Thelen & Bates, 2003). The three main principles of this approach are: (1) “movement is controlled by the non-specific Central Nervous System (CNS) input; (2) principles of continuity and discontinuity can be explained by a non-linear model of physical biology; and (3) information is a physical variable unique to the changing geometry of a system’s dynamics” (Clark & Whitall, 1989). As a result, motor development is interpreted as the result of the cooperation of different systems (as opposed to an executive system controlling all the processed involved). Additionally, changes in the organism occur on different timescales (Smith & Thelen, 2003). Bernstein’s ideas were subsequently incorporated into contemporary theories of motor control generated by theorists such as Kelso, Reed and Turvey (Rose, 1997). These new approaches consequently sparked an interest in the following areas: motor skills, perceptual motor development in children with learning disabilities, and changes in sensory-perceptual skills as evidence by future research (Lewis, 2000; Sugden & Dunford, 2007).

Methodologically, one of the main differences between the dynamic systems and the maturational approach is that the first suggests that behaviour results from softly assembled acts[2], whereas the latter proposes that behaviour is the result of hard-wired processes within the organism. Hence, the dynamic systems approach suggests greater flexibility and adaptation to different situations. Another difference from the maturational approach is that dynamic systems explain motor behaviours in later life rather than the first decades of life when motor development reaches an endpoint based on maturational theory (Haywood & Getchell, 2009). Indeed, in the dynamic systems approach, motor development is viewed as a changing landscape of preferred rather than obligatory states with varying degrees of stability and instability across the life-span (Thelen (a), 1995).

Spencer and Schoner (2003) provide a very good summary of both the main weaknesses and the main strengths of dynamic system theory which are outlined in Table 2.3 below:

Table 2.3.

Strengths & Limitations of Dynamic Systems Approach

STRENGTHS	LIMITATIONS
1. Qualitative & Quantitative framework of behaviour.	1. Descriptive character of behaviour.
2. Critical insights into the nature of developmental change.	2. Difficulty relating concepts to neuroanatomy.
3. Non-linear nature of development.	3. Limited connection with formal theory building.
4. Behaviour as the result of multiple sub-systems.	4. Lack of information of the representational states of movements.

[2] "The concept of soft-assembly is critical to allow the child to act in a changing and variable world" (Spencer, Corbetta, Buchanan, Clearfield, Ulrich & Schoner, 2006). For example, when an infant wants to perform a stepping task the stepping patterns will change as a result of the child's weight, position and surface.

5. Emphasis on lower control centres. 6. Across domain investigation. 7. Explanations of behavioural variability.	5. Cannot offer “a priori” predictions on behavioural changes.

As summarised in Table 2.3 one of the strengths of this approach is the development of a detailed picture of behaviour with both qualitative and quantitative information, allowing experimental research in the area to evolve. It additionally offers critical insights on the developmental process by focusing on the role of self-organisation, flexibility and active spontaneity. The support of a non-linear nature of developmental change suggests that change can be produced within the same system, therefore qualitative behavioural changes do not need separate control processes. Additionally, if a motor skill is characterised as non-linear this means that there are certain periods where children develop “faster” than others (Adolph & Berger, 2005). Another main strength is the support of the non-hierarchical interaction of various systems such as; neurological, biological and musculoskeletal for behavioural change, therefore explaining the cases where bottom-up movements occur first. By emphasising the lower control systems the theory explained a series of voluntary movements. Finally, one of the main strengths and important concepts of dynamic systems approach is that development is soft-assembled and is characterised by multi-causality. Hence, it succeeded in explaining the observed variability of development.

One of the first limitations of dynamic systems theory is the lack of a thorough explanation of the underlying mechanisms involved rather it provides a more descriptive account of the behavioural patterns. Another limitation that can serve as a future suggestion for dynamic systems is to build a more formal theory of their principles. Some movement decisions are based on long-term memory in cases where information is not always available to the person and dynamic systems fail to capture the differences in these movements. Finally, the approach cannot offer “a priori” predictions regarding specific behavioural transformations since it supports a more flexible pattern of change.

Conceptually, therefore, a dynamic systems approach added a series of new elements to the field of motor development theory. One of the main differences with the previous two discussed approaches (the maturational approach and the information processing approach), is that there was a conscious effort to view the individual as a self-organising, active, and complex organism. The dynamic systems approach also interpreted development as a non-linear dynamic process during which several developmental changes can take place, all derived from the same system (Spencer & Schoner, 2003). Compared with the maturational approach, it also prioritised the contribution of other systems (such as the muscular system) to the production of a movement. Additionally, it provided explanations for bottom-up movements and incorporated the role played by the environment on motor development. Like maturational theories, however, the dynamic systems approach suggested that there is a neural basis for behavioural development; nevertheless, it did suggest that the maturation of the central nervous system could not be assigned final causality (Thelen, Ulrich & Wolff, 1991). On the contrary, the dynamic systems approach added to the restricted S-R model (proposed by the information-processing approach) and explained the observed flexibility of the individual performing different movements. On the other hand, though, dynamic systems theory has yet to establish a well-defined theory of learning (Spencer & Schoner, 2003).

As mentioned earlier, the other approach inspired by the ecological perspective of development was the ‘perception-action approach’. The main proponent of this approach was Gibson, who suggested that perceptual and motor systems should be studied together (Haywood & Getchell, 2009). He also introduced the concept of ‘affordance’, which proposed that the individual is highly intertwined with the environment. Additionally, he disagreed with maturation or information-processing theorists who emphasised that the CNS should be viewed as the executive system for developmental changes. Instead, he suggested that the individual perceives the environment directly using their eyes, ears and bodies (Haywood & Getchell, 2009).

Further research is needed to investigate the nature of the interactions between environmental stimuli and the child's selections, as well as the variations that are observed on the aforementioned interactions upon motor development. Additionally, interventions are necessary to establish the causal links of this relationship. Therefore, the present research is important because it addresses the need for further investigation by delivering a MSI for the Early Years and observing its effects upon children's academic and motor performance.

The sections above provided a presentation of the three dominant theories of motor development as they have developed over time. During motor development an individual acquires various motor skills and patterns. Both concepts differ, since the first is characterised by a precise and accurate motor performance, whilst the latter is perceived as the general movement pattern that an individual can exhibit (but which can vary in levels of proficiency). The growing child is capable of performing several motor patterns and develops the required motor skills for each pattern. Due to the complexity of the motor system, movements can be viewed and categorised as different activities.

As this literature has outlined, child development was initially perceived to be the result of the maturation of the CNS, with motor behaviour understood to be the product of the autonomous nervous system. Later, it was thought that motor behaviour was the outcome of the processing of sensory information by the person producing the relevant output. Finally, it has more recently been suggested by those who advocate a dynamic systems approach, that motor behaviour results from the interaction of multiple subsystems (Sugden, 2007). The three approaches to development differ but at the same time they can complement each other.

All three of the aforementioned approaches have had a profound influence upon later motor skills interventions, providing the underlying principles for their development (Sameroff, 2010). For instance, the MSI for the Early Years used in this study has drawn upon both the information processing and the dynamic systems approach.

If studied separately, however, all of three of the abovementioned approaches exhibit significant weaknesses. For example, the dynamic systems do not provide an understanding of the neuro-anatomy involved in the proposed model. The information processing model can fill this gap by providing explanations of how specific mechanisms work during development. On the other hand, the information processing approach lacks flexibility and fails to provide a description of the active nature of the learner, something that the dynamic systems approach achieves. More specifically, the dynamic systems approach includes other systems, such as the muscular system, in the production of movement. Additionally, it can also explain variability among individuals through the principles of stability and instability, which are both necessary "conditions" for developmental change and flexibility.

As these examples suggest, the main reason for adopting a combined approach in this project is that the limitations of one theory can be covered by the other, and vice versa. Moreover, at present there is no dominant theory on motor development or any one theory that can solely explain the various developmental processes involved. It is therefore felt that if an intervention were to be based on a single approach it would be too limiting and too specious to do justice to the complexity involved in the development of motor and cognitive skills.

Having reviewed the literature on how motor development takes place, the next question is how motor learning and motor control develops, and if learning is permanent or not?

2.5. Dynamic Systems & Motor Learning

The main concepts which serve as the necessary "tools" for motor learning to take place are: stability, instability/flexibility and soft-assembly (Spencer & Schoner, 2003). But how are these concepts defined? These three concepts are defined by Spencer and Schoner (2003) in the following manner:

- "Stability: Can be defined as the persistence of behavioural or neural states in the face of systematic or random perturbations". For example, muscles can provide stability by keeping joints stable against perturbing forces.
- "Instability/Flexibility: A change of a system that leads a particular state to become unstable is referred to as instability". Instabilities are central in allowing the individual to flexibly switch between behavioural states or tasks.
- Soft-Assembly: Is the general principle of the dynamic systems, described earlier, that views behaviour as the product of continuous adaption to changing environmental conditions, rather than as hard-wired and pre-determined.

Based on these principles, motor learning takes place when the individual actively interacts with the environment and adapts his/her internal elements to the changing conditions. Therefore, motor learning can be seen to be continuous, and learning a motor skill or task can change depending on the nature of this interaction.

But how can a person, while performing a motor interaction task, already know how to behave unless there are conditional rules already stored in memory or in a similar mechanism? (Rose, 1997) This is one of the main criticisms of dynamic systems theory on motor learning.

Next, some of the theories focusing on motor control will be discussed. It is important to have an understanding of such theories, since motor control forms an essential part of motor skills development.

2.6. Theories of Motor Control

It is very important to have a clear understanding of motor control because future research in the area of motor development and movement will benefit greatly. More specifically the present research's interest is associated with the area of motor control. Areas of motor control are involved in the MSI for the Early Years that has been developed as part of the research; such as tactile control. Other than specific connections between motor control and the current intervention, motor control is involved in all our movements. An individual has to establish motor control to correctly perform a motor task. Furthermore as theories suggest, since motor control is influenced by environmental stimuli it can be manipulated in a beneficial way in the educational setting. Further implications will be discussed later.

Movement behaviours occur originally in the form of reflexes and start as early as the foetal period. Reflexes are said to have a strong impact to later motor development. After the first year an infant's movement repertoire changes dramatically and reflexive movements start to become more "conscious".

Both the quality and quantity of movement are significant parameters in the child's motor development. The quality of movement is related with how efficient and correct a movement is performed, whereas the quantity of the movement is characterised by the richness of an individual's movement repertoire. One of the goals of the current intervention is to improve or further develop children's motor skills. More specifically, since it is addressed in TDC it is anticipated that the current intervention will have a preventative role to the various risk factors associated with poor motor skills, which will be discussed later.

Over the years several theories of human motor control have been proposed. The main focus of research has been the investigation of the processes that are involved in achieving motor control and outlining what these processes actually control (Rose, 1997). Thus understanding motor control and its nature is essential for developing effective interventions.

Three key approaches associated with research on motor control—reflex theories, hierarchical theories and dynamic systems theories—are discussed below.

Reflex Theories

One of the earliest approaches to motor control movement was that of reflex theory. Conceptually, this theory was based on neurological principles. The most influential neurophysiologist associated with the theory was Sherrington, who believed that reflex was the primary unit of motor control (as cited in Rose, 1997). The basic model used in this approach is the stimulus-response model, which had been previously used by Watson. In this model, the person is considered to be a passive recipient of various stimuli that trigger motor systems and produce motor actions. When more complex behaviours are produced, they are considered to be the result of compound reflexes and their successive chaining together (Rose, 1997). Although reflex theories have provided some great insights in the area of motor control, they are currently considered outdated and thought to be too limited to provide a full account of motor control. Some of their main limitations are:

- Failure to explain the vast amount of voluntary movements that cannot be explained by the stimulus-response paradigm.
- Failure to account for movements that are performed without sensory feedback.
- Failure to explain a person's ability to produce novel movements or respond to rapidly occurring ones (Rose, 1997).

Although reflex theorists failed to explain a large amount of a person's movement repertoire, some contemporary interventions are still based on their insights. For instance, the Primary Movement Programme (PMP) is an intervention that aims to inhibit the persistent primary reflexes which are believed to play a central role in difficulties found in dyslexic children (McPhillips & Sheeny, 2004). Indeed, recent research has even found some initial evidence to suggest that the intervention is effective at reducing the reading and motor difficulties that dyslexic children exhibit (McPhillips, Hepper & Mulher, 2000). As such, it seems that there might be some merit to reflex theories.

Hierarchical Theories

Hierarchical theories were initially based on a top-down model of motor control according to which the higher cortical centres command the lower ones to carry out prescribed movements (Greene, 1972). According to this approach, movement representations are stored in the memory as motor programmes that consist of pre-structured sets of motor commands. These motor commands are believed to be constructed at the highest cortical levels and then move to the lowest centres for movement execution (Rose, 1997).

Hierarchical theories have developed significantly over the years, inspiring many new concepts in the field of motor skills research and contributing significantly to the understanding of motor control. A possible limitation of this theory, however, is the exclusive focus on the cortex as the main motor control centre, disregarding the role of other systems that might be involved. As mentioned earlier, this is a general problem that tends to be common in theories that are based on the information processing approach (Rose, 1997). Additionally, it is also worth noting that a top-down approach cannot explain movements where children gain motor control using their lower limbs first.

Dynamic Systems Theory

Dynamic systems theory emerged after the hierarchical theories approach. Its most influential early representative was Bernstein (1967). As it was mentioned earlier, Bernstein was the first theorist to define movement in terms of the coordination and interaction of different body parts (Thelen, (a) 1995). Based on his ideas, numerous experiments were performed in order to test whether movement takes place in coordination with the environment. For example, in one experiment, people were asked to hold and move a handheld pendulum. In order to perform the movements, however, people had to manipulate both the physical (weight) and the energetic (frequency of movements) parameters of the instrument. The above manipulations produced both movement changes and motor control which, as the model had predicted, were in coordination with information from the environment (Thelen, (a) 1995).

Emphasising the central role of the interaction between the environment and the performer, the dynamic systems theory provided important information about motor control and helped inform subsequent motor interventions. Another contribution has been the recognition of the importance of the spinal and skeletomuscular systems for the production of highly coordinated movement patterns, such as locomotion. However, a possible limitation of the approach might be the lack of a link with any specific internal components (such as neuroanatomical areas). Compared with reflex theories dynamic systems argue that some reflexes such as the stepping reflex do not disappear but masked. More specifically, it is believed that infants change their movements due to developmental changes in nonneural biomechanical variables (Adolph & Berger, 2005). The shift from the traditional developmental theories that were based on strict age-related outcomes is now apparent suggesting that psychological functions are integral to movement control and adaptation. Overall, dynamic systems theories have offered important insights to the area of motor control and, most importantly, they have helped to bridge the divide between psychological and neurological explanations of movement organisation. Based on the most recent evidence and reviews, the dynamic systems approach offers the most complete explanation to motor development and motor learning (Spencer, Thomas, McClelland, 2009; Spencer, Perone, Johnson, 2009).

2.7. Summary of Main Points

All the aforementioned theories have provided valuable information about human motor control. Nevertheless, although research in the area of motor control and movement in general has developed over the years, there remain many questions regarding movement control. Some of these questions relate to the impact that the environment has on the developmental process, as well as the role of the person in their interaction with various environmental stimuli.

In order to better understand the different views on motor development and learning motor tasks we can consider the example of walking. A maturational approach would explain walking as the outcome of biologically driven autonomous neural maturation; thus, no sensory input can affect the learning of walking and the learner is considered to be passive. By contrast, the information processing approach focuses on the cognitive abilities that precede action and the continuous processing of environmental information. Thus, the stages involved in walking (or any other motor task) would be as follows: first, the person perceives the goal or decides where they want to go; second, he/she receives perceptual information upon which he/she must decide and select a response from a repertoire of movements; and, finally, the person specifies the parameters of the chosen response, such as, direction and organise his/her muscles to perform and execute the act of walking. Alternatively, if one were to adopt a dynamic systems approach, the processes involved would be quite different. Most notably, dynamic systems theory has shown that development is not necessarily continuous and pre-established skills or patterns can change. The process of walking is thus seen to involve the interaction of various systems, both within and external to the child. Some of these processes involve kinematic changes in step parameters, joint excursions, changes in muscle patterns and coordinating changes of limbs (Thelen, 2000). Moreover, according to the dynamic systems approach the child, through self-organisation, is capable of changing the state of their system to achieve stability and complete the motor task.

It is obvious that all three approaches to motor development have different contributions to make to the area and that each can provide unique explanations for understanding movement behaviour.

However, over the years, the theory that has gained the largest recognition is the dynamic systems approach as it seems to overcome many of the limitations of previous theories. As such, most recent research has sought to further investigate the impact of the theory, not only to the areas of motor development, but also to other areas such as cognitive development (Johnson, Spencer & Schoner, 2008; Smith & Thelen, 2003).

At the same time, the role of earlier theories should not be underestimated since they provided a basis for future theories and many of their principles continue to inform current research. For example, the maturational approach significantly contributed to the study of development by examining and comparing twin populations. Likewise, the information processing approach explained some of the mechanisms involved in the process of receiving environmental information and producing a response.

To conclude, various aspects of motor development have been presented in this section. Each of the theories and approaches has offered information relevant to future research. Since the present study is focused on motor skills and relevant aspects of movement, the above section is very important as it sets the theoretical context for the area under investigation. Furthermore, the theories presented have also informed the current intervention in many ways. Evidence of this impact can be seen in the following examples drawn from the current intervention:

- Ensure the child’s active participation in the activities which both the information-processing and dynamic systems approach suggest is significant for shaping motor behaviour.

- Include functional tasks such as; drawing which as dynamic systems suggest it is important to help the child with daily activities.
- Teach activities which can be generalisable. For example, teaching manual dexterity which can be applied in several other tasks. This principle can be found both in information-processing and dynamic systems approach.
- The current intervention was informed by combining perspectives from both information-processing and dynamic systems theories; hence, it is evidence based.

As these examples demonstrate, this review of the most influential theories on motor development has significantly shaped and influenced the development of the MSI for the Early Years. To sum up, the current thesis supports a combination of dynamic systems and information processing view on motor development. Based on the literature review it is believed that movements and motor learning are the result of the interaction of multiple systems both within and external to the individual. The child is learning by adapting to the constant changes experienced. Therefore, new motor skills can be perceived as new opportunities for learning as well as developing a child’s social and cognitive abilities. At the same time as mentioned earlier some of the principles of the information processing approach have been included in order to decrease some limitations of the dynamic systems mainly concerned with the underlying processes involved during behavioural change. Therefore, the current thesis has adopted a combined approach to the study of motor development producing a hybrid approach to motor skills intervention.

2.8. COGNITIVE DEVELOPMENT

As it has been discussed in the Introductory Chapter the current thesis seeks to explore the relationship between motor development and cognition. The first part of this Chapter offered a presentation of the different approaches to motor development and how these approaches have informed the current research. This part will introduce the second "element of the equation" under investigation which is cognitive development.

It is outside the remit of this thesis to provide a detailed account of all the theoretical literature on cognitive development; instead, the focus will be on how the study of cognition is relevant to the study of motor skill development.

Research on cognitive development has investigated the changes that occur in an individual from birth onwards. More specifically, it has focused on the changes that occur in cognitive activities such as mental processes and thinking (Oakley, 2004). Changes are typically observed either by focusing on children or on adults, depending on the field of research. However, research on cognitive development in childhood is more advanced and also tends to be "richer" since this period is characterised by continuous cognitive changes as well as the learning of new cognitive skills. Numerous cognitive skills and processes, including attention, memory, information processing, problem solving, and comprehension have been studied. In the present thesis, however, the focus is solely on the academic skills of reading and maths. Both reading and maths involve a number of different underlying cognitive processes that must be learnt and internalised.

Over the years, many theories have been proposed in an attempt to explain the complex processes involved in cognitive development. Some of the most influential theories that have emerged include: Thorndike's stimulus response theory; Piaget's cognitive theory; information processing theory; Vygotsky's socio-cultural theory; and connectionism (Byrnes, 1996; Miller, 2002; Thelen & Smith, 1994). As with motor development and the approaches described earlier, these approaches have been applied to cognitive development sharing the same principles. For example, according to information processing, cognitive development is considered continuous rather than stage-like and involves small quantitative changes rather than large qualitative ones (Shaffer & Kipp, 2010). As with motor development described earlier a limitation of this approach to cognitive development is that it does not consider the richness and complexity of cognitive development by applying a computer-based model. The developmental process is more complex from what was originally thought and there are many systems involved for changes to take place (Spencer, Thomas & McClelland, 2009).

Research on the relationship between motor and cognitive development has been far less conclusive. Indeed, for many years these areas were viewed as unrelated since earlier research was not able to find strong evidence of any connection. One of the first theorists who tried to explore the relationships in more depth was Piaget, who suggested that early motor skills are used by children to help develop cognition (Thelen, 2000). Inspired by the work of Piaget, many theorists from different areas further investigated the link between cognitive and motor skills. Their approaches will now be discussed in more detail.

2.8.1. Early Links between Cognition and Motor Skills

The first attempts to associate the cognitive to the physical or motor area can be traced back to 1949 when Olson proposed his organismic age theory. According to this theory, certain physical stages (such as height, weight, and grip strength) are related to certain non-physical stages (such as mental age and school performance). Each measure was then converted to a comparable age category, before being averaged out to produce an overall score called the “organismic age” (Kirkendall, 1986). Although contemporary research has not found supportive evidence for the aforementioned theory, it still serves as a useful example of the sorts of early investigations into the relationship between the body and the brain.

A second early approach to the study of the relationship between cognition and motor skills can be found within the principles of Gestalt psychology. According to Gestalt psychologists:

"The organism always behaves as a unified whole and not as a series of differential parts. Mind and body are not separate entities nor does the mind consist of independent faculties or elements and the body of independent organs and processes. The organism is a single unity. What happens in a part affects the whole" (Hall & Lindsey, 1957, p.297).

This theoretical foundation provides a basis for studying mental and physical activities together. Moreover, Gestalt theory supports the notion of plasticity of the CNS which allows for plasticity during the development of motor processes as well (Katz, 1951). In addition, the Gestalt approach has also proved influential in the areas of perception, learning and social psychology (Galotti, 2007).

At the same time, though, the Gestalt approach to psychological constructs has also been heavily criticized on for its lack of scientifically sound research and its poorly defined psychological assumptions (Katz, 1951). For these reasons, it is now rarely used in the study of cognitive development.

2.8.2. Contemporary Links between Cognition and Motor Skills

Moving to the more contemporary views on the relationship between motor and cognitive development, the main source of inspiration has been the work of Piaget. For instance, in 2000 Campos et al. provided an extensive and influential work on human development that built on Piaget's views (Campos, Anderson, Barbu-Roth, Hubbard, Hertenstein & Witherington, 2000). According to their work, a motor developmental event or milestone such as the onset of locomotor experience initiates tremendous consequences in other developmental areas such as emotional, social and cognitive development. They use locomotion in explaining their views on development. Contrary to the views of stage developmental theorists who suggest that development takes place at the same time across domains, Campos et al. argue for a new approach based on the premise that:

> *"A single, universal, developmental acquisition-the onset of locomotion-produces a family of experiences, with each member of the family being implicated in some psychological changes but not in others. In some cases several processes coalesce, sometimes in apparent synchrony with each other, sometimes one preceding another in an orchestrated fashion, to generate a specific psychological change" (Campos et.al. 2000, p. 150).*

Hence, according to this view, independent mobility, which is achieved while the infant practices locomotor activities, is perceived as the result of the changing experiences involved in movement. On the other hand, the authors suggest that locomotor experience, although significant, should not be viewed as a necessary prerequisite for producing developmental changes and suggest four reasons why this is the case:

1. Locomotor experience cannot be responsible for creating a phenomenon, but it can elevate psychological skills to a higher level.
2. There are cases where infants can acquire a psychological skill prior to a locomotor experience.
3. Human development shows the operation of alternative developmental pathways to the ones that usually bring transition, a principle known as equipotentiality.
4. Locomotor experience can be necessary for updating or maintaining an already learned skill.

As such, it is argued that locomotion does not have a causal role in developmental change. As Campos et al. suggest the absence of necessity and sufficiency is the common rule in most of human psychological and biological development (Campos et.al., 2000). The authors also provide further evidence on the important role of locomotor experience and show how it can be applied to a wide spectrum of psychological changes in infants. For example, locomotion brings to the infant changes such as the development of autonomy and motivation towards goals such as reaching an object. What, though, are the implications of this work for human development? According to the abovementioned research, locomotor experience had a significant long-term role on the course of development, since once attained it is typically maintained. Additionally, this relationship is dynamic since it can initiate changes in the interaction between the individual and the environment. When children start to engage into interactive play they increase at the same time their locomotion experience and become more independent. These behaviours can be perceived as early indicators of language development; therefore, motor development can now be more closely linked to language development (Viholainen, Ahonen, Lyytinen, Cantell, Tolvanen & Lyytinen, 2006).

This research by Campos et al. is a representative example of contemporary work that investigates the relationship between motor skills and cognition. At present, however, the mechanisms by which movement can lead to changes in cognition have not been fully identified. In addition, further research is needed to investigate the developmental process in other situations where typical development is not the case. For example, what happens to children who fail to develop their locomotor abilities due to illness? Are these children inevitably left behind in other areas of development or do they fail to experience psychological changes, which, as the article by Campos et al. suggests, are linked to locomotor experience? As discussed earlier, to answer this question Campos et al. suggested that locomotor experience can be a condition for changes in other psychological areas, but it cannot be perceived as a necessity.

The connection that is being suggested between motor developmental milestones and changes in other areas of development such as cognitive, is a connection that is being supported in the current thesis. More specifically, it is anticipated that children who participate in the MSI for the Early Years will not only improve several motor skills but cognitive changes will follow. Overall, Campos and colleagues' work has been influential and is as important since it provides a theoretical background for the current thesis by supporting the connection of the bodily experiences with the cognitive ones.

2.8.3. Embodied Cognition

Piaget's view on cognition was that it was formed under the influence of sensorimotor experiences. More specifically, Piaget argued that cognition is shaped by sensory and motor experiences, "hence the movement which takes place with those experiences is remembered and recalled to the same degree as information form the other perceptual senses" (Thelen, 2000). According to this line of thought, as the child grows up, there is a degree of dissociation between mental events and direct sensory information, but the link remains. Later theorists have drawn upon Piaget's views on the link between actions and thoughts, but have challenged his belief that the mind and body are categorically distinct.

One of the most prominent such theories were that of "embodied cognition", which suggests that there is no separation between the mind and the body. In addition, it also suggests that bodily experiences form cognitive experiences (Thelen (b), 1995). One interesting example which demonstrates the role of the body on cognition is based on a classic Piagetian task; namely, the A-not-B error. In this task, an infant observes an object being hidden in one location (A). The infant then searches for the object and, inevitably, finds the object in the right location. This process is repeated a number of times before the infant observes the object being hidden in a different location (B). Interestingly, infants still go back and search in location A (Spencer, Smith & Thelen, 2003). Initial reviews of this task emphasised that, given the task's outcome; important information on the state of the infant's brain at a specific developmental point/stage could be extracted (Spencer et.al., 2003). Later theorists who advocated a dynamic approach to development replicated the task and interpreted the outcome in a different way. According to their dynamically driven approach, the error which infants make in this task should not be linked to specific developmental stage; rather, it should be seen reflective of the general processes involved in producing goal-directed tasks, particularly those of vision, attention, memory and other motor processes (Spencer et.al., 2003). Thus, the A-not-B error is explained as a broader spatial memory error that can occur at different points in development and at different ages, meaning that the focus shifts from what the infants know to what they do (Spencer et.al., 2003). Additionally, the above explanation reflects the different contemporary approach to cognitive tasks that as discussed are inseparable from bodily experiences.

The link between this task and embodied cognition is that infants, by reaching multiple times to a location they recognise, eventually build-up a location memory that incorporates the feel of the arms and the posture. This subsequently influences later decisions. Hence, movement seems to be inseparable from memory and decision making — both processes that are traditionally considered to be cognitive.

2.8.3.1. Main Principles of Embodied Cognition

The main premise of embodied cognition is that the "cognitive processes are deeply rooted in the body's interactions with the world" (Wilson, 2002). According to Wilson (2002), embodied cognition theory is composed of the following six principles:

1. Cognition is situated: suggesting that cognitive development takes place in a real-world environment and in the context of task-relevant inputs and outputs.
2. Cognition is time pressured: cognition must be understood in terms of how it develops within environmental time-limits.
3. We offload cognitive work onto the environment: since the organism has limitations (for example attention limitations), the individual offloads information to the environment reducing the cognitive load.

4. The environment is part of the cognitive system: since information between the physical world and the mind are continuous, cognition should be studied in relation with the environment and not solely the mind.
5. Cognition is for action: cognitive mechanisms must be viewed in terms of their contribution to appropriate behaviours according to different situations.
6. Off-line cognition is body based: the activity of the mind is grounded in mechanisms evolved for environmental interaction; such as sensorimotor control.

These six principles represent, in detail, the main ideas surrounding embodied cognition and they have provided important insights on the relationship between motor and cognitive abilities. The theory of embodied cognition has informed research and offered alternative explanations on the relationship between cognition and motor skills (Thelen, 1995). Based on embodied cognition many links between cognition and motor abilities can be explained. For example, babies acquire knowledge from performing several movements with their bodies (Thelen, 1995). Additionally, cognition's role changes since it is perceived as rooted in sensorimotor processing (Anderson, 2004). Finally, it has also been shown that there are numerous cases where the person needs to offload cognitive work to the environment, such as when opting to use a pen and paper to perform calculations rather than performing mental arithmetic (Anderson, 1984).

At the same time, numerous weaknesses have been highlighted in the embodied cognition approach. With regards to the first principle listed above, it should be noted that not all cognitive abilities are situated. For example, a person is able to form mental representations of situations that are remote in time and space (Anderson, 2004). Daydreaming and planning provide two such examples of this. In terms of the second principle, it is only partly true that cognition needs to cope with time limitations as there are activities that are performed without the pressure of time (for reading example a paper). In terms of the fourth statement, it is often true that the cognitive actions of a person are better understood and explained by including the body to form a uniform system; however, depending on the task, sometimes actions are better understood using a more computational approach or through more restrictive boundaries (Anderson, 2004). With regards to the fifth principle, it is perhaps too simplistic to claim that cognition is simply only used for action since this view overlooks the richness of the cognitive system as well as the fact that not all actions are purpose-based.

Other than the specific criticisms surrounding the main principles of embodied cognition, there are also a number of more general criticisms of the theory. One such criticism focuses on the fact that physically disabled people are still able to learn, which, if one adopts an embodied cognition approach is difficult to explain. The answer to this problem is that people can also learn through analogy, imagination, and demonstration, meaning that physically disabled people are able to, and indeed do, learn (Anderson, 1984). Furthermore, there are still a number of important unanswered questions surrounding the theory, such as: how can representations be derived from perceptual experience; how can they be related to action; and how it might be possible to reason with representations generated in this matter? This question represents one of the strongest criticisms of embodied cognition theory since other theorists propose that it is not possible for an intelligent creature to “develop” without representations. As such, there is the need for future research to investigate how embodied representations work and how they are created from sensorimotor and perceptual information (Anderson, 1984; Anderson, 2004). Finally, another limitation of embodied cognition theory is the difficulty it has in explaining how abstract concepts where no sensory or motor information are involved can be represented in the brain (Mahon & Caramazza, 2008).

The theory of embodied cognition has been discussed in this current thesis because it provides a rich background to the study of both cognitive development and motor development. The six main principles of embodied cognition, presented earlier, suggest a strong link between the motor and cognitive areas, which are the two areas under investigation in the current thesis. Additionally, embodied cognition theory provides a strong theoretical framework for investigating this relationship and developing a MSI for the early years that incorporates both motor and sensory tasks. For example, based on the first principle "cognition is situated", the current intervention took place in a real-world environment (school classroom) and the context had both inputs and outputs associated with each task that children were required to perform. Therefore, principles from embodied cognition informed the current MSI for the Early Years. Since the learning process of the child is achieved through the combination of bodily experiences and thoughts, a MSI for the Early Years can help in the development of both areas. As Smith (2005) suggests "knowing is bound to the world through body" (Smith, 2005, p. 279). Earlier theories tended to study motor and cognitive development separately but, as recent research suggests, motor and cognitive development are actually linked; thus, it makes sense for them to be studied together.

In the MSI developed for this thesis, the two intervention measures under investigation are reading and maths. An in-depth description of both now follows.

2.9. Cognitive Skills Involved in Reading & Maths

Numerous cognitive mechanisms and processes are involved in the acquisition of reading and maths, both of which develop during the early years until they reach their ultimate level of proficiency later in life. As the literature emphasises, reading and maths are both areas in which improvements resulting from motor or physical skills interventions have been recorded (Castelli, Hillman, Buck & Erwin, 2007; Ericsson, 2008; Son & Meisels, 2006). Generally, both reading and maths performance are associated with physical activity during the early school years. What now follows is a brief overview of the mechanisms involved during the learning process of these two areas. In addition, the cognitive mechanisms that are involved in language and literacy acquisition will be discussed.

2.9.1. Language & Literacy Acquisition

Research suggests that infants acquire the first characteristics of their native language by learning individual speech features such as consonants and vowels (Bergelson & Swingley, 2012). The common belief is that the learning of the words' meaning is acquired later, usually around nine to 15 months of age. However, an experiment by Bergelson and Swingley (2012) showed that infants are able to understand the meaning of specific categories of words (mainly food and body parts) at an earlier age, sometimes starting from six months. The importance of these findings lies in the fact that they challenge our previous knowledge of the age that infants start to understand language meanings. In addition, this finding can help to explain why two year old children show a rapid increase in their vocabulary, since initial learning takes place at an earlier age. Similarly, there is evidence suggesting that children's development of phonological[3] recognition of words' sounds starts from as early as eight months of age (Swingley, 2008). These findings provide valuable insights into the study of language and literacy acquisition in the early years since one of the later stages in children's literacy acquisition, which is highly related with reading, is the development of phonological awareness. Phonological awareness can be defined as the ability to manipulate segments of speech and is considered as one of the main predictors (along with working memory and information processing speed) of later reading performance (Schneider & Berger, 2012). Typically, phonological awareness, comprised of a series of different phonemes and develops at the beginning of the first year in school. Moreover, research also suggests that children who have phonological difficulties can also have motor problems (Ramus, Pidgeon & Frith, 2003).

[3] Phonology: processing of information contained in speech sound (Frith, 1999).

One of the measures that the current research assessed was reading. According to Hulme and Snowling (2005), reading can be defined as “information-processing: transforming print to speech or print to meaning.” There are different models and approaches that attempt to explain the mechanisms involved in reading. One basic model that describes reading focuses on the development of orthographic, phonological and semantic processing. Briefly: orthographic refers to the recognition of the symbols of a written language; phonological refers to the auditory representation of the symbols and semantic refers to the meaning of a word. All three skills work together in order to produce reading (Byrnes, 1996). As they become more automatic, so the reader becomes more proficient. Several problems may become evident in any area of the reading model, resulting in reading difficulties such as developmental dyslexia. Developmental dyslexia and its common symptomatology with motor difficulties will be discussed later in this Chapter.

It is, however, beyond the scope of this study to further analyse the various reading models and approaches that have been developed. In general, though, it should be recognized that early reading involves the acquisition of several different skills, all of which are essential for later reading, and that research in the area is on-going since not all neural mechanisms involved have been discovered.

2.9.2. Maths

Mathematical skill is complex involving language, space and quantity. These are skills that are typically developed during childhood. Indeed, in one study in which infants were required to discriminate between different small item numbers, it was shown that humans can possess true numerical concepts from as early as five months old (Wynn, 1992). This finding implies that humans have some innate knowledge regarding arithmetic values. Moreover, these findings are also important for the advancement of understanding the processes involved in acquiring knowledge about maths.

Mathematical knowledge can be divided into conceptual and procedural categories. Conceptual knowledge refers to concepts such as symbol comprehension, relative numerosity comprehension, and knowledge of mathematical facts. Procedural knowledge involves the understanding of basic mathematical concepts such as addition, subtraction, multiplication and division (Byrnes, 1996). These two categories have been also expressed as knowledge about quantitative relations and knowledge about the counting system respectively (Bryant & Nunes, 2012). In order for children to achieve understanding of maths, they need to learn the relation between procedures, facts and ideas; by doing so, they are thus able to create strong mental concepts that can be easily retrieved when needed (Hiebert & Wearne, 1996). Furthermore, children with strong conceptual knowledge in school mathematics can better develop new procedures or adapt their already-learned ones. As research suggests, it is important to acquire a robust conceptual understanding at an early stage in order to improve later performance (Hiebert & Wearne, 1996).

Another important concept in the acquisition of mathematical knowledge is an understanding of the two different properties of numbers: cardinal and ordinal (Bryant & Nunes, 2012). As Bryant and Nunes (2012) explain, a "number's cardinality refers to the principle that sets with the same number are equivalents in quantity, whereas the ordinal property refers to the fact that numbers can be arranged in terms of magnitude (going from smaller to larger)." Both concepts are important and teachers should be aware of the need to learn about them in their maths lessons.

During primary school years, children are required to learn the basic computational concepts. Children who have difficulties learning and remembering arithmetic facts, executing calculation problems or using immature solving techniques can be in the at-risk group for developing a maths-related difficulty. More specifically, children exhibiting the aforementioned problems are thought to have "developmental dyscalculia" (Landerl, Bevan

& Butterworth, 2004). Maths is an ability that, like reading, involves different mental and motor abilities in order to be performed without any difficulties. Children sometimes exhibit problems in both these areas. Future intervention may benefit from studying this common symptomatology in more depth and from research on the underlying mechanisms involved.

2.9.3. Motor & Cognitive Skills in Reading and Maths

Research has shown that some cognitive skills — notably, simultaneous coding, planning, attention and successive processing — involved in both reading and maths are influenced by physical exercise (as cited in Asonitou, Koutsouki & Charitou, 2010). Furthermore, aside from those children that have Developmental Coordination Disorder (DCD) or other developmental disorders, studies indicate that motor skills and academic performance are closely related in TDC (Etnier et al., 1997; Wassenberg et al., 2005). In addition, there is also research suggesting that increased emphasis solely on the teaching of reading or arithmetic alone cannot accelerate the developmentally-delayed child's academic performance; however, increased opportunities for fine and gross motor tasks might benefit these children (Blythe, 2000).

As recent research suggests, the body's role in the process of learning should not be underestimated. More specifically, according to the embodied cognition theory, bodily experiences form cognitive ones; thus, movement needs to be viewed as being inseparable from memory and decision making (skills that are traditionally cognitive ones). Furthermore, the dynamic role of development can inform this research area and further explain the relationship between different developmental processes. For example, as has been suggested by Campos et al. (2000), a single developmental acquisition can potentially produce changes in several processes either motor or cognitive.

Physical development and motor skills form a major part of a child's development between the ages of four and eight years when the child is engaging more actively in tasks requiring more complex motor skills. Pupils tend to show rapid progress in reading and maths during their first year in school (Tymms, Merrell & Henderson, 2000). Children whose physical skills are under-developed need more time and opportunity to develop these skills before reaching a stage of "readiness" for fine motor tasks such as writing. Since children develop early these aforementioned skills in a parallel way, it is essential to further investigate this relationship so as to maximise school performance and develop interventions for the school environment. As Son & Meisels (2006) suggest on their study with a nationally representative sample of 12,583 children in kindergarten the predictive role of early motor skills to later development of both reading and maths should not be underestimated but further studied to benefit children's future development and academic achievement.

2.10. EVIDENCE OF THE RELATIONSHIP BETWEEN MOTOR SKILLS & COGNITIVE FUNCTIONING

One of the main research questions in this study is whether the training of motor skills can improve cognitive functioning as expressed through performance on reading and maths. Evidence supporting the relationship can be derived from different fields, with numerous studies highlighting the relationship between motor skills and different areas of academic achievement (Asonitou, Koutsouki & Charitou, 2010; Ericsson, 2008; Ericsson & Karlsson, 2012; Wassenberg et al., 2005). Additional research performed on healthy and preterm children shows significant positive correlations between motor scores at the age of four and academic achievement at the age of eight (Sullivan & McGrath, 2003). Moreover, a recent quantitative review performed in the USA further revealed the importance of incorporating motor or physical activity interventions into the school day to enhance motor and learning performance (Erwin et al., 2012). Overall, then, the weight of theoretical evidence would seem to provide enough justification for examining motor skills together with cognitive or academic skills (Bushnell & Boudreau, 1993; Roebers & Kauer, 2009; Son & Meisels, 2006).

2.10.1. Developmental Disorders Co-morbidity Evidence

Supporting evidence for the relationship between motor and cognitive skills comes from the comorbidity of motor and cognitive symptoms in a number of developmental disorders. Comorbidity refers to the overlap of symptoms between disorders and indicates the presence of at least two disorders (Kaplan, Dewey, Crawford & Wilson, 2001). The developmental disorders that will be considered in the following section are developmental dyslexia, ADHD, developmental coordination disorder (DCD), specific language impairment (SLI) and autistic spectrum disorder (ASD). Individuals with these disorders exhibit difficulties in the motor, academic or cognitive domain. In the sections to follow more emphasis will be given to those disorders that exhibit problems in both motor skills and the academic skills of reading and maths. Before presenting each developmental difficulty separately, however, three theories attempting to explain this observed comorbidity will be discussed.

2.10.2. Theories on Co-morbidity

The area of developmental difficulties has always been challenging for both the research and clinical disciplines. One of the main reasons for this is the difficulty in setting clear-cut boundaries for diagnostic criteria, due to the degree of overlapping between various developmental difficulties. In order to understand the similarities that developmental disorders seem to exhibit, different theories have been developed over the years. The focus of the present research is on the relationship between cognitive, academic and motor difficulties in children, which, as recent research suggests, often co-occur. One particular interesting example is that of DCD and its comorbidity with other developmental disorders. DCD is mainly associated with a marked impairment in the development of motor coordination (American Psychological Association, 2000). Furthermore, motor problems have been attributed to deficits in the sensorimotor integration (Visser, 2003). Other than the main symptoms of motor problems, children with DCD appear to exhibit difficulties in other domains such as learning, attention and reading (Sugden & Chambers, 2005). In addition, children with DCD often exhibit common symptoms with ADHD and developmental dyslexia (Dewey, Kaplan, Crawford & Wilson, 2002); as such, the idea that many cases of DCD, ADHD and reading disability can represent more generalised deficits rather than discrete deficits is growing. DCD and its comorbidity with other developmental difficulties will be analysed in more detail in a later section.

During the 1970s and 1980s, the idea of a more generalised concept of developmental difficulty gained support from the theory of Minimal Brain Dysfunction (MBD), which asserted that disorders such as clumsiness, ADHD and learning difficulties should be grouped together under the “umbrella” of non-specific problems in brain function (Visser, 2003). This theory was highly criticized at the time, with many scientists asserting that the symptoms of developmental difficulties derived from more localised brain dysfunctions. However, recent research has sought to re-evaluate the MBD theory due to the high comorbidity rates between different development disorders and new theories have been developed, namely: the Atypical Brain Development Hypothesis (ABD) and the Automatization Deficit Hypothesis (ADH). These theories approach the observed comorbidities with a more neural or brain- based focus. On the other hand the Causal Modelling Approach is the most contemporary attempt to explain the observed similarities among developmental disorders suggesting a more holistic approach. Briefly, the ABD suggests that based on brain imaging both dyslexia and ADHD show atypical brain development which cannot be limited only to certain brain areas, but involves areas other than the ones in focus (Kaplan, Wilson, Dewey & Crawford, 1998). The ADH was developed during research with children with dyslexia; it suggests that children with dyslexia have problems in automatizing[4] skills (Visser, 2003). These two theories will not be presented in detail since they are not directly related with the current research.

By contrast, the next theory to be discussed — the causal modelling approach — is based on a much more holistic understanding of developmental difficulties. Additionally, it will be presented in detail, since the current research has been informed by this framework.

2.10.2.1. Causal Modelling Approach

The Causal Modelling framework suggests that co-morbidities can be explained using a three level model that includes biology, cognition and behaviour (Morton, 2004). Environmental influences can also be added to the model at the biological or cognitive level, therefore they can interact at any level. In this causal model, a disorder is perceived as the end product of the interaction of different factors at either the cognitive or biological level (Krol, Morton & Bruyn, 2004).

[4] Automatization refers to the process by which the performance of a task, following extensive practice, becomes automatic, requiring minimum or no effort (Nicolson & Fawcett, 1994).

The framework is important because when clinicians are required to reach a diagnosis, they often face difficulties identifying the comorbidity of different symptoms and differentiations of the core symptoms from the secondary ones. The causal modelling framework suggests that the definition of a diagnostic entity can be validated by the existence of a single causal chain (Morton & Frith, 1995). Since this single causal chain can be applied to different developmental disorders, the existing comorbidities can be explained by this single chain of causality. More specifically, differences can take place at the cognitive level that result in different behaviours or, when it comes to developmental disorders, to co-morbid symptoms.

For example, a child diagnosed with dyslexia may also have motor coordination problems, whilst another child who is diagnosed with dyslexia may not exhibit any motor coordination difficulties. According to the causal modelling approach, the explanation for this variability lies in the changes that take place in the cognitive processes, which result in major differentiations in behaviour. Thus, this new model adds cognition to the "equation", rather than explaining human development based only on biology. As Morton (2004, p. 39) puts it, "observed behavioural abnormalities are caused by abnormalities at the cognitive level; these in turn have biological precursors." A basic model of this approach provided by Morton (2004) is depicted on the figure below:

Biological Precursor

↓

Cognitive Abnormality

↓

Behavioural Abnormality

***Figure 2.2*: Basic Framework of Causal Modelling Approach**

According to this framework, at the biological level, the factors that can change how behaviours will be expressed can be either a virus or a brain abnormality. At the cognitive level, such variables can be the lack of theory of mind for children who are autistic. Finally, the behavioural level represents the outcome of the two aforementioned factors, which can be expressed by a low intelligence quotient (IQ) (Morton, 2004). Therefore, observed behavioural abnormalities can be caused by abnormalities at the cognitive level, which, in turn, have biological precursors. In this model, the environment can also act at either the biological or the cognitive level. Morton (2004) further outlines some of the underlying principles of the model:

- Causal pathways are never deterministic since there is an interactive complexity of both biological and cognitive development.
- Contingencies are not causes; some factors can be present in the environment without causing any behavioural effect later on.
- There are degrees of compensation on every level; for example, at the behavioural level, a task can be performed using different cognitive mechanisms; at the cognitive level, increased motivation increases attention and can compensate for distractions;

and, at the biological level, the plasticity offers compensation since damaged tissue function can be taken over by other cortical areas.

- There are both protective factors (good parental care) and vulnerabilities (deprived background) that can produce changes and variability among individuals.

Moreover, if there is a cognitive/motor ability or a research finding that cannot be explained by the current theory, it should be added to the model, with a note explicitly stating that it is excluded (until there is a complete theory that can explain it).

A causal modelling approach suggests that having a cognitive account enables us to explain observed variability in behaviour by revealing the interaction of a basic deficit with variability in other cognitive functions or environmental factors. In causal modelling, the therapist can link elements into the same or at different levels of the framework. For example, conduct disorder which is the behavioural level of the model can have several different variables in the cognitive or biological levels. On the cognitive level, the person can have insecure attachment relationships or an aggressive environment, whereas on the biological level birth complications or anomalies in neural development can be found (Krol et.al., 2004). As has been suggested, the framework can help remind practitioners that the specific behaviour under investigation always has multiple determinants (Krol et.al., 2004). For example, a child that exhibits symptoms commonly found in children diagnosed with autistic spectrum disorder can differ significantly from another child with similar symptoms in terms of the underlying determinants of the observed behaviour. The model also offers an alternative explanation to the underlying factors involved in co-morbidity. Most existing diagnostic theories focus on different areas (such as biological, cognitive, and sociological) without integrating them; hence, the causal modelling framework is a useful tool for practitioners since it integrates different categories into a single developmental causal framework.

Whilst causal modelling has gained increased popularity as a framework for explaining developmental disorder, it also has a number of limitations. Some of these limitations are summarised by Krol et.al. (2004):

- The environmental elements of the model need further specification.
- The model needs to have a cognitive/computational model to illustrate the dysfunction in the online functions that lead to behavioural disturbance in any situation.
- Needs to state transition models to describe child-parent interaction.
- Where there is no need to specify a cause, the model cannot be applied or offer useful information.
- It is believed that the model can better explain dyslexia and autism (i.e. ones that have a strong genetically mediated biological basis as well as a well-defined core); therefore, it has been suggested that the model might be an inadequate model for explaining other disorders such as: conduct disorder or anxiety.

There is indeed a need for a better explanation of the environment's role in the model, since there is no specific information on the degree to which the various environmental influences can change the behavioural level. More specifically, although the model suggests that environmental variables (such as the social environment) can "fit" under either the biological or the cognitive levels of the framework, the specific details on the factors that this decision should be based on need to be clearer. Another point of interest is the suggestion that the causal modelling framework can only be successful in explaining developmental disorders with a strong biological basis. Clearly, it is difficult to use this approach for disorders that depend largely upon context such as conduct disorder. But, overall, the model can still be a useful tool in helping practitioners and researchers identify the existing relationships among different disorders or various aspects of a single disorder. More specifically, a single disorder can be expressed differently based on the variability that can be found either in the cognitive or the biological level. This can serve as an explanation of the observed differences that children with the same disorders exhibit.

The causal modelling framework has heavily influenced the current study, since it explains the co-morbidities between motor and academic difficulties. As will be discussed in the sections to follow, developmental difficulties which exhibit both motor and academic or cognitive problems provide further evidence of the association of these two areas. Therefore, investigating this relationship and having a framework under which these similarities can be explained adds to the evidence-based research of the current thesis. Additionally, since it is being suggested changes in the cognitive level can alter the behavioural outcomes, and because these changes can include environmental changes as well, it seems only beneficial to develop an intervention which can positively affect children. Earlier theories on co-morbidity focused mainly on the biological factors influencing behaviour; causal modelling added cognition and other environmental influences to the model. Therefore, based on this framework, the MSI for the Early Years can act as an environmental variable with the potential to change behavioural outcomes such as motor and academic performance.

2.10.3. Developmental Dyslexia

Developmental dyslexia is mainly characterised by difficulties in reading, writing and spelling ability, which are considered to have underlying neurological causes (Elliott & Place, 2004). Additionally, some other symptoms may include: speech and language difficulties, poor short-term verbal memory, difficulties in ordering and sequencing, and clumsiness (Elliott & Place, 2004). The main causes of dyslexia have been attributed to problems in the phonological processing (Snowling, Goulandris, Bowlby & Howell, 1986). In addition to evidence of phonological deficits, there is considerable evidence for deficits in motor skills such as; throwing or catching tasks, bead threading and postural stability (as cited in Fawcett

& Nicolson, 1995; Ramus, Pidgeon & Frith, 2003). Additionally, observational assessments suggest that dyslexic children show impaired development in a series of motor tasks relating to speed of movement, balance and coordination (Portwood, 2003). There are also findings revealing that children with dyslexia exhibit problems in their motor skills. To give one example, in an experiment performed by Fawcett & Nicolson (1995), it was found that dyslexic children exhibited significantly lower performance on bead-threading than their reading age controls, supporting the notion that motor skill deficits are present and co-exist with the other difficulties and persist into adolescence. As discussed earlier in section 2.9.3 based on Campos work (2000) motor and language development are closely intertwined therefore early motor delays can be associated with later language delays. Hence, it seems beneficial to deliver a motor skills intervention in the early years especially to children who are at risk of dyslexia.

The next developmental disorder that will be discussed is attention deficit hyperactivity disorder (ADHD). Recent research has demonstrated that fine motor problems that are found in children with ADHD cannot be attributed to the hyperactive symptomatology but are most likely linked to a motor deficit (Pitcher, Piek & Hay, 2003). Furthermore, both ADHD and children with developmental coordination disorder (DCD) share common reading problems. Consequently, it seems necessary to investigate the relationship between ADHD and DCD since they share similar academic, cognitive and motor difficulties.

2.10.4. Attention Deficit Hyperactivity Disorder

Attention deficit hyperactivity disorder is characterised by a childhood onset pattern of hyperactivity, inattention and impulsivity (Fliers et al., 2008). Among other limitations, children that have been diagnosed with ADHD tend to exhibit reduced academic performance, as well as reading and spelling difficulties (Fliers et al., 2008). Furthermore, primary school children who appear to be severely inattentive, hyperactive and impulsive in the classroom but have not been diagnosed with ADHD also seem to have impairments in their school performance (Merrell & Tymms, 2001). The above correlations were revealed during a study involving a nationally representative sample of 4,148 children through the ages of four, five, six and seven years (Merrell & Tymms, 2001).

Clinical studies reveal that 30%-50% of children diagnosed with ADHD also have motor coordination problems (Fliers et.al, 2008). According to the National Institute for Health and Clinical Excellence (NICE), symptoms of ADHD frequently overlap with other related disorders, including: mood, conduct, learning, motor control, communication and anxiety disorders (Taylor et al., 2009). Although evidence of the coexistence between ADHD and motor coordination problems is strong, many aspects of the association remain unclear. Current research suggests links between both fine and gross motor skills deficits with ADHD. Numerous studies, both cross-sectional and longitudinal, have documented the interaction between ADHD and motor skills deficits (Kadesjo & Gillberg, 1998; Pereira, Landgren, Gillberg & Forssberg, 2001; Rasmussen & Gillberg, 2000). Future research should aim to further investigate this relationship and uncover the underlying causes of this observed comorbidity. Furthermore, future research should investigate whether the motor coordination problems can be viewed as a comorbidity of ADHD, or rather as a concurrent phenomenon. Additionally, research might benefit from studying this relationship while controlling for attention in the various assessments, since problems in attention might be a possible factor that decreases children's performance in both motor and cognitive tasks.

The common symptomatology between ADHD and children with developmental coordination disorder (DCD) will be discussed in the next section, which focuses on the comorbid symptoms that children with DCD exhibit.

2.10.5. Developmental Coordination Disorder

As mentioned in an earlier section, some children have difficulties with tasks involving motor coordination that cannot be assigned to a general medical condition. Over the years many different terms have been used to characterise these children, including: developmental dyspraxia, clumsiness, apraxia and many more (Losse et al., 1991). The term that is widely used today is “developmental coordination disorder”, which is defined as a “marked impairment in the development of motor coordination, which cannot be attributed to a general medical condition or mental retardation” (American Psychological Association, 2000). According to the DSM-IV-TR (2000), children with DCD have coordination difficulties with gross and/or fine motor skills, locomotion, agility, manual dexterity and complex skills. Another criterion for the diagnosis is that the motor difficulties have a negative impact on a child’s academic performance and daily life. It should also be acknowledged that children with DCD form a heterogeneous group with varied motor coordination deficits. Additionally, children with DCD differ from children that appear to be clumsy since their motor coordination is substantially below what is expected for their chronological age. Developmental coordination disorder has not been extensively studied and the fact that many of the symptoms of DCD overlap with other developmental difficulties (such as ADHD and specific language impairment) makes research more complicated. Recent longitudinal research reveals that children with DCD tend to exhibit poor academic performance, as well as social and emotional problems that persist into adulthood causing serious difficulties (Hyland & Polatajko, 2012). Once more, it should be noted that in this developmental disorder motor, cognitive and academic symptoms all overlap.

Another study performed with 45 children aged five years in Greece revealed that children with DCD have a lower performance in variables such as static and dynamic balance as well as planning and simultaneous coding compared with non-DCD. The last two variables were associated with reading and maths achievement and more specifically with the motor aspect of maths (i.e. planning-issues of how to set out sums) which is the focus of the current research as well (as cited in Asonitou et al., 2010).

The relationship between children that have been diagnosed with DCD and problems in reading and maths performance has also been documented in other studies (Baker, 1981; Gubbay, Ellis, Walton & Court, 1965; Smyth, 1992).

DCD and other disorders can be recognised as patterns of impairments that are manifestations of an underlying deficit as described in the ABD hypothesis presented earlier (Kaplan et al., 1998). DCD has been associated with ADHD, Asperger Syndrome and Autistic Spectrum Disorder. Due to the close links between these disorders, there should be caution during diagnosing. Also the overlapping nature of the symptoms should be taken into careful consideration.

Another interesting perspective that adds to the literature associating motor coordination with attention and academic skills problems is the “Deficits in Attention Motor Control and Perception” (DAMP). DAMP was an attempt by researchers to put under the same category children that exhibit symptoms of both ADHD and DCD. According to DAMP, there are underlying neurodevelopmental problems that act as the source of difficulties in areas such as: attention, motor control, learning, language and perception (as cited in Gillberg, 2003). Studies have shown that 65-80% of children diagnosed with DAMP between the ages of ten to 13 years also had learning problems in areas such as reading, maths and language (Gillberg, 2003). DAMP can be used by researchers and clinicians for diagnosing children who fulfil the diagnostic criteria for both ADHD and DCD. At the same time, caution is needed since further research is required to better establish the underlying mechanisms involved in the aetiology of DAMP, along with research that outlines treatment approaches.

The observed comorbidity between motor coordination problems and academic difficulties in children with DCD can be viewed as the bridge between TDC and children with atypical development. Since children with DCD exhibit difficulties in both areas the investigation of the aetiology of DCD can provide valuable information on the relationship between the motor and cognitive areas.

All the studies described in this section emphasise the urgent need for research into early intervention to prevent the risk of academic underachievement and poor motor development. Although the current intervention only targeted TDC, many children who might be diagnosed with DCD or any other developmental disorder are not diagnosed until later. Therefore, the preventative role of the MSI for the Early Years is relevant not only for the several risk factors discussed earlier, but also for those children who might possibly receive a diagnosis at a later age.

In the next section two additional developmental disorders will be presented: first, the Autistic Spectrum Disorder and, second, the Specific Language Impairment, which have also both been associated with motor difficulties.

2.10.6. Autistic Spectrum Disorder & Specific Language Impairment

Autistic Spectrum Disorder (ASD) is characterised as a neurodevelopmental disorder with an onset prior to three years that causes difficulties in three main domains: reciprocal social interaction, communication and restricted/repetitive interests and behaviours (American Psychological Association, 2000). Other than the above symptoms, DCD and other motor problems have been associated with ASD (Baranek, 1999; Dziuk et al., 2007; Kopp, Beckung & Gillberg, 2010).

The literature suggests that the common symptoms exhibited by children with ASD and DCD start in the early years and persist during childhood. Motor impairments, and specifically difficulties in motor gestures, that are found in children with autism might be responsible for the low communicative development that the children later develop (Dziuk et.al., 2007). By investigating further the common symptomatology, valuable information might arise that can be used for decreasing such difficulties in the future. A recent meta-analysis studying the relationship between motor coordination and ASD found a very large effect size equal to 1.20 suggesting that motor coordination difficulties can be found in a substantial group of children with ASD (Fournier, Hass, Naik, Lodha & Cauraugh, 2010). Additionally, motor coordination problems seem to be pervasive across diagnoses, hence they can be considered to be a major characteristic of ASD. There has been a long debate concerning motor difficulties in children with ASD, mainly attributed to the heterogeneity of the condition, as well as, the influence of other moderating variables (such as the different sub-groups with ASD). The above meta-analysis compared ASD children to typically developing controls showing that ASD children tend to be less coordinated and have a lower movement repertoire. This meta-analysis of 51 studies suggests that such symptoms appear to be widespread, therefore they should be considered as core symptoms (Fournier et.al., 2010).

Specific language impairment is diagnosed when language abilities are below the expected age level but non-linguistic expectations are within age (American Psychological Association, 2000). Some children with SLI may exhibit speech production problems as well. Various studies reveal that SLI shares some common symptomatology with DCD and that certain motor problems are evident in children with SLI (Bishop, 2002; Estil, Whiting, Sigmundsson & Ingvaldsen, 2003; Hill, Bishop & Nimmo-Smith, 1998; Owen & McKinlay, 1997). In 2002, Bishop performed two studies to investigate whether motor immaturity and SLI have a common genetic basis. The study involved a tapping task. The results revealed that children with SLI had impaired motor skill, in which children holding a tally counter were instructed to tap with the thumb as fast as possible (Bishop, 2002). Furthermore there were some suggestions of common genetic influences between motor and articulation impairments. In the second study that followed, a motor skill task was linked with language. The study appears to share some common findings with the study conducted by Wolff et al. (1995) on developmental dyslexia: “The study suggests that motor problems can be part of the phenotype of heritable speech and language disorder” (as cited in Bishop, 2002, *p*. 870).

It is evident that both ASD and SLI are connected with motor impairments. On the other hand, based on the principles of causal modelling theory (section 2.10.2.1.) although disorders may share similar behavioural symptomatology they can have different origins. For example even if a child with SLI exhibit common symptoms with a dyslexic child they may have different cognitive impairments. When interpreting different developmental disorders the distinction between the observed behaviours, the cognitive processes, the neurobiology and aetiology should be made clear. In this section, two more developmental difficulties characterised by cognitive weaknesses have been linked with motor problems. This fact makes the relationship between motor and cognitive development seem even stronger and provides a fruitful rationale to further study this relationship.

It should be acknowledged that all the developmental difficulties discussed exhibit different profiles not only in the range of the difficulties but also in the degree of severity experienced by individuals.

2.10.7. Physical Activity & Academic Performance Evidence

Several studies have been developed in order to investigate and document the relationship between physical exercise and cognitive functioning, with some exhibiting very promising results. In this section evidence from different studies will be discussed, but first how can physical activity be defined? According to the World Health Organization (WHO) "physical activity is defined as any bodily movement produced by skeletal muscles that requires energy and expenditure" (WHO, 2014).

The first study that will be presented was conducted in seven public elementary schools, including 1,538 children as participants (Sallis et al., 1999). The aim of the study was to investigate whether a physical education health-related programme had an effect on standardised academic achievement scores. There were three groups in the study: (1) specialists who taught the Sports, Play, and Active Recreation for Kids (SPARK) curriculum; (2) classroom teachers who delivered the curriculum; and (3) controls who continued to perform their original programmes. Schools were randomly assigned to each intervention group. The mean age was nine years and the length of the study was two years. The SPARK programme included various activities promoting physical exercise and play such as aerobic dance, running games and jump rope. Results indicated that time spent in physical education does not harm academic scores. Furthermore, significant effects were found on reading, with performance in the specialist condition being superior to control. Overall, the study provides evidence to support the positive effects of physical education programmes on children's academic performance (Sallis et al., 1999).

The second paper was a review of 14 published studies that investigated the effects of physical activity on student performance (Taras, 2005). Results and details from these studies have been collected from Taras' (2005) paper. The premise that this review mainly supports is that there might be some short-term improvements after physical activity (such as in concentration), but that the long-term effects on academic performance is yet to be established and requires further investigation. On this theme, one recent study did succeed in finding long-lasting effects from physical exercise (PE) on motor skills and academic achievement over a period of nine years. More specifically, these findings revealed that structured lessons of PE paired with motor training can improve children's performance in physical activity, maths and English language (Ericsson & Karlsson, 2012). Other studies, reported in the review by Taras (2005), and outlined below showed some positive effects from physical exercise upon academic performance, self-concept, and class behaviour.

The third study that will be presented in this section studied the relationship of physical fitness to academic achievement of third and fifth grade students. This study was an attempt to further investigate "the relationship between physical fitness (aerobic exercise) and academic achievement" (maths and reading) (Castelli et al., 2007). The sample involved 259 children in the third and fifth grade. Children were assessed on their muscle fitness, aerobic capacity, body composition, as well as maths and reading levels. Correlational results indicated that total fitness scores correlated positively with all three achievement measures; total academic achievement, maths and reading achievement. In addition, higher academic achievement scores were also associated with greater total fitness and total fitness was related with mathematics achievement. Moreover, children's physical and cognitive scores were positively associated even when controlling for variables such as sex, age and poverty index (Castelli et al., 2007). These results demonstrate that opportunity for physical exercise in the elementary level is an influential predictor of future academic achievement, specifically in reading and maths.

Overall, then, several studies have shown positive and significant correlations between physical activity and academic achievement (Coe, Pivarnik, Womack, Reeves & Malina, 2006; Strong et al., 2005; Trost, 2007), whereas only some have shown no correlation (Daley & Ryan, 2000; Fisher et al., 1996).

Supporting evidence can also be derived from different parts of the world, such as the United States, United Kingdom, Hong Kong and Australia, where statistically significant positive correlations have been found between participation in physical activity programmes and improved academic performance (as cited in Trost, 2007). One example of the above results is a national study conducted in the US in 2006, where 11,957 adolescents were examined with the use of questionnaires. The questionnaires assessed physical education policies and practises as well as general characteristics of physical education (Lee, Burgeson, Fulton & Spain, 2007). Data was collected at a classroom level from teachers of randomly selected classes. The results showed that adolescents who participated in physical activity were 20% more likely than their peers to earn an "A" in maths or English when compared with adolescents with restricted or no physical activity (as cited in Trost, 2007). Although findings are promising caution is needed since the data were collected by questionnaires, where accurate information is not always supplied by the participants.

A more recent study by Hopkins, Davis, VanTieghem, Whalen & Bucci, in 2012 investigating the effects of exercise to learning and memory performed originally in rats found that rats that exhibited ADHD-like behaviour reduced these behaviours after exercise. When the study was repeated with 18-36 year old human adults positive changes in cognition were reported as an effect of exercise. Additionally, the effect of exercise in an earlier age was more beneficial than a later age.

The above findings are important for three main reasons: (1) they serve as evidence of the relationship between physical exercise and academic achievement; (2) findings show that this relationship seems to exhibit common characteristics in different populations and settings;

and (3) they also document that the relationship exists in TDC, as well as in children diagnosed with developmental disabilities.

Therefore, when time is allocated to physical activity or other extracurricular activities (such as sport, drama, and music) it may enhance children's academic achievement. Throughout this thesis different terms regarding physical and motor behaviours have been used and it is beneficial for a better understanding of these terms to provide their definitions and clarify their differences.

2.10.7.1. Physical Activity, Physical Fitness, Motor Control and Motor Skill Development

At this point, a distinction of the following terms: physical activity, physical fitness, motor control and motor skill development needs to be addressed. The aforementioned terms are used to describe different concepts but there is an observed tendency for some of them to be used interchangeably. For example, it is common for physical activity programmes to be developed aiming in improving motor skills development and motor control (See: Ericssoon & Karlsson, 2012). Therefore, it is often the case that the effects of physical activity and motor skills development are studied together. More specifically, it is common for the terms of physical activity and physical fitness to be perceived as the same behaviours, although that is not the case. As described at the start of this section physical activity refers to the bodily movements produced by muscles producing energy expenditure (WHO, 2014). The amount of physical activity can vary among and within an individual throughout life. On the other hand, physical fitness is described as "a set of attributes that people have or achieve that relates to the ability to perform physical activity" (American College of Sports Medicine, 2013).

Both definitions have been provided to help clarify these terms and subsequently assist with the interpretation of different studies in this research area. More specifically, it is advantageous to be able to discriminate between studies that use these terms and focus on the investigation of the relationship between physical activity and physical fitness that produce either health or academic benefits. Before the differentiation between the physical and motor is discussed the difference between motor control and motor skills development will be clarified.

Earlier in this chapter some of the existing theories of motor control were described and later on (section 2.19) the different categories of motor skills will be discussed. But a clarification of motor control and motor skill at this stage seems necessary since both areas fall under the umbrella of motor development but refer to different aspects of it. Both areas are significant since they seek to understand the complex and critical area of human movement. Motor control refers to "the study of neural, physical and behavioural aspects of movement" (Schmidt & Lee, 2005). The achievement of motor control over a movement, such as walking, originates from a purposeful coordinated movement resulting from the interaction of the body with the environment (Latash, Levin, Scholz & Schoner, 2010). Therefore, motor control focuses mostly on understanding the control of an already acquired movement. On the other hand, a motor skill such as swimming involves motor control. Hence, motor control can be perceived as a necessary aspect of a motor skill. During the study of the development of a motor skill both the movement and the outcome are emphasised (Newell, 1991). As mentioned earlier, based on the premises of the dynamic systems approach both motor control and motor skill development involves the active interaction of the individual with the environment while he/she adapts to the continuous change of conditions (Spencer & Schoner, 2003). Furthermore, motor control seems to be a prerequisite for the performance of motor skills.

Regarding the differentiation between the physical and motor behaviours the former is mainly used to describe the observed physical activity or inactivity that people exhibit (i.e.

sports participation or household) and the various levels of physical fitness which are measurable (i.e. cardiorespiratory endurance or muscular health) (Caspersen, Powell & Christenson, 1985). On the other hand, the latter (motor) is more closely related with the investigation of the development of specific motor skills (i.e. catching, writing) and the processes involved during the production of movement as well as the motor control required to perform a movement. Although the above areas may refer to different areas they are also linked since programmes of physical activity are being developed as interventions for practising or improving motor skills. While children are being physically active (i.e. climbing ropes or running) they engage into movements requiring motor control and a number of different motor skills.

The purpose of clarifying the aforementioned terms was to discuss their differentiations since many times findings from the research areas investigating the relationship between physical activity and academic performance as well as motor skills and academic performance tend to be studied closely or in a parallel fashion. Actually, many school-based interventions focusing on motor skills are being delivered during PE classes associating physical activity with motor training (Ericsson, 2008).

As has been already stated the present research is concerned with the relationship between children's motor skills and their reading and maths abilities. Therefore, in the section that follows, evidence supporting this specific relationship will be analysed.

2.10.8. Motor Skills & Reading-Maths Performance Research Evidence

Performance in various motor skills and its effects on several cognitive skills has been studied in a more focused way, with the aim being to understand which specific cognitive skills are affected.

In a study by Son and Meisels performed in 2006 in the United States they examined the relationship between motor skills at the beginning of kindergarten and reading and mathematics achievement at the end of the first grade. The study used the Early Childhood Longitudinal Study Kindergarten (ECLS-K) cohort national dataset, comprising of 12,583 children (Son & Meisels, 2006). The children's mean age was 65 months, with gender evenly spread between boys and girls. The motor skills studied included measures of both fine and gross motor skills such as eye-hand coordination, balancing and hopping. The first piece of evidence was derived from correlational data, which revealed that visual-motor skills were more positively correlated with cognitive achievement than gross motor skills, with significant correlations of r =.40 for reading and r =.48 for maths. The second set of results was a series of four-step hierarchical regressions that were performed separately for reading and mathematics. Regressions revealed that motor skills and early reading are significant predictors of spring first grade reading achievement (Son & Meisels, 2006). Furthermore, visual motor skills together with early mathematics scores can predict later mathematics scores with substantial success. The above study suggests that, other than phonics, there can be other pathways (visual or spatial processing) that influence achievement in areas such as reading and maths. The results also show that developmental domains (motor, reading, maths skills) are inter-correlated aspects of a young child's developing skills; a premise supported by the dynamic systems approach described earlier.

There are several studies that demonstrate the relationship between motor skills and cognitive development and more specifically reading and maths (see for example: Chomitz et al., 2009; Ericsson, 2008; Grissom 2005; Tomporowski et al., 2008). Other than the effects on motor skills a recent meta-analysis has found that reading and maths are two academic outcomes that hierarchically produce amongst the highest effect sizes during a physical activity intervention (Fedewa & Ahn, 2011). Investigating whether there are specific motor skills that directly or indirectly correlate with other cognitive skills, therefore, has important benefits for future research. One such benefit is that it will allow for the development of new teaching techniques that will aim to increase academic performance through its motor correlates. Additionally, it will also provide a stronger basis for the creation of new treatment programmes and screening tools for TDC in the early years.

Overall, the main conclusion that can be drawn from the existing research is that early intervention in the educational setting can be beneficial for both TDC and children with atypical development. Furthermore, since the role of the environment is equally significant with the role of genes, it is beneficial to enrich a child's environment with experiences that can improve his/her motor, academic and cognitive development.

Other than specific developmental disorders that influence a child's motor and cognitive development there are other factors that are considered to affect both TDC and children with atypical development. Consideration of these factors played a significant role in the selection of TDC for the current research and they will be discussed in the next section.

2.11. Risk Factors for Physical & Academic Performance in the Mainstream

The natural "route" of both motor and academic performance is affected not only by various developmental disorders, but also by other factors such as obesity, children's lifestyle and parenting styles, all of which are considered to influence development since they can all negatively affect a child's typical development and shadow his/her potentials. They also constitute one of the important motivations for the development of school interventions that are targeted at TDC.

Based on the latest NICE guidelines (2009), it is recommended that children between the ages of five to 18 should do a minimum of 60 minutes of at least moderate intensity physical activity on a daily basis. Additionally according to the report by the British Heart Foundation National Centre (BHFNC) in 2011 children less than five years of age should engage in 180 minutes of daily exercise spread through the day. However, one recent finding shows that over a fifth of school aged children are now obese, compared with 15% in the mid-1980s

(Lobstein & Leach, 2008). More specifically a report by the National Health System in 2012 has found that one in ten children in reception are obese. The same pattern is evident in the USA, as documented by a recent meta-analysis investigating the effects of physical activity on children's achievement and cognitive outcomes covering 59 studies from 1947 to 2009. Overall, the findings suggest that children, in the mainstream, engage in much less daily physical activity than is recommended and, furthermore, they fail to regain the lost physical activity in their home environment, suggesting that sedentary behaviours are increasing (Fedewa & Ahn, 2011). Such findings have alerted researchers for the need to develop programmes that promote physical activity. They also reaffirm that physical activity is important for children's health and wellbeing and contributes to their physical, social, emotional, psychological, academic and cognitive development.

2.12. **Parental Styles & Lifestyle: Effects on Physical Activity & Academic Performance**

The number of overweight children in the United Kingdom has been tripled over the past thirty years (Rhee, Lumeng, Appugliese, Kaciroti & Bradley, 2006). Two of the main factors that have been attributed to this rise in childhood obesity or limited physical activity are parental styles and sedentary lifestyles.

The literature identifies four main different parenting styles. The first is the authoritarian style, which focuses on reinforcing the child’s obedient behaviour and, in cases of conflict, applying strict measures. The second is the permissive style in which the parent has a more passive role and freely permits the child to be responsible for and regulate his/her own behaviour. The third style is the mediating style, which sits between the two aforementioned categories. In this approach, the parent shapes the child’s behaviour through logical reasoning and discussion and sets up realistic boundaries without strict or irrational methods to control the child’s behaviour (Carter & Welch, 1981). Finally, the fourth style is neglection, in which the parent is disengaged and he/she does not demand or respond to the child’s needs (Smetana, 1995).

A positive association has been found between authoritative parenting style and gains in academic performance, self-esteem and adaptive responses (Aunola, Stattin, & Nurmi, 2000; Radziszewska, Richardson, Dent & Flay, 1996). Moreover, it seems that parenting styles have an important influence on children’s eating habits and may either benefit them or not. Having an authoritarian parent can also result in a restricting environment in which the child has limited or no chances to take initiatives or make choices. This, in turn, can result in lower levels of self-esteem and withdrawal from physical activities (Rhee et.al., 2006). The authoritarian parent may also regulate the child’s eating patterns by creating a strict environment with pre-determined choices made already for the child. The above strict pattern can produce a negative reaction from the child and result in the development of unhealthy eating patterns. On the contrary, parents who attempt to provide a warm environment and try to consider their child's needs can better regulate their children's eating patterns through considering their child's needs, encouraging them to make healthier eating choices.

Another study involving 4,000 school children that was conducted by academics at the University of Essex (2012) revealed that lack of physical activity among parents results in the establishment of poor role models for their children. In particular, the study identifies the important role that parents have in shaping their child's attitude and habits towards physical activity. Considering that children in the UK spend less than 15% of their time at school and that they have only two hours of PE per week, it becomes obvious that the family environment has a significant role too.

Lifestyle

Another factor that influences children's physical development is their lifestyle. Some of the habits that can negatively influence the aforementioned areas are: many hours of television (TV) viewing, playing video games and low levels of physical activity leading to a sedentary lifestyle (Andersen, Crespo, Bartlett, Cheskin & Pratt, 1998). When children are engaging in passive activities they are more likely to consume snack foods, instead of fruits and vegetables. Additionally, while watching TV they are exposed to food commercials that advertise low-nutrient density foods (Caballero, 2007). Researchers report that when children in a young age group engage in a sedentary lifestyle they tend to get into the habit of not exercising; thus, extending this sedentary behaviour as they grow older (Dishman, Sallis & Orenstein, 1985). Also, it has been reported that, in Britain, levels of physical activity for children under the age of 11 years seem to be insufficient to promote a healthy lifestyle (Health Education Authority, 1997). Although the pre-school curriculum does include physical development, this is only one of six areas of learning (the other being personal, social and emotional development, language and literacy, mathematical development, knowledge and understanding of the world). Outdoor play in nurseries and the Early Years Foundation Stage Profile (EYFSP) is now becoming more widespread, but it remains to be seen whether children are being afforded the time and facilities to develop all their motor development capacities.

It progressively becomes obvious that early habits influence later development and preferred activities. Adopting a sedentary lifestyle in early childhood increases the likelihood of having the same activities in later life. Therefore, the risk of difficulties associated with lack of physical activity (hence limited chance of developing various motor skills) does not only exist amongst those children that have been diagnosed as having motor skills problems; it also exists amongst the mainstream. Therefore, the need for motor skills interventions designed for TDC seems both necessary and beneficial.

2.13. Consideration of an Opposing Evidence Base

The above sections were dedicated to the review of the diverse research that supports the interrelationship between the motor, cognitive and academic areas. For the sake of fairness, the section that follows outlines some of the opposing views that do not support this relationship.

Although there is strong evidence that motor and cognitive development are linked, several studies have failed to document a relationship between physical activity and improvements in academic performance (see for example; Fisher et.al, 1996; MacMahon & Gross, 1987; Sanders, Field, Diego & Kaplan, 2000). All of these studies have investigated the effects of different levels of physical activity on academic achievement and have not found significant gains. There are various explanations that can account for this failure to document significant effects such as: the specific programme that was used, lack of standardised tests and other confounding variables. At the same time, though, based on the non-significant outcomes, researchers might conclude that there is no association between being physically active and practising various motor skills and academic areas.

Considering the complexity of the area and the several different mechanisms involved, there are a number of researchers who claim that physical exercise or a motor skills intervention are not directly linked with cognitive development. Indeed, they attribute any potential improvements in performance to external factors, such as an increase in self-esteem or confidence. For example, according to Berger (1996), when children engage in physical exercise their self-esteem increases; thus, their performance in both motor and cognitive tasks can also be increased. From this perspective, it is argued that the cognitive benefits are not a direct product of the actual exercise, but, instead, result from indirect variables that are improved during exercise. The above argument is mainly based on research investigating the relationship of physical activity and physical exercise with academic performance which appears to be more extended in the TDC than the motor skills training and academic achievement research.

Additionally, some researchers remain sceptical as to whether a motor skills intervention improves any skills other than the ones trained (Bishop, 2007). More specifically, if a child has a difficulty in motor skills, motor skills should be directly addressed, to address a difficulty in reading, reading and literacy skills need to be directly addressed rather than implementing an intervention which addresses skills other than the ones being targeted. Moreover, improving cognitive skills by employing a motor skills intervention or increasing physical exercise is not an easy task, and a lot of research suggests that there is no actual link (Daley & Ryan, 2000; Fisher, et al., 1996; MacMahon & Gross, 1987). The complexity of the area is also reflected by the fact that although many different intervention strategies have been developed and delivered, it remains unclear as to which is the best for improving motor and cognitive performance. Given these doubts, scepticism on whether or not there is a relationship between motor skills and cognitive development remains.

One other issue is that physical education has been perceived as a threat to the academic areas as the time spent in physical exercise could be spent in direct teaching of reading or maths. Therefore, children are potentially missing the chance of engaging in physical activity which can potentially help them develop their motor skills. Given the complexity of the area, more evidence is needed to prove that motor activities can influence cognitive functioning. At present, scientific evidence does not support the notion that if children engage in any physical exercise they will automatically show benefits in other areas. However, ample evidence does exist to suggest that improvement can be achieved through a combination of applying a well-structured intervention on a regular basis and being motivated to help children achieve their full potentials. Hence, it is suggested that a research-based, well-structured intervention can potentially benefit children, not only in their motor capacities, but also in terms of academic skills.

2.14. Summary of Main Points

In the above sections, evidence supporting the relationship between motor skills and cognitive functioning and academic performance was discussed. Some of the different research fields that evidence can be drawn from were: developmental psychology, educational research and others. Briefly, the main categories of evidence are outlined:

- Contemporary theories linking cognition and motor development, such as "embodied cognition".
- Co-morbidity of developmental disorders sharing motor, cognitive and academic symptomatology (Developmental Dyslexia, ADHD, DCD, Autistic Spectrum Disorder and SLI).

- Research indicates that physical activity is associated with benefits in academic performance.
- Research indicates that motor skills are associated with later performance on cognitive skills as expressed by reading and maths performance.
- Physical inactivity, parental styles and sedentary lifestyles can impair physical, academic and cognitive functioning.
- The aforementioned factors add to the literature supporting the need for well-structured motor skills interventions in the school environment that target TDC.

It is clear that development is a complex process that involves the interaction of multiple domains, many of them not yet fully explored. Overall the weight of theoretical evidence provides a conceptual justification for examining motor skills in relation to later academic achievement. Indeed, there is ample research to suggest that a child who develops physically at a younger age, and who is better coordinated, has fewer learning difficulties than a child who develops later. In short, then, motor skills can be an indicator of academic skills development. Given these findings, it can be concluded that opportunities for movement and physical exercise are as important as teaching literacy and maths especially during the early years.

In view of these facts, a motor skills intervention has been developed and its effects upon reading, maths and motor skills have been measured. The intervention will be explained in more detail in later sections. In order to develop the current MSI for the Early Years an evaluation and consideration of different approaches to intervention programmes was essential. Thus, in the next section, an overview of existing motor skills interventions from various fields and designed for various populations is provided. One of the main aims of this review was to outline the theory that the MSI would be based on. More specifically, it sought to develop a holistic view of several approaches delivered in various populations and producing different outcomes in order to compare, evaluate and inform future intervention programmes.

2.15. EXISTING MOTOR SKILL INTERVENTIONS

On-going research on the relationship between motor, academic skills and cognitive functioning has led to the development of different theories and interventions. However, this intervention research area is fairly new, meaning that there are a limited number of studies and development of well-established interventions. Additionally, the complex nature of this relationship makes it more difficult to reach robust conclusions. On the positive side, however, recent research has encompassed true experimental designs in which participants are randomly assigned; thus, producing a stronger causal link between an intervention and an outcome (McPhillips et.al., 2000; Pless & Carlsson, 2000; Salmon et.al., 2005) Up until now, the majority of early intervention programmes have been focused on young children who are at risk of acquiring a developmental delay or who have already been diagnosed with a developmental disorder along with motor skills difficulties. The interventions include a wide array of services and activities aimed at maintaining or maximizing the child's development.

The school setting is considered to be the most critical context outside of the family for the development of various skills and beliefs about oneself (Elbaum & Vaugh, 2001). Thus, many of the interventions are addressed to an educational setting. Furthermore, as has been suggested in earlier sections (2.11, 2.12), the importance of a stimulating environment during the early years of a child's development is of major importance.

There are many issues relating to finding interventions which can be generalised, be beneficial for all children, are cost-effective and can be easily applied. Many of the current interventions are highly specialist and they need well trained professionals to implement. Additionally, they lack extensive evaluations and are mainly addressed to children with very specific needs (Higgins, Katsipataki, Kokotsaki, Coleman, Major & Coe, 2013). The MSI for the Early Years has been based on the ideas of what has been done in the past and what can be done by teachers; therefore it draws on a range of ideas and does not follow a single approach. There are a number of advantages when teachers deliver the intervention such as an increase in the sustainability of the intervention and a decrease of the costs involved (Riethmuller, Jones & Okely, 2009). The current intervention aims to benefit all children. Inevitably some children will benefit more and some less. For example, children with more delayed motor development may benefit more, others will do well independent of the intervention and some others within the normal range of motor development may be benefit too. As it has been suggested by recent research, interventions in the school setting that produce a small effect but are easy and cheap to administer make a real contribution (Higgins et.al., 2013). Therefore, the MSI for the Early Years is characterised by a pragmatic nature.

Recently, there has been an increased interest in the development of programmes of physical exercise interventions to increase children's physical activity participation. This category of activities mainly involve warm-up, aerobic and cool down exercises that are administered daily. The NICE (2008) reports a number of different programmes that have been issued either in the United Kingdom or in the United States that follow similar patterns of introducing increased time for physical activity. Many of the programmes (for example: CRCT+, CBA-) have no theoretical basis, lack appropriate measures of physical activity, are not properly evaluated, and do not involve a follow-up on the outcome measures to investigate long-lasting effects.

Apart from programmes based primarily in increasing the time spent on general physical exercise in schools, there are a number of more specialised interventions. These include: sensory integration therapy, (SIT) dance therapy, (DT) neuromotor task training, (NTT) neurodevelopmental treatment, (NDT) reflex therapy, and Cognitive Orientation to Daily Occupational Performance (CO-OP). The aforementioned therapies are all usually applied to children with DCD, autism, cerebral palsy and children with learning disabilities. The studies all yield mainly positive results in a number of different areas of interest, including general motor skills, fine and gross motor abilities, self-concept, academic achievement and many more. Long-term follow up studies have also demonstrated the effectiveness of school-based early intervention in non-typically developing children in almost all areas (Elbaum & Vaugh, 2001; Harris, 1988). In the sections to follow, some of the different interventions that have been developed for both TDC and children with atypical development will be discussed.

2.15.1. Selection Criteria

It is recognised that the approaches that will be presented in the following section do not represent the full range of intervention methods. This is because it was beyond the scope of the present thesis to provide a full account of all the available approaches to motor skills interventions. However, indicative cases have been purposely selected to demonstrate the diverse nature of interventions. The main criteria for selecting the interventions were the following:

- Have a theoretical background.
- Report findings of their effectiveness.
- Include measures of motor, academic, or cognitive performance.
- Administered mainly in a school setting.
- Administered in the early years.

2.15.2. Types of Interventions

The areas of motor development and motor impairment are studied by several different fields, including psychology, education and health research. Therefore, it is logical to have different approaches to intervention originating from a range of different perspectives. Motor skills interventions mainly fall under two broad categories: process/deficit approaches and functional skill/task oriented approaches. Other interventions also exist that do not fall under either category; two of them will be presented in later sections. Finally, although over the years different approaches and theoretical frameworks to intervention have been developed, there remains a common consensus over a specific approach that can be used for a wider population range, easily fit the school schedule and document significant improvements on TDC's academic performance.

The first category/type of intervention that will be discussed is the process or deficit approach.

2.15.2.1. Process/Deficit Approach

The process or deficit approach or process-oriented approach suggests that difficulties in motor behaviour arise from problems in the functioning of underlying neurological mechanisms. This approach was developed during the 1960s and 1970s and has gained increased interest. Some interventions that fall under this category include: Sensory Integration Therapy (SIT), Auditory Integration Therapy (AIT) and Neurodevelopmental Treatment (NDT) (Polatajko & Cantin, 2005). The main premise of this approach is the transference of the competence of sensory and neural practise to other skills. During treatment there is no direct practising of specific motor skills; rather, there is an indirect stimulation of the underlying problematic areas. Hence the aim of this approach is to influence the underlying processes involved in movement (Peters & Wright, 1999). Moreover, improvements in the sensory areas are said to transfer to motor areas as well (Sugden & Dunford, 2007). For example, according to the process/deficit approach, if a child has a problem with static balance, the underlying processes that are involved in balance (such as exercising eye-hand coordination) will be included in the motor therapy programme. As this example illustrates, a potential strength of process-oriented approaches is that, when addressing the underlying processes of a task, it is possible to generalise these processes to a group of different tasks and situations. Once the processes are learned the child is able to perform several kinds of different motor tasks that involve eye-hand coordination.

Another example of this approach is the learning of the syntax systems or semantics for pre-school age children, which involves the organisation of visual and auditory input, retention of the information and formulation of appropriate responses. For those children that do not properly manage these systems, learning and academic success can be influenced (Klecan-Aker, Brueggeman-Green & Flahive, 1995). To summarise, then, the process/deficit approaches aim to pinpoint the underlying processes that a child has not developed to an adequate level that are considered to be necessary for the acquisition of motor skills (Sugden & Chambers, 2005). In the following sections some of the therapies that fall under this category will be presented.

2.15.2.2. Auditory Integration Therapy

Auditory Integration Therapy (AIT) has been introduced as a technique for improving sound sensitivity in children that fall under the spectrum of autistic disorder. It represents a form of physical exercise of the hearing apparatus through an electronic machine (Francis, 2005). AIT has two similar methods: namely, the Berard method and the Tomatis method. Both methods use a modulating and filtering device that manipulates sounds. More specifically, Berard's method involves 10 hours of listening to electronically modified music during two half-hour sessions over 10 days. By contrast, the Tomatis method uses electronically modified human voice and music delivered through an "electronic" ear (Sinha, Silove, Wheeler & Williams, 2006). Both methods take place on a one-to-one basis and are highly technical. The main goals of this auditory training are: (1) the improvement of distorted hearing; (2) hypersensitivity to specific frequencies; and (3) enhancement of attention, social skills and balance. Research remains limited, but that which has been done suggests that AIT results in some improvements to a range of abnormal responses, sensory abnormalities and behavioural problems (Dempsey & Foreman, 2001). Nevertheless, further investigation is needed to evaluate the effectiveness of AIT to various autistic symptoms and the inclusion of a control group would help in the examination of AIT's effectiveness. Additionally, the AIT is an expensive treatment to administer and needs specialised equipment. Hence, there remains a need to establish whether this treatment is beneficial or not for children within the autistic spectrum and if it can be affordable to a wider population.

2.15.2.3. Primary Movement Programme

Primary Movement (PM) is a movement programme that seeks to replicate the early movements of the foetus and to enhance the maturation of the central nervous system (Jordan-Black, 2005). The movement programme is based on the notion that primary reflexes play an important role in the functioning of the CNS and their persistence during the first year of life can be linked to reading delays (McPhillips & Sheeny, 2004). The PM programme can be categorised as a process/deficit approach since it aims to improve motor and academic skills through the inhibition of underlying reflexes. One main reflex that, if it persists to later life, can cause fine and gross motor delays is the Asymmetrical Tonic Neck Reflex (ATNR). This is characterised by a sideways turning of the head along with the extension of an arm or leg to the side which the head turns. The ATNR has been linked with visuomotor development and is thus related with reading (McPhillips & Sheeny, 2004). The programme involves the repetition and rehearsal of the primary-reflex movements to achieve inhibition. It takes 10-15 minutes to complete and it is administered on a daily basis.

A study evaluating the effectiveness of the programme in 60 children aged eight to 10 years showed that reducing ATNR interference resulted in significant improvements in reading and writing (McPhillips et.al., 2000). During the application of the intervention, children were given a list of specific movements that were repeated each evening at home during the course of a year. In another school-based study involving more than 1000 children, it was found that the PM programme had a significant effect on ATNR persistence and academic attainments such as reading, spelling and mathematics (Jordan-Black, 2005). It is suggested, therefore, that the repetition of primary reflex movements can play a role in the inhibition of primary reflexes; resulting in academic achievements. The PM programme is mainly used in Northern Ireland and is mostly addressed to children with dyslexia, although it can also be used with TDC.

Further research is needed to assess the effects of the programme in other areas and populations. There is also a need for the results to be replicated by other researchers. Additionally, a study by Hyatt, Stephenson and Carter (2009) questioned the magnitude of the effects of the PM programme, suggesting that this approach is unlikely to be more successful than previous programmes in improving reading abilities. Another point that needs to be stressed is that McPhillips et al. (2000) acknowledge the fact that not all children have persistent reflexes along with reading difficulties, so caution is needed when selecting the population for applying the programme.

2.15.2.4. Neurodevelopmental Treatment

Neurodevelopmental Treatment (NDT) “is a neurophysiological approach that aims at maximising the child’s potential to improve motor competence and prevent musculoskeletal complications” (Tsorlakis, Evaggelinou, Grouios & Tsorbatzoudis, 2004). The NDT is based on Bobath’s model which argues that motor problems in children with cerebral palsy arise from dysfunctions in the CNS that impedes normal motor development. The focus of NDT is on normalising muscle tone, integrating of primitive reflexes and facilitating normal movement patterns through specific handling techniques (Krigger, 2006). More specifically, the handling techniques control various sensory stimuli to facilitate normal muscle tone. The NDT can fall under the category of the process-oriented approaches since it has an underlying approach to treatment. A study performed with 38 children with an age range of three to 14 years who had been diagnosed with cerebral palsy revealed that, after intensive NDT, children’s gross motor skills improved (Tsorlakis et al., 2004). However, an earlier study performed with infants with Down's syndrome showed no significant motor gains of the experimental over the control group (Harris, 1981). Similarly, a 2001 review of several studies that have used NDT showed that overall results appear to be contradictory and that further systematic research is needed to establish a more conclusive view (Buttler & Durrah, 2001). Overall, then, NDT can be an effective treatment and appears to produce positive motor gains; however, future research is needed in order to establish a strong theoretical and empirical basis.

The fourth therapy that will be presented in this section is the Sensory Integration Approach, which the MSI for the Early Years incorporated into some of the tasks as well as some of its principles.

2.15.2.5. Sensory Integration Therapy

Sensory Integration (SI) Therapy was developed by Jean Ayres in 1972. She defined SI as the "neurological process that organises sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment" (Baranek, 2002). The theory postulates that adequate processing and integration of sensory information is an important substrate for adaptive behaviour and therefore provides the foundation for mastering academic tasks. As Schaaf and Miller (2005) put it: "This theory is based on the principles that sensorimotor development is a substrate for learning, the nervous system is capable of change and sensory-motor activity can be a mediator of plasticity." The approach incorporates many principles from the information processing theory of early motor development that was presented earlier in this chapter. Additionally, and in accordance with Piaget's views, it emphasises the importance of the sensorimotor experiences in early years. For example, a meta-analysis of research findings from 50 studies based on 983 children with DCD and 987 children acting as controls showed lower performances on the measures of information-processing. More specifically, it showed that processing of the visual modality was associated with motor coordination difficulties, revealing a difficulty in DCD children that is associated with problems in information processing (Wilson & McKenzie, 1998). The basic assumption of SI approach is that learning-associated difficulties arise from problems in the neurological processing of vestibular, tactile and proprioceptive sensory information (Parham et al., 2007). Therefore, children's motor difficulties are perceived not as problems in the execution of a motor task, but as problems in the processing of sensory information, which therefore result in motor problems. The three sensory systems mainly involved in SIT are: vestibular (balance), proprioceptive (body awareness/gravity), and tactile (fine motor movements). All three systems are of vital importance for the SI treatment plan, since they form the core of SI therapy. In fact, over 80% of a person's nervous system is involved in the processing of sensory input making the brain a sensory processing "machine" (Ayres & Robins, 2005).

Activities in SI therapy involve the use of several instruments, such as therapy balls and swings, as well as several training activities, such as hopping and jumping, with the aim always being to provide stimulation to the three sensory systems (Parham et.al, 2007). SI approaches are frequently used by occupational therapists, with 61% of United Kingdom therapists reporting that they currently use them (Bond, 2011). The SI therapy was originally developed for children with learning disabilities, but it also became applicable to different clinical populations, including: children with ASD, ADHD, DCD, fragile X syndrome, children with sensory integration problems and children from deprived environments (Schaaf & Miller, 2005).

Over the years, a large number of studies (see for example: Ayres, 1972; White, 1979; Kavale, 1982; Polatajko, Law, Miller, Schaffer & Macnab, 1991; Parham, 1998; May-Benson & Koomar, 2010) have reported positive effects from SI therapies in a number of key areas, including: Academic, Language, Motor, Postrotary Nystagmus, Self-Stimulation, Behaviour and other (as cited in Cermak & Henderson, 1990).

Nevertheless, it should be appreciated that SI therapy has limitations as well. One of the basic limitations is the lack of a specific design, since the treatment plan is tailored to the individual's needs; something that makes replication difficult (Cermak & Henderson, 1990). Some other limitations related with the design of the SI Therapy include: lack of a control group, not controlling for maturation, non-equivalence of groups at pre-test and small samples (Cermak & Henderson, 1990). Additionally, another limitation of the SI approach is that it is derived from the broader theoretical framework of the process/deficit approach. This is an issue because an intervention which is derived from the process/deficit approaches has the risk of developing activities which do not tap the true underlying processes involved in the targeted skills. Thus, there is the possibility that the activities provided are not representative enough for the skills that need to be taught.

From a more practical perspective, SI therapy also requires specialised equipment, making it difficult to apply it in a school setting and making it an expensive treatment. Furthermore, more recent reviews have found small or no effects of SI therapy and insufficient evidence of its effectiveness. For instance, Shaw (2002) provided a meta-analysis of 41 SI studies that noted the very small effect sizes in both the motor and academic areas. There have also been suggestions that, by focusing on the maturational aspect of development, motor difficulties can be improved over time without delivering a specific therapy programme (Cermak & Henderson, 1990). Additionally, some contemporary reviews suggest that SI therapy, although previously promising, is now outdated and has failed to show significant results (Blank, Smits-Engelsman, Polatajko & Wilson, 2012; Parham et.al., 2007; Sugden, 2007; Vargas & Camilli, 1998; Wilson, 2005).

As with many interventions, therefore, SI therapy has both several strengths and weaknesses. The goal of any future intervention should be to focus on using its strengths, limit the weaknesses and document contemporary effects of the intervention's effectiveness.

In the next section the second category of intervention — the task oriented approach — will be presented.

2.16. Task Oriented Approach

The Task-Oriented approach or Functional Skills approach represents a more contemporary approach to motor skills intervention. It suggests that motor performance emerges from the interaction of the following systems: the environment, the task and the individual (resources the individual brings to the situation) (Polatajko & Cantin, 2005). This approach has been influenced by and is linked with the dynamic systems approach presented in section 2.4.1.4 by supporting the interaction of the environment and elements within the individual that influence the execution and completion of a task. Task-oriented approaches focus on the specific problems that the child experiences by teaching skills to overcome these problems (Sugden & Chambers, 2005). Some of the interventions that fall under this category include: Neuromotor Task Training (NTT) and Cognitive Orientation to Daily Occupational Performance (CO-OP). Conceptually, this approach has drawn upon a combination of theories on sensorimotor and cognitive milestones, maturational change and self-directed behaviour (Wilson, 2005). Treatment tactics that are based on this approach are mainly focused on the amelioration of daily motor tasks, with the focus being on directly targeting the motor tasks that appear to be problematic and setting a specific plan and goals with the child in order to improve performance. The first therapy based on this approach to intervention that will be discussed is the NTT.

2.16.1. Neuromotor Task Training

Neuromotor Task Training (NTT) is a task-oriented and child-centered approach to motor skills development and is based on the cognitive neuroscience approach to motor processes. In cognitive neuroscience, motor development is perceived as the relationship between the brain processes and the influence of various experiences (Wilson, 2005). NTT was first developed in the Netherlands for treating children with DCD (Schoemaker, Niemeijer, Reynders & Smits-Englesman, 2003). It focuses strictly on teaching those skills that a child needs in his/her daily life, having as an ultimate goal the transference of those skills to daily situations. The first step of this approach is the therapist's assessment of the strengths and weaknesses of a child's functional performance. The second step is the analysis of the cognitive or motor control processes that are involved in the lower motor performance that the child exhibits. The third step is the development of an individually-tailored treatment programme (Schoemaker et. al., 2003). Through this approach, several functional skills are trained in order to tap the motor control processes that are involved.

An example of the effectiveness of NTT can be seen in a pilot study performed with 15 children with an age range of seven to nine years who had DCD (Schoemaker et al., 2003). Children were either assigned to the intervention or the no-treatment group. The intervention group received the therapy for 30 minutes, once a week over a period of 18 weeks. All the therapists were paediatric physical therapists who had tailored their treatment plan based on NTT guidelines individually for each child. The results revealed that children in the intervention group improved both on gross and fine motor skills, whereas the control group did not show any improvement. A later study performed with a larger sample of 26 children with an age range of six to ten years, supported the previous results of the pilot study on the effectiveness of the NTT on motor skills (Niemeijer, Smits-Englesman & Schomaker, 2007).

Overall, NTT has shown some positive outcomes for children's motor skills, but further research is needed since this approach is fairly new and replication of these early positive findings is necessary. In order to better evaluate NTT's effectiveness, the application of the therapy to a larger sample would also be beneficial. Additionally, it would also be interesting to investigate the effects of NTT on other areas apart from motor skills, such as self-esteem and academic performance.

2.16.2. Cognitive Orientation to Daily Occupational Performance

The Cognitive Orientation to Daily Occupational Performance (CO-OP) is another recent approach established in Canada by Dr. Polatajko et al. that falls under the category of the task oriented approaches (Wilson, 2005). The emphasis of this approach is on the acquisition of the sensory, motor and cognitive milestones along the specific time of the typical developmental stages. Hence, assessment in this approach is focused on the acquisition of the aforementioned milestones in reference to the identified age norms. Methodologically, the CO-OP belongs to the top-down category of approaches, which start with the child's goal for action and then move on to look at the processes involved to acquire motor skills. One of the main processes used to achieve this goal is the development of problem-solving techniques with the help of the therapist (Wilson, 2005).

CO-OP is predominantly a child-centered approach to treatment of DCD that has its origins in occupational therapy. The main goal is the remediation of the functional tasks that the child is falling behind with. Furthermore, there are four other main objectives to CO-OP: namely, skill acquisition, cognitive strategy use, generalization, and transfer of the skills taught (Sugden & Dunford, 2007). During the CO-OP, the therapist teaches the child to use self-talk and to build problem-solving strategies for their individual motor problems. This strategy has been named "Go-Plan-Do-Check", as the children set up their goals, plan how to achieve them, perform them and, finally, evaluate their performance. The therapist guides the child throughout this process by asking various questions such as: "how did you do that?" In a pilot study performed with 20 children with a mean age of nine years old and low motor performance, the CO-OP treatment showed higher improvement than other comparable treatments (Miller, et.al., 2001). More specifically, children performed better in the measures of the Canadian Occupational Performance Measures (COMP) (Law, Baptiste, Carswell, McColl, Polatajko & Pollock, 2000). This measure was used to identify problems in occupational performance by interviewing the children. The children then responded to the intervention by rating the tasks on a 10-point scale. Tasks on this measure involved activities in three categories: self-care (dressing), productivity (play skills) and leisure (hobbies) (Law et.al, 2000). The chosen three tasks were then selected to be the goal of the treatment.

Overall, the main strengths of CO-OP are that it is cost-effective and that it seems to produce possible gains in motor performance. Nevertheless, further research is needed to establish CO-OP's effectiveness involving a control group. Additionally, stricter guidelines to the therapists might help in the process of evaluating CO-OP. Another possible limitation of CO-OP is the limited ability of this therapeutic approach to incorporate and work on motor skills other than the ones taught.

The next programme that will be presented is called the Manchester Motor Skills Programme (MMSP), which has been recently developed as well.

2.16.3. The Manchester Motor Skills Programme

The Manchester Motor Skills Programme (MMSP) is based on the principles of cognitive-motor approach, which focuses on the child's role as an active problem solver (Bond, 2011), and the setting of direct motor goals as the task oriented approach. The programme has been developed by educational psychologists together with the respective school's specialists. It has been applied to children that were found to have motor skills difficulties after being assessed with the Manchester Motor Skills Assessment (MMSA) which measures both fine and gross motor skills.

The main characteristics of the MMSP are the teaching of direct skills, adaptation according to the children's needs and the analysis of the various tasks. The intervention can be delivered either daily, for a period of eight weeks, or three to four times a week for a period of 12 weeks. Each session lasts for 20 minutes and the children involved ranged from five to eight years of age. The programme involves fast-paced fine and gross motor activities which are evaluated based on the individual's progress and the child's goals and ends with a collaborative activity and future target setting (Bond, 2011).

Initial results from the programme appear to be promising. Two of the programme's main strengths involve the fact that it is flexible and theory based. On the other hand, the programme does have a number of limitations, including: the need for a more methodologically sound programme, the lack of established reliability and validity of the MMSA, the small scale evaluation, the lack of a randomised controlled trial design, and some problems relating with the programme's delivery by the school staff. Given these limitations, more research is needed to evaluate and further develop the MMSP.

Two more therapies will be presented that do not fall under a specific intervention category, but which are commonly used as interventions to improve motor or academic performance. The first therapy that will be discussed is Dance Therapy.

2.16.4. Dance Therapy

Dance Therapy (DT) can be defined as the "psychotherapeutic use of movement as a process which furthers the emotional and physical integration of the individual" (Couper, 1981). Dance Therapy aims to increase motor performance, self-esteem and academic performance. It involves a wide array of rhythmic movements specifically designed by the therapist. The effects of Dance Movement Therapy (DMT) on different motor areas (balance, coordination) and cognitive areas were tested with children with learning and perceptual motor problems (Berrol, 1984). Activities were oriented to enhance sensory-perceptual motor function through dance and movement experiences. Some of the activities included: sliding, rolling and moving to a specific tempo. A total of 68 first-grade children were divided into three groups: control, dance therapy and sensory integration activities therapy. Children had 30 minutes sessions, three times per-week for a total of 13 weeks. The results showed significant differences between the experimental groups and the control group. However, there were no significant differences among the two treatment groups. Moreover, although both treatments differed in style and application, both engaged the sensory-perceptual-motor channels to ameliorate behavioural dysfunction.

In another study, dance therapy was used with children from aging seven to 11 years old. The subsequent results revealed significant gains in terms of motor performance (Couper, 1981). Furthermore, a large-scale study with a sample of 721 first-grade students revealed that students participating in the dance programme improved significantly over the control group on all reading measures (McMahon, Rose & Parks, 2003). Apart from the aforementioned studies, and the classical activities that DT encompasses, a number of other programmes have been influenced by DT such as the "Write Dance" programme.

As part of this research, some of the current initiatives used in the United Kingdom and specifically in the North East were also reviewed. One of these programmes was the "Write Dance" programme, which has been influenced by some of the concepts that characterise DMT. "Write Dance" is a progressive music and movement programme for the development of pre-writing and writing skills in children. The programme's effects have been documented through the teacher's reviews, involving mainly improvements in handwriting. Nevertheless, it should be acknowledged that caution is needed when reporting the effectiveness of the programme since these reports are based only on teacher's reviews.

Overall, DT appears to be effective in the school and clinical setting; however, further research is needed to document its direct effects on motor and cognitive measures, and there is a need for the development of a sounder design and methodology.

The next intervention reviewed in this section is Physical Education, which is widely used in different approaches and programmes, especially in the school setting.

2.16.5. Physical Education

Physical Education (PE), or exercise, is part of the curriculum activities that children engage in schools worldwide. The majority of the studies in this area demonstrate the positive impact of PE not only on physical health, but also on motor and cognitive performance as well as self-concept, mental health and mood (see for example: Folkins & Sime, 1981; Haga 2008; Taras, 2005; Wrotniak, Epstein, Dorn, Jones & Kondilis, 2006).

One way of improving the aforementioned areas might be to increase the time that children spend in PE, although evaluating the effectiveness of this could be difficult. Alternatively, the development of more structured and focused interventions based on PE programmes can be used. This might include the following activities: aerobic exercises, walking, hopping, balancing activities and cardiovascular exercise (Taras, 2005). Furthermore, PE can be administered to both TDC and children with atypical development. A recent programme that has been created and tested in the school setting is SPARK. This programme involves 30 minutes of both health-related and physical activity and skill activity. The programme should be taught a minimum of three days per-week throughout the school year. An interesting finding from this study is the fact that while children were taking part in SPARK intervention programme their academic performance was not affected negatively (as cited in Castelli et al., 2007). Another finding reported in the study by Castelli (2007) is that aerobic exercise was positively associated with reading and maths whereas Body Mass Index (BMI) was negatively associated in elementary school children. These findings support the notion that physical activity can improve academic performance without interfering with the child's typical learning environment.

Another study performed by King et al. in 2011 with children from first through to sixth grade involved 40 minutes of daily exercise (rather than 40 minutes per-week). The results showed that students tests scores subsequently improved, indicating that a carefully designed PE intervention can potentially improve academic performance (American Academy of Pediatrics, 2011). It seems, therefore, that a regular PE programme could be the key to improving academic scores. Nevertheless, caution is needed since research has not yet established any direct causal links between PE and increased academic performance.

Another intervention that was discovered when exploring the available interventions that are currently used in schools in the United Kingdom, was a physical exercise programme used in the majority of schools in County Durham (Dr. Madeleine Portwood). Overall, it is based on the development of gross motor abilities. The programme involves activities that are designed to develop movement skills and is administered by experienced staff from the Educational Psychology Service of County Durham. Tools that are commonly used are: tunnels, beanbags, circle mats, and ladders. Contact was made with staff administering the intervention and a presentation was subsequently provided with children in different schools. The results indicate that children generally benefited from the intervention. From a practical perspective, this experience was very helpful, since it offered great insights into the sorts of movement programmes that are currently used. One important observation was the fact that a significant number of schools were participating in this motor intervention just to improve gross motor skills, which is important in its own right. As with other programmes, however, the limitation of the intervention was the lack of any sort of standardised tools to test the programme's effectiveness.

Generally, physical activity has positive effects on building up physical fitness; however, the benefits to either cognitive development or academic performance remain unclear and sometimes questioned. Further research needs to address in more detail which PE activities produce greater gains in specific cognitive skills and then further investigate the relationship. Furthermore, the use of standardised tests for assessing performance in the educational setting would be beneficial and would allow for an adequate evaluation of the various intervention programmes.

In the next section the reasons for combining elements and tasks from both of the approaches previously presented in the development of a new intervention are discussed.

2.17. Summary of Main Points

It was beyond the scope of the present research to demonstrate all the available interventions related to motor skills development. Therefore, a representative number of interventions were presented that reflected different approaches and programmes. These are summarised in Table 2.4.

Table 2.4.

Summary of Interventions for Improving Motor & Academic Skills

Intervention	Tools	Population	Improved Areas
AIT	Auditory Device	Autistic children	Balance-Hearing
NTT	Physiotherapy	DCD	Fine-gross motor skills
NDT	Normalizing muscle tone	Cerebral palsy	Gross motor skills
DT	Rhythmic movements	Learning difficulties	Reading-motor performance

PE	Aerobics-Cardiovascular	TDC & not	Motor-academic performance
PMP	Primary reflex movements	Dyslexia	Academic performance
CO-OP	Problem-solving techniques	DCD	Motor performance
MMSP	Fine & gross motor targets	Motor difficulties	Motor performance
SIT	Targeting sensory systems	Autistic, DCD	Motor-academic performance

As has been shown, some of the main limitations of the aforementioned therapies are: too expensive to administer (AIT); cannot be generalised easily (NTT, NDT, CO-OP); lack of a more structured design (DT, PE, SI); and need for further research to test their effectiveness on different outcomes (PMP, MMSP, CO-OP).

Aside from these limitations, however, all the interventions presented here provided important information about the effects of different intervention strategies on children, which is of vital importance to future studies. The presented interventions all targeted different areas and sought to improve either physical/motor performance or academic performance (or both). Several of the studies suggested that physical activity or targeted interventions can benefit children's performance and prevent them from having lower academic scores, limited physical activity and even obesity (Li et.al., 2008; Roberts, et.al., 2010). In addition, during the research on these different approaches, it became clear that, in many situations, the boundaries between the different interventions become blurred. For this reason, the MSI for the Early Years used in this project has adopted task/functional skills and process/deficit-oriented principles.

Apart from the interventions presented in the previous sections, a variety of movement programmes that have been developed and used in the school settings also exist. These programmes include: “brain gym”, “move to learn”, “DORE” and “music together program,” all of which are currently in use in different school settings. However, these programmes also tended to lack sound evaluation methods or strong theoretical basis. Moreover, further supporting evidence of the effectiveness of these interventions is needed since, so far, research findings report very small effect sizes (Hyatt et.al, 2009). Nevertheless the presented interventions appear to have both strengths and limitations. Consequently, it became evident that there is a need for new or revised interventions that will both address these abovementioned limitations and investigate the relationship between motor and cognitive skills.

2.18. Considerations for the Development of a Hybrid Intervention

In the previous sections, several interventions were presented that originated from different theoretical backgrounds. After careful consideration, it was decided to encompass elements from both theoretical approaches so as to create a new intervention. Thus, the MSI for the Early Years used in this project encompassed principles from the process/deficit approach, while also adding some direct motor tasks based on the task oriented approach. As such, the current intervention does not fall under any specific approach, but, instead, offers a new approach to motor skills interventions that combines traits from both process and task oriented approaches. Originally, some of the principles of SI therapy were integrated into the intervention because, although there are no contemporary studies to provide evidence of its effectiveness, it has historically produced significantly positive outcomes in a wide range of motor and academic skills. Additionally, 60% of practitioners in the United Kingdom are still using this therapy, which implies that, although there are no recent systematic high-quality studies that have produced statistically significant positive effects, there could be positive qualitative and practical outcomes (Bond, 2011). Previous research also supports the existence of common underlying neural mechanisms involved in both the motor and academic areas. One possible explanation for the lack of recent significant findings is the difficulty of correctly identifying the underlying processes involved in motor activities. It is suggested in this thesis that a potential solution for this difficulty might be the combination of SI therapy tasks with direct motor tasks. Therefore, it is anticipated that if indirect sensory activities are delivered along with direct motor activities under the umbrella of this newly developed MSI for the Early Years, the limitations of each approach can be compensated for by the inclusion of elements of other approaches. For example, the limitation of being unable to integrate other skills than the ones being taught, which the functional/task approach encompasses, can be potentially compensated for by including indirect activities from the process-oriented approach, such as eye-hand coordination, that can simultaneously improve other skills. On the other hand, since there is a difficulty in correctly identifying the underlying mechanisms involved in different skills, the inclusion of direct motor tasks can be viewed as a compensation for including elements from the other approach. As such children will practise and further develop specific motor skills.

An additional goal of the current research was the administration of the intervention in small groups of children. Administration to small groups in a school setting means that more children can potentially receive the intervention within the time and staffing constraints of a school day. Furthermore, this selection is linked with the decision to deliver the intervention to TDC. As discussed earlier, TDC can be just as at risk of developing motor skills difficulties as children with atypical development. Additionally, because the intervention will be delivered to TDC, rather than children with atypical development, it will be easier to manage and monitor the children's progress in small groups. Given this decision, the selection of a strictly task oriented approach such as CO-OP would not be practically possible, since these approaches target and practise the specific motor problems of each child. Although SI therapy also targets SI problems individually, it can be more flexible and generalisable since it involves the training of the underlying mechanisms rather than specific skills. Therefore, the decision to combine both approaches to develop a hybrid intervention can be further justified.

Another essential aim of this project was to develop a motor skills intervention that could easily fit the school's schedule, be pragmatic and be administered by a non-trained professional, such as a teacher, in order to be delivered in the future on a wider scale. For this purpose, it was decided that the new intervention should combine underlying motor tasks involved in SI therapy along with direct motor tasks involved in functional/task oriented approach. In addition, a detailed manual was also designed. Moreover, it was also decided that this school-based intervention should specifically target motor and academic skills in children in the early years because, as discussed earlier, they tend to be more responsive than older children to such interventions. Finally, when deciding on which approach to adopt for the current intervention, it was noted that many of the interventions that were presented earlier were conducted as a pilot study and thus did not have any robust findings with regards to their effectiveness. As a result, the current research developed a new hybrid approach to investigate the relationship between motor and academic areas.

To summarise, the decision to base the current intervention on a combination of tasks and activities from both the process/deficit approach and the task oriented approach was based on the following criteria:

- Ability to generalise effects to include other motor skills.
- Activities could be tailored to be cost-effective.

- Prior research on both approaches has documented positive effects on motor and academic measures.
- Support of a combined theoretical framework.
- Development of a hybrid approach combining process-oriented with direct skill training, complementing each other.
- Easier delivery in a school setting and easily replicable by teachers.
- Small group rather than individual delivery.

Given these considerations, the current MSI for the Early Years approach is a new approach to motor skills intervention by attempting to combine elements from the two aforementioned approaches.

2.19. Overview of Categories of Motor and Movement Skills

By reviewing the relevant literature on motor development different categories of motor skills were investigated. These informed the current intervention since it taps a range of different types of motor skills and they are being introduced in this section to better understand the MSI for the Early Years in the next Chapter. Fine motor activities are defined as those that require precision and manual dexterity to perform various tasks, such as writing. (Malina, Bouchard & Bar-Or, 2004). Gross motor activities are associated with movements involving major bodily parts such as postural balance (Malina et.al. 2004).

The second set of activities incorporates fundamental and specialised motor skills. A fundamental motor skill is the observable performance of the basic movements that are used for stability and manipulation, such as running or jumping (Gallahue & Ozmun, 1995). A specialised motor skill refers to a more advanced level of the fundamental motor skill in which a child is able to combine both basic and more advanced motor skills (Gallahue & Ozmun, 1995).

The third set of movements is the open and closed movements. An open movement activity is one that is performed while the conditions in the environment constantly change; hence, the individual needs to continually adapt in order to complete the activity (Gallahue & Ozmun, 1995). A closed movement activity takes place in a stable, predictable environment in which the individual initiates the launch of an action (Gallahue & Ozmun, 1995).

The fourth category of movements is the discrete, serial and continuous movements. A discrete movement is characterised by a definite beginning and ending, such as a throwing or kicking activity. A serial movement is characterised by the repetitive performance of discrete movements, such as rhythmical hopping. A continuous movement is one that is repeated for a specified time period, such as swimming (Gallahue & Ozmun, 1995).

The aforementioned categories comprise different attributes of movement which evolve during development. They can also be found within the same movement. For example, the current intervention has a hopping task in which four elements featured in the same activity: first, there was fundamental movement since hopping requires stability; second, there was closed movement since the environmental demands of the task did not alter; third, there was discrete movement involvement because the task had a definite start and end; and, finally, there was serial movement as the task featured a repetitive pattern. It is therefore desirable that an intervention to enhance motor development and skills incorporates elements of all four categories. Thus, these are the basis for the MSI for the Early Years.

The next section discusses and critiques the main aspects of the theories of human motor development.

2.20. Links between the Literature Review & the Current Research

The current research was inspired by the author's interest in the areas of developmental psychology, education and the impact of the environment upon children.

The first part of the literature review discussed the influence of the environment over a child's development by reviewing the key theories and arguments in the "nature versus nurture" debate. As this section outlined, it has become evident over the years that both nature and nurture considerably affect development. As such, there are strong reasons to believe that an intervention for children in the early years that seeks to enrich their environment with positive experiences can produce positive effects.

The next section involved a discussion of the key theories concerning motor development and their development over time. Additionally, a wider perspective on motor development theories and learning processes was included to provide a background for the various approaches that have been discussed in relation to motor skills interventions. This section offered valuable insights into the processes by which children develop motor skills and highlighted the importance of the early years to this development. Moreover, both motor control and motor learning were shown to be inseparable processes that develop and continually adapt as an individual progresses through the lifespan. In the current research, motor control is involved as part of the activities in the MSI for the Early Years and, during the intervention, motor learning amongst the children was active and changing.

The following section considered several theories that focused on the association between cognitive development and motor development, which is the constructivist relationship that is of most relevance to the current intervention. Additionally, supporting evidence from multiple areas was presented, including: developmental disorders co-morbidity evidence, co-morbidity theories, embodied cognition theory, physical activity and academic performance research, and motor skills and reading and maths performance evidence. All these areas provided a foundation for investigating changes in children's academic performance through their motor correlates. This section was very important for the current study as it served as a link between the two areas of research and described the effects that one has upon the other. Furthermore, different evidence was brought together from several research areas to demonstrate that there is strong supporting evidence to suggest that cognitive development and motor skills are related and should, thus, be investigated. Another important part of this section was the presentation of the factors that further influence physical, academic and cognitive functioning in TDC, with evidence being provided of the preventative potential of school-based motor skills interventions delivered to typically developing population - a factor upon which the current MSI for the Early Years was based.

Additionally, views and evidence which did not support the idea of there being a relationship, along with research that had failed to find a strong link between the different areas, were discussed. This section was valuable in providing a more complete and objective perspective on the subject, as well as demonstrating the complexity of the research area. Furthermore, this evidence also further suggests that many factors are involved in cognitive and motor skills development that can affect the dynamics of this relationship.

Next, a discussion of a selection of several motor skills interventions was provided. Significantly, although the interventions all targeted different populations and had diverse theoretical backgrounds, they still all yielded some positive motor outcomes, with some documenting positive academic outcomes as well. This section was important as it provided a multidimensional background to current interventions in the field. This, in turn, helped in deciding what approach to adopt in the current intervention. This section also provided justification for the development of a MSI for the Early Years based on a combination of the two dominant theoretical approaches to create a new hybrid approach to motor skills intervention. Finally, this section also provided a brief overview of the links between the literature review presented and the current research.

Perhaps most importantly, however, the process of conducting this literature review also confirmed that there is a significant “gap” in the current research on the relationship between motor skills and cognitive development. Most notably, there is, to my knowledge, no other motor skills intervention that has been developed for TDC that both incorporates the tools and activities used in the current intervention and, then, evaluates their effectiveness using an experimental design. Additionally, in my knowledge there is no other intervention that has combined both process and task oriented approaches to develop a new type of intervention. For these reasons, therefore, this current intervention offers an important and original contribution to the research area.

CHAPTER 3

METHODOLOGY OF THE STUDY

3.1. Introduction

The previous chapters provided a detailed background which formed the theoretical basis of the current research. Considering different aspects of research in the area under investigation the need for the development of a structured motor skills intervention for the early years and its beneficial role became evident. Hence the next step was to design and work on the methodology of the intervention and research as a whole.

One of the objectives of this study was to develop a motor skills intervention and to test its effects on children's motor skills as well as reading and maths performance. In order to investigate this relationship the MSI for the Early Years has been developed. It has been hypothesised that children receiving the MSI for the Early Years will yield better performance results in the aforementioned areas than children who do not receive the intervention, after controlling for their baseline measures of development. In order to fully describe the methodology used in this study the chapter will discuss the following topics: rationale for the research methods, overview of the MSI for the Early Years pilot study, ethics approval, sample selection, design, research tools, assessment tools, intervention measures, description of the delivery of the intervention, issues of validity and reliability, data collection, an additional short research for test-retest reliability and validity and a summary of the methodology's main points discussed. Before examining the different methodological points Table 3.1 will show the eight-stage model of the Scientific Method proposed by Cohen, Manion & Morrison (2007). This model will be followed with the current research. The decision for using this model was based on the fact that the stages that are included in this model represent the general stages that are most commonly followed in the process of building the methodology on educational research.

Table 3.1

An eight-stage model of the Scientific Method

Stage 1: Hypotheses/ hunches/guesses
Stage 2: Experiment designed/samples taken/variables isolated
Stage 3: Correlations observed/patterns identified
Stage 4: Hypotheses formed to explain regularities
Stage 5: Explanations & predictions tested/falsifiability
Stage 6: Laws developed or disconfirmation (hypothesis rejected)
Stage 7: Generalizations made
Stage 8: New theories

This model was a useful guide through the course of the research. In the next section the rationale is presented for the research methods used.

3.2. Rationale for Research Methods of the Study

Designing an effective intervention for children is a very challenging task, especially in an area with limited or controversial research. It should fulfil some criteria such as, being based on theoretical constructs, if is to be replicable it needs to establish clear guidelines, to be easily replicable and the main focus should be the child's well-being. Existing research focuses on the relationship of motor skills, academic and cognitive functioning by studying mainly populations with atypical development. Furthermore, existing interventions tend to focus on the practise of either too specific motor skills or too general. The majority of programmes currently used, adopt an intervention plan based on enhancing different PE activities or using expensive equipment, resulting in interventions that cannot be widely available. Also when it comes to evaluating the intervention, the outcome measures are generally based solely on teacher or parental reports which are of questionable validity, due to their subjective nature (Mattingly, Prislin, McKenzie, Rodriguez & Kayzar, 2002). Another characteristic is that many times interventions are tailored to the individual, which can be a weakness towards the development of an intervention that can be generally applied to the school setting in groups, hence being more time efficient. When the intervention is tailored to the individual it might have limited generalisability but where positive results have been found, the general approach of individualised programmes can be potentially generalised.

On the other hand, it should be acknowledged that it is not ethical to have a control group, when the study involves clinical populations. In order to solve this, therefore all children to receive an intervention many contemporary studies use the children involved in the study as their own controls. See for example: Sugden & Chambers, 2003. Additionally, when an intervention is applied to a large number of children who may not have sufficient difficulties to warrant a clinical diagnosis but they can also benefit from practice.

The present intervention was developed having specific criteria in mind and considering the characteristics of existing research. More specifically, the MSI for the Early Years has adopted principles from both the process and task-oriented approach to motor skills interventions. Therefore, it included direct and indirect motor tasks aiming in producing improvements in both motor and academic skills which as literature suggests (Asonitou et.al., 2010; Wassenberg et.al., 2005) are linked. Drawing upon the theory of embodied cognition children's bodily experiences during the intervention can form cognitive ones (Thelen (b), 1995). These criteria have been inspired by research that has been already performed, but also adding to the existing literature with new elements. The criteria to be taken into account in the development of the intervention for the current research are outlined below:

- Easily applied in different groups of children in the Early Years.

- Adaptive according to the performance of the children (i.e. changes in difficulty levels if it is too easy or too difficult).
- Delivered pragmatically in any school setting, by non-specialists (teachers) and without the use of expensive equipment.
- Include a manual and a set of instructions for the intervention to be replicable.
- Addressed to TDC to enhance the preventative role in the educational setting and protect against potential factors decreasing physical development; such as parenting styles, the English school timetable and sedentary lifestyle.
- Include activities which have a multisensory nature and be sufficiently challenging as well as fun for children.
- Designing an intervention that would be purely motor by keeping cognitive activity as low as possible to better document the effects of the motor to the cognitive or academic domain.

After the study of relevant literature and the decision of which approach the current intervention was to be based, an important step was the creation of tools and activities to be used in the intervention. The selection of the tools and activities was completed having as a focus tapping the three sensory systems and also practise direct motor skills. The next section will provide an outline of the terminology of the motor skills that were targeted in the MSI for the Early Years.

3.2.1. Introduction of the Terminology of the Motor Skills Involved

Before presenting the different tasks that the intervention entailed some terminology related to the motor skills exercised will be summarized on Table 3.2 in order to provide a better comprehension of the later sections:

Table 3.2

Motor Skills Involved within the MSI for the Early Years

Name	Brief Description	Example	References
Bilateral Coordination	Simultaneous Coordination within & across the limbs to complete a task.	Clapping, typing.	Tseng & Scholz, 2005.
Balance Control	Maintain body's COM within the BOS.	Walking (dynamic), standing on 1 leg (static).	Hatzitaki, Zisi, Kollias, Kioumourtzoglou, 2002.
Eye-Hand Coordination	Involvement of several systems: visual, vestibular etc & cognitive systems: attention, memory.	Eating, using a tool.	Crawford, Medendorp & Marotta, 2004.
Locomotor Skills	Precise positioning of the limbs during a task.	Hopping, galloping, reaching.	Georgopoulos & Grillner, 1989.
Postural Control	Cooperation of visual, proprioceptive & vestibular system for a stable stance with no body sway.	Standing.	Peterka, 2002.
Spatial Awareness	Move independently & initiate one's own movements.	Walking in a straight line.	Foreman, Orencas, Nicholas, Morton & Gell, 1989.
Manual Dexterity	Coordination of limbs during fine motor tasks.	Writing.	Hughes & McLellan, 1985.

Tactile Discrimination	Ability to discriminate through touch between objects.	Buttoning, hand manipulations.	Case-Smith, 1991.

Notes: COM: Body's Centre of Mass, BOS: Balance of the System

It is clear that there are no clear-cut boundaries between the skills needed or sensory systems that are involved during the performance of a motor task. For several activities the cooperation of more than one sensory system is required. Hence motor skills that have been involved during the performance of one task can be present to other tasks too. Due to the nature of this complexity by targeting the underlying processes that are thought to be involved in different motor skills the degree of generalisability to other skills is increased. Ultimately, children will improve their motor learning, which involves changes in motor performance. The next section will provide an introduction of the tools and activities that were selected for the current intervention.

3.2.2. Selection of Intervention Tools

The next step of the research was to decide upon the selection of the tools and activities for the intervention. The tools that were selected were a combination of the two approaches covering the areas on which the intervention was based. Hence, a combination of indirect sensory and direct motor tasks was the ultimate goal, as well as the use of tools and activities that have not been used before in such combinations. For example, children may already be familiar in using maracas in schools but during the intervention both the frequency, movement and rhythm was different. Moreover, the tools were being manipulated by the children in specific combinations that children have not tried in the past.

The tools and activities that were selected were divided in three categories. Each category involved three tasks. As it was mentioned earlier in Section 2.15.2.5, the three main sensory systems involved in the process-oriented approaches are the vestibular, proprioceptive and tactile system. On the other hand each category also involved direct motor tasks. In order to better identify the potential changes in motor performance the categories were named after the three sensory systems. For example, the vestibular category involved mainly tasks which are thought to tap the vestibular system more than the other two systems. It needs to be clarified that the other two systems are active and stimulated during a “vestibular” task and all systems interact since there are no clear-cut boundaries among them. Furthermore, the categories involved direct motor tasks taken from the task/functional oriented approach. Therefore, the structure of the MSI for the Early Years was developed based on the creation of a hybrid intervention model. For the purposes of this thesis the three categories of the different tools and activities will be named after the three aforementioned sensory systems.

The first step was to develop a plan of the tools and activities that would be used and the second was to test these in a pilot study before proceeding with the main intervention study. In this section a description of the tools and activities used is given, as well as which motor skills are involved. A detailed description of the procedure of the intervention will be provided later in this chapter.

The first category was the vestibular activities that used light-up maracas, a tube with a balancing ball and hopping on each foot. Maracas were used to activate the vestibular system through motion, sound and light that provide sensory input to the system. Eye movements and visual perception are linked to balance (Cheatum & Hammond, 2000). Hence some visual stimuli may “trick” the balance mechanism into thinking that the individual is moving (Blythe, 2000). This activity involved movements of the maracas in different directions. The selection of the maracas was based on the fact that they provide auditory and visual stimuli to the child’s vestibular system. Visual because the maracas light once moved and auditory because of the sound they produce. Light was a useful indicator of the movement’s rhythm. Research suggests that the involvement of rhythm to movement tasks can improve fundamental motor skills (as cited in Deli, Bakle & Zachopoulou, 2006). Additionally, research suggests that children with learning disabilities often exhibit problems with their rhythmic skills, so it is recommended that rhythm is involved in the acquisition and development of some motor skills (Liemohn, 1983). Bilateral coordination was achieved through parallel manipulation of the maracas and the development of this skill is necessary for the coordinated use of both sides of the body (Swinnen & Wenderoth, 2004). The tube with the balancing ball was for children to practice their balancing skills; balance is a major part of the vestibular system since the inner ear is one of the main controllers of balance (Highstein, Fay & Popper, 2004). The selection of the tube with the balancing ball was based on the criterion of exercising balance. As balance improves the amount of movement in the body reduces, but during the learning of each new skill the movement of different body parts helps to master that skill. The selection of hopping on each foot activity was based upon the criterion of exercising coordination and locomotor skills and it is also an activity that is used both in process and task oriented approach (Cornish, 1980; Uyanik & Kayihan, 2011). Hopping is one of the basic locomotor skills (Deli et.al., 2006). Locomotion requires the child to practise self-control and control over his/her whole body. By the age of three and a half years old the majority of children are able to hop from one to three times (Sugden & Wright, 1998). Additionally, hopping exercises static balance (Peters & Wright, 1999). All activities of this category involved gross motor skills.

The second category was the proprioceptive activities that included mazes, miming and clapping activities. The walking activity through the different mazes (horizontal, vertical, butterfly shape and snail pattern) enabled children to practise a coordinated and smooth pattern of movements as well as practising their dynamic balance (Uyanik & Kayihan, 2011). Walking is considered to be one of the most important movement patterns upon which many other motor skills develop (Malina, 2004). Another motor skill that can be exercised while walking in specific directions is spatial awareness (Werner & Burton, 1979). In addition, the miming included hand rotation movements, which through the alternation of body positions helped children with better orienting themselves in space and practising their postural control (Riemann & Lephart, 2002). While the children perform the movement of hand/arm rotations they develop a better awareness of the position of their body in space (Werner & Burton, 1979). Miming is another way of body awareness relevant to the position in space (Jackson, 1983). Handclapping involves simultaneous hearing, seeing, touching and motor experience, through which bimanual coupling (coordination) is achieved as well as eye-hand coordination and synchronization (Brodsky & Sulkin, 2010). The above activities involved mainly the gross motor skills as well.

The last category was the tactile activities which practised more directly the fine motor skills focusing mainly on manipulation skills by moving objects with fingers. This category included pegboards, play buttons and a bucket with rice. Children were expected to develop their fine motor skills and receive sensory feedback from the use of pegs. Children started by placing a small number of pegs in the board, and gradually increased the number. This activity develops precise coordination and increased manual dexterity (Gardner & Broman, 1979). By threading buttons through strings, children exercised their fine motor skills and developed better control. Tactile control was the main focus. Additionally, eye-hand coordination is involved in the threading task (Hobart & Frankel, 2005). This activity is also used in the task-oriented approach. In order to complete this task children were required to change finger positions and eventually select the best for them. With the bucket of rice children developed their tactile control and sense, and received sensory stimuli from searching for the balls inside the rice bucket. This activity, which can be perceived as a “treasure hunt”, is also used in process-oriented approaches (Cheatum & Hammond, 2000). Children during this activity also developed their tactile discrimination ability. This category involved fine motor skills.

Additionally, all activities fall under the following four movement categories that were previously presented in Section 2.19 and namely are: fundamental, closed, discrete and serial movements. They were fundamental because they required stability and manipulation; such as hopping and walking in mazes. They were closed because the environment was stable in all the intervention's activities and the child was the one initiated the start of each movement. They were discrete because all activities had a definite start and end. Finally, some activities were serial too, since they involved a repetitive pattern of performance; such as rhythmical hopping and clapping.

The tools and activities presented, comprised the final ones that were selected or altered following the pilot study. The tools and activities selected for the intervention are used in schools and children might were already familiar with some of them, but it was the first time that all of them were used in these combinations and under a structured setting and environment, so it was a new learning experience. In the next section some of the characteristics of the MSI for the Early Years are discussed.

3.2.3. "Motor Skill Intervention (MSI) for the Early Years" Characteristics

One of the biggest challenges of the current research was the development of an intervention for children that would improve their motor skills and ultimately their academic performance.

Contrary to previous approaches, children received the intervention in small groups and also the population receiving the intervention consisted of TDC. Since the children in the experimental group all received the same treatment, the idea of delivering the intervention in manageable groups of four to five emerged because in that way there would be time to administer the intervention to more children. The decision to administer the intervention in small groups was also reinforced after the pilot study in which it was observed that when children received the intervention within a group they seemed to attend more and have higher willingness to continue with the activities than when working in a one-to-one situation with the researcher. This observation comes in accordance with a psychological perspective to behaviour which supports that people are prone to commit more in a task while other people are present (Gobinath & Nyer, 2009). The reason for selecting TDC was discussed in Chapter 2, which was mainly based on the preventative focus of the intervention. Another element of the MSI for the Early Years was the development of a detailed manual of the tools and activities used.

Since one part of the activities was of a somatosensory nature children of four years of age was selected for the intervention. Research suggests that between the ages of four to six children tend to use extensively somatosensory and vestibular inputs (Uyanik & Kayihan, 2011). Additionally, direct motor tasks were employed such as pegboards, to an attempt to combine process and task-oriented approaches under the umbrella of a hybrid intervention. It is hypothesised that this newly developed motor skill intervention will have a positive effect on children's reading and maths performance. A detailed presentation of the intervention follows in the next section.

3.2.4. Description of the "Motor Skills Intervention for the Early Years"

In the previous section an introduction of the research tools and the activities was presented mainly addressing the reasons for the selection of these tools and activities. In this section a more detailed description of the activities and their delivery is provided. But first, some conditions characterising the intervention will be presented.

Conditions

- All of the activities have been designed bearing in mind not to involve cognitive elements, since the intervention should be a "pure" motor skills intervention. This was achieved through careful planning and simple instructions. Each task was firstly demonstrated and then tried by the children themselves.

- All the activities were increasing in difficulty level as the intervention progressed and also altered to some extend throughout the intervention to avoid loss of interest and ceiling effects.
- Both the order and the time that children were taken from the class differed each day. The reason for this decision was to try and keep to a minimum the levels of conditioning if children were to perform the intervention activities exactly with the same order every day. Also children were taken at different times to avoid missing out the same time on a school day and also to balance out any possible effects of time on performance.
- The intervention was initially divided to 12 stages with each stage comprising of two sessions. Each stage represented a week, but since the intervention lasted 11 weeks there were 11 stages.
- It was decided for ethical reasons that, in the case that some children progressed faster than others in a group, there was the option to alter the original groups depending on their daily progress.

If a child made errors on more than half on the activities or their time was much slower than expected, they were deemed not ready to move to the next stage. On the contrary, children who performed the activities in both sessions of each stage with consecutive successful trials and performed within the expected time limits on the timed activities could progress to the next stage of the motor skill intervention. During the intervention after the first stage (i.e. the first week) in one of the schools, following careful observation of their performance, some children were moved from one group to the other because there were big observable performance differences. The author made a judgement that to maintain the self-esteem and motivation of the children, they should work in groups with others at a similar stage of development. After the change was made, children appeared to be happier and more motivated to participate in their new groups. The researcher was blind to the children's pre-intervention scores thus the decision for changing the group was based on pure observations of the children's performance during the first days of the intervention. On the other hand, this change can be considered as a limitation of the design and needs to be acknowledged.

The tools other than the floor mazes (which were already made) were introduced in each session one at a time to avoid frustration and inattention. The above resulted from observing children getting distracted in the pilot study if many tools were around them. There were three categories of activities involving three subcategories that have been named based on the three sensory systems (vestibular, proprioceptive and tactile). As it was suggested earlier it is acknowledged that there are no clear cut boundaries and an activity of the vestibular category can stimulate the other two sensory systems. Thus this categorisation is only a means to identify easier the activities and tasks rather than implying a direct relationship.

A. *Vestibular:* The vestibular activities involved the use of maracas, tube with balancing ball and hopping on each foot.

    1. Maracas with light: Children were required to perform different movements using their hands and arms, while holding either one or two maracas. Initially, they needed to shake one maraca holding it tight with both hands up, down, right and left, three times each direction. Then they had to do the same while holding two maracas, one in each hand. Later on they needed to do the same movements while crossing their hands. Children were given visual instructions and a demonstration of each activity before performing it. Then they tried it once and then they were ready to perform the task themselves. Children's accuracy on performing the task was recorded.

2. Tube with balancing ball: Children were required to balance the ball in the middle of a tube. They were instructed to place their hands in the two ends of the tube and try and make the ball stop in the middle. They were then asked to repeat the activity three times. While the intervention was progressing they had to change their hand positions, by moving their hands closer to the middle of the tube and try to balance the ball in the middle. Children's accuracy on performing the task was recorded.
3. Hopping on each foot: Children were required to hop on each foot (left-right) a certain number of times without touching the floor with their other foot or losing their balance. The number of times the children needed to hop increased as the intervention progressed. Children's accuracy on performing the task was recorded.

B. *Proprioceptive*: The proprioceptive activities involved walking through different mazes, hand clapping and hand/arm rotations.

1. Mazes Walking: Children were required to walk through the floor mazes without touching the lines or go out of the lines. There were four different types of mazes; horizontal with vertical, v-shape, butterfly shape and snail shape. All mazes became narrower during the intervention to increase the difficulty level. Children were timed in this activity and also their accuracy was recorded while they were walking, placing one foot directly in front of the other.
2. Hand Clapping: Children were required to clap their hands, learning different types of clapping. Upper palm clapping, lower palm clapping, whole palm clapping and a combination of all three. Before beginning the activity children,

were given visual instructions and a demonstration, and then they were asked to repeat the activity. Children's accuracy was recorded.

3. Hand/arm Rotations: This activity involved the rotation of the hands/arms in a clockwise manner. There were three variations: Rotations of both hands clockwise, rotations of both hands anticlockwise and rotation of one hand clockwise and the other anticlockwise. Children as always were given visual instructions and a demonstration and then they were asked to repeat the activity. Children's accuracy was recorded.

C. *Tactile:* The tactile activities involved the use of pegboards, buckets with rice and threading buttons.

1. Pegboards: This activity involved the use of two different pegboards (easy and harder). Children were asked to place a specific number of pegs inside the board in a precise amount of time. The number of pegs increased during the course of the intervention and half way through, the pegboard changed to the harder version one. This was a timed activity.
2. Buckets with Rice: Each child had a bucket filled with rice, which had small balls hidden inside. The task was to put both hands in the bucket and try to find the balls as fast as possible before time ran out. It was like a timed treasure hunt. The number of balls hidden changed during the intervention and the time that children had to find the balls decreased as well to increase the difficulty level.
3. Threading Buttons: Children were given a certain number of buttons and a string and they were asked to thread the string through the button holes. The number of buttons, as well as the time that children had to perform the activity

changed during the intervention. This was also a timed activity. Figure 3.1 depicts the format of one day's session.

A.-Vestibular Activities-Session1-Stage 1

1. Maracas	Children will perform the activity holding 1 maraca tight with both hands. *Starting point:* Holding the maraca in front of them. I count: 1, 2, 3 and move the maraca up while shaking it. Allow 1 practise trial & then children repeat 3 times. The same to be applied moving the maraca down.
2. Tubes with Ball	Children will hold the tube from 2 ends and try to stabilize the ball. Place the children's hands in the correct positions and allow 1 practise trial & then children repeat 3 times. Between each trial instruct the children to shake the tube.
3. Hopping	Children will need to hop on their right foot while I count up to 3 and repeat 3 times. Allow 1 practise trial before the activity. Children will need to try to stay in their original position while hopping.

B.-Proprioceptive Activities-Session1-Stage 1

1. Floor Mazes	Children will be requested to walk through the horizontal and vertical mazes. Children first form a line behind me and walk through the mazes. Afterwards they will need to repeat the activity themselves and return back the same way without touching the lines.
2. Clapping	Children will be asked to clap using their upper part of their palm while I count up to 4. Counting intervals are 2 seconds. Allow 1 practise trial & then try themselves, repeating 3 times.

3. Hand/Arm Rotations

Children will be asked to move both hands/arms clockwise. First I place my hands on the children's hands to show the movement and after 1 practise trial children try themselves 3 times. The rotation is a full clockwise circle movement.

C.-Tactile Activities-Session1-Stage 1

1. Pegboards

Children will be provided with 15 pegs and will be requested to place them on the pegboard with no particular order before the time runs out. I time the activity with a stopwatch.

2. Playing Buttons

Children will be requested to thread 2 buttons in a lace/string before the time runs out. I time the activity with a stopwatch.

3. Bucket with Rice

Children will be requested to place both hands in a bucket full of rice and find 6 hidden small golden balls before time runs out. I time the activity with a stopwatch.

Figure 3.1: Example session of intervention

The current intervention was delivered by a researcher who provided a detailed manual with visual information (photos) along with instructions to be easily replicable and monitor the therapy's standards. More specifically, the criteria for recording as successful or unsuccessful the child's performance in each trial had been set before the start of the intervention in order to monitor the intervention's quality and standards.

3.2.5. Ethics Approval, Pilot Study & Schools

In the following three sections the procedures of obtaining ethics approval, piloting the tools and tasks before the intervention and searching for schools for the actual intervention will be presented.

3.2.5.1. Ethics Approval

In order to engage in research with children an Ethics approval of the study needed to be obtained from the University. The research Ethics Committee is responsible for: "reviewing all research involving human participants conducted by individuals within an institution, ensuring that ethics review is independent, protecting the dignity and rights of the participants, considering the safety of the researcher, making informed judgements of the scientific merit of proposals and making informed recommendations to the researcher if the proposal is found to be wanting in some respect" (British Psychological Society, 2010). Especially when the research involves working with children the Ethics committee has to ensure that all conditions are met and that the research will take place following the written consent of both the parents/caretakers and teachers of the schools. Before the research proposal and the application for the Ethics approval a Criminal Records Bureau (CRB) clearance was obtained. Two Ethics applications and forms were completed; one for the pilot study and one for the main study. In the Ethics application details about the participants, confidentiality issues, debriefing of the participants as well as the goal and description of the research were provided. Furthermore, two different copies of informed consent were created; see Appendix 2 one for the parents and the other for the teachers, which were handed together with the Ethics form. Before the first session of the intervention the researcher explained to the children that they will take part on a programme that involves different exercises in order to improve some skills. Specific details were provided during each task of the first session. Also children were told that by participating in the programme they help the researcher conducting university research. Children were also informed that they had the right to stop at any time if they wished according to the participant's rights. Once Ethics approval was granted, research started first at a pilot study level.

3.2.5.2. Pilot Study

A pilot study is conducted as a preparation for a major study, acting as a trial run or for pre-testing various research tools (Van-Teijlingen & Hundley, 2001). The main goal of the current pilot study was to evaluate the newly developed intervention programme and observe how different ages and genders could manage the various activities. The only information needed at this stage was the age and gender of the children. For the pilot study both Durham's University Nursery and children of staff who work at the Centre for Evaluation and Monitoring (CEM) were contacted and helped to complete the pilot study. CEM is an organization within Durham University that mainly produces assessment batteries for school aged children. Some of the staff kindly helped by allowing their children to participate in the pilot study. The sample was an opportunistic sample rather that a fully representative one, but at this stage of the research that was sufficient. The aim of the pilot was to observe how children manipulate the different tools and how they behave during the different activities, so a representative sample was not needed. The length of the pilot study was approximately three weeks. Nine children aged between three and five years old participated, with each session lasting from 15-20 minutes. Children were tested either individually or in groups of three. For children from Durham University Nursery, staff from the Nursery as well as the other children in the Nursery room were present during the administration of the intervention by the researcher of the present thesis. For children of CEM staff, the children's parents were present during the delivery of the tasks by the researcher. Careful observations and note-taking was important for future alternations. An important observation was that prior to each activity a simple and well explained plan of what will follow really helped. Children were curious about each activity that followed and were trying to do their best to successfully complete each task, especially when they were in groups. At some times children became frustrated if they could not finish a task or if they were struggling, so the activity was stopped at that stage. Another point for consideration was that activities should be kept short and continuous to avoid loss of attention. Furthermore, the tools that were going to be used should be introduced one at a time and the rest kept out of direct sight in order to avoid loss of concentration. In relation to age, the main observation was that in the majority the tools and activities were hard for the three year old children, well managed by the five year old and challenging enough for the four year old children.

The pilot study was very useful because it provided feedback for alternations, changes and additions to the original intervention. Changes included the instructions and the use of some tools and activities. Furthermore, the pilot study was a good practice before the actual administration of the intervention, mainly because it provided information on what to expect when working with larger groups for a longer time. Additionally, important information was gained regarding the research tools, the way of administering the intervention and children's reactions. Some of the main gains and adjustments that were made to the final intervention following the pilot study are outlined below:

- Recorded and adjusted the time taken to complete the activities.
- Discarded unnecessary or difficult instructions.
- Observed how children manipulate the tools and adjusted their use accordingly.
- Excluded one of the activities (metronome movements) since it was too hard for children to perform it correctly and synchronize.
- Presented the tools one at a time instead of presenting them altogether.
- Confirmed that the tools and activities were appropriate for the selected age (4 years old).

- Adjusted the difficulty levels of some tools and activities to become challenging enough.
- Decided to progress children to higher intervention stages for children that some of the activities appeared to be too easy.
- Decided upon which activities would be measured with either accuracy, speed or both.
- Decided on the measurements and distances that some activities had.

One of the final stages before the application of the intervention was to develop a set of detailed instructions (see Appendix 3) and a manual that would be indicative of the intervention sessions through time. Instructions were kept simple and always a visual aid was provided. The visual aid was the detailed demonstration of each activity by the researcher before the children tried the activity themselves. The manual has been made to describe activities on a stage basis as the difficulty levels gradually change. Further details will be provided during the description of the procedure of the intervention. The next step was to search for schools willing to participate in the research.

3.2.5.3. Finding Schools

An important criterion on the selection of the schools was that they should not have been participating or participated in the past in any motor skill intervention or programme. The reason for that was to eliminate any confounding effects that a previous intervention could have on the outcomes of the current MSI for the early years and therefore being able to document the current intervention's pure effects. Two primary schools were approached after meetings in which the intervention and the goal of the study were explained to the head teacher and class teachers, both schools agreed for children in the reception class to participate in the intervention. In England, reception class entry age is four years old. Both schools and parents were given consent forms asking permission to perform the research and briefly explaining the procedure. The majority of consent forms were returned, 24 out of 36 in one school and 34 out of 34 in the other, showing that parents were interested in a motor skill intervention. A timetable was formulated which included; the timing of the pre and post assessment, the days and times that the intervention would be delivered in each school. This timetable was created with accordance to the schools' schedule and activities. Additionally, the intervention was delivered at different times during the school day. Children were assessed both before the start and at the end of the intervention with measures of motor development and academic skills of reading and maths. Before introducing the assessments that were used in the current study, details about the sample selection, duration, length and measurements are provided.

3.2.6. Participants

One of the first steps of the study was the selection of the population that this intervention would be applied and tested with. After careful examination of the literature in the area of motor skills interventions and also SI therapy's research the age group of four years in reception class was selected. More specifically, children had a mean age of 58 months ranging from 52 to 64 months of age. The mean age was calculated on the day of starting the assessment. Children in both schools were assessed either in the middle of January or the middle of February. The age groups that are usually getting the SI therapy are primary school children. During the pre-school and early primary school years basic movement patterns are developed which form the foundation for activity at later ages (NICE, 2008). Furthermore, the benefits of early intervention have been documented in many studies. See for example; Erwin et al., 2012; Ramey & Ramey 1998; Son & Meisels, 2000. During the pre-school and early primary school years basic movement patterns are developed which form the foundation for activity at later ages (NICE, 2008).

Another decision regarding the population was the decision to work with TDC. Also since there is research that provides evidence of the positive effects of physical exercise on cognitive functioning and academic skills during school years an intervention applied to TDC could only be beneficial (Deli et.al., 2006; Trudeau & Shepard, 2008). So, after the careful selection of age group and other criteria, the current research comprised initially of 60 children in total for whom parental permission had been obtained. None of the children has been previously diagnosed with any developmental disability. From the 60 children, four dropped out due to moving to a different school close to the end of the intervention, and so the remaining sample was 56 children with 27 children in the treatment and 29 children in the non-treatment group.

Children were randomly assigned to class level from their reception classes to either the experimental or control group. The individual random assignment rather than a cluster randomised control trial (RCT) was based on the fact that only two schools were participating in the intervention. The cluster RCT is frequently used in the educational setting and involves groups of participants to be the unit of randomisation (Puffer, Torgerson & Watson, 2005). Hence in order to perform cluster RCT more than two schools are needed. The only person administering the assessment and the intervention was the writer of this thesis, so variation at the group level was likely to be less. The RCT was chosen as the experimental method to evaluate the effectiveness of the MSI since evidence suggests "a well-designed quasi-experimental design is inferior to a well-designed RCT" (Torgerson & Torgerson, 2001). Until recently, RCTs were not commonplace in educational research. However, this situation is changing. An example of that change in England is the establishment of the Education Endowment Foundation (EEF) and Sutton Trust Teaching and Learning (Higgins, Katsipataki, Kokotsaki, Coleman, Major & Coe, 2013). More specifically the Toolkit provides a summary of educational research guiding teachers and schools on how to use their resources to improve attainment based on evidence drawn from quantitative meta-analyses and RCT research. Moreover, similar attempts have been developed in the United States by the "What Works ClearingHouse" and the "No Child Left Behind Act" which are both supported by the Department of Education and investigate the impact of different interventions mainly on disadvantaged children (For more information see: http://www.ies.ed.gov/ncee/wwc/ & http://www2.ed.gov/nclb/landing.jhtml). On the other hand, many previously published studies cannot provide robust evidence of their findings since their results may be the product of a number of confounding variables. Hence, since one of the aims of the current research was to provide robust evidence if the MSI for the Early Years improved children's performance using RCT seemed to be the right choice.

Two schools participated in the study with one school being girls only and the other mixed gender. The study comprised of 39 girls and 17 boys.

Children in the experimental group were further divided into small groups of four or five to receive the intervention. Further details are provided in the next section.

3.2.7. Design

There are three basic experimental designs namely; between-subjects design, within-subjects design and mixed factorial design. The current study was a mixed factorial design, since it included both between and within subjects variables. Between subjects design is the design in which only one group receives treatment and the other receives no treatment or a placebo. Within subjects design is the design in which the same subjects receive all levels of treatment (Breakwell, Hammond & Fife-Schaw, 1995). One type of mixed design is the pre-post-control design. In this design all subjects are given a pre-test and a post-test and these two serve as a within-subjects factor/test since all subjects receive them. Participants are also divided in two groups; an experimental and a control group. Only the experimental group receives the treatment/intervention, which serves as the between subjects variable. The current research had all the above conditions. By using this design the internal validity is increased. The internal validity of this design is strong because the pre-test checks that the two groups are equivalent. A usual limitation in previous research was the lack of a control group to compare the changes between groups. A well-controlled research design is an important feature of the experimental method (Cohen et al., 2007). Additionally, by using a control group the potential problems caused by "regression to the mean"[5] are avoided. Both groups were pre-tested and post-tested, offering control over possible confounding variables.

Another point that needs to be stressed is that all of the activities involved in the intervention were gradually increasing in difficulty level. During the pilot study the researcher was able to rehearse and test out the different difficulty levels of the motor tasks. The purpose for that was initially to avoid symptoms of inattention, lack of motivation and also to control for ceiling effects. If children were engaging in the exact same activities throughout the intervention then their performance would be close to the top of the scale due to practice and not due to the impact of the intervention. The current research separated the participants into a treatment and non-treatment group. The treatment group received the intervention, whereas the non-treatment group continued with their normal teaching activities. Children that did not receive the intervention would get the chance to receive it after the completion of the intervention, possibly in year one, delivered by their teachers. For that purpose at the end of the intervention, the participating schools received the MSI for the Early Years manual along with detailed instructions.

Another important feature was that children were randomly assigned to either group. Random assignment took place at the pupil level, meaning that all children in reception class with a parental consent form were assigned different numbers and randomly assigned to

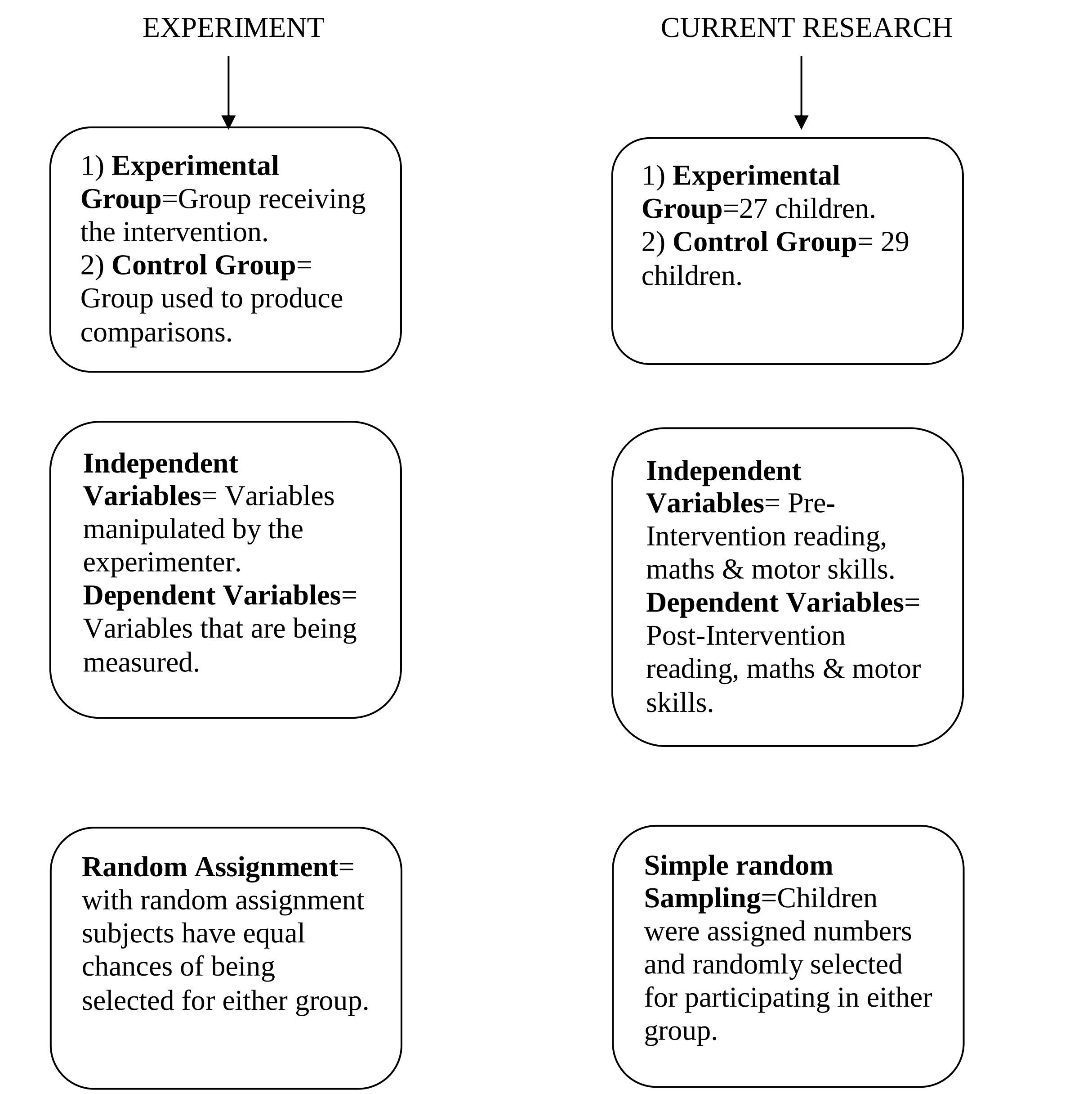
[5] Regression to the Mean: Statistical phenomenon that can make natural variation in repeated data look like real change. It usually happens when unusually large or small measurements tend to be followed by measurements that are closer to the mean (Barnett, VanDerPols & Dobson, 2005).

groups. The random assignment took place within each school. So the random selection took place by assigning pupils to either groups rather than whole classes. This type of randomisation is called; simple random sampling and is useful when there is a small to moderate sample size (Breakwell et al., 1995). The random allocation of children helps maximise the probability that children are as homogeneous as possible regarding variables such as background and environment and promotes fair comparisons between groups. With randomisation one of the main disadvantages of the between-subject design which is group differences, was decreased. The use of an experimental design and the random assignment of subjects to treatment and comparison groups provide valuable techniques for the isolation of the variables of interest and production of good answers to causal questions.

Since the experimental group received the same treatment, the idea of delivering the intervention in manageable groups of four to five emerged because in that way there would be time to administer the intervention with more children than on an individual basis. Furthermore, as reported earlier, during the pilot study one of the observations was that children tend to engage better in the activities while in a group rather than alone. Additionally, a meta-analysis comparing school-based interventions delivered either on a one-to-one basis or in a group showed that the effect size for the first was 0.45 whereas for the second 0.96 (Pless & Carlsson, 2000).

Another important characteristic of the intervention's design was the development of score-sheets that were used to measure the accuracy and speed of the children in the various tasks. These scores were recorded daily during the intervention in order to monitor children's performance on the various activities.

Overall, half of the children participating in the study received the intervention (27) and half did not (29). Both schools had roughly the same number of children in the intervention as well as in the control group. The intervention was delivered in groups of four or five children each time. Initially, in the first school there were two groups of five children and two groups of four children, although three children dropped out but near the end of the intervention. In the second school there were three groups of four children. In Figure 3.2 a graphic representation of the association between the main criteria of an experimental design and the criteria of the current research based on this design is provided. Following that the duration and length of the intervention are presented.



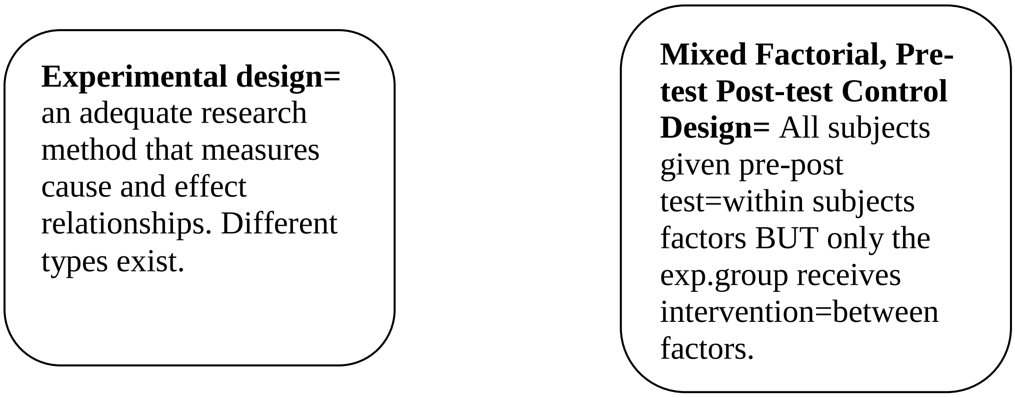


Figure 3.2: Association of experimental designs & current research

3.2.8. Duration & Length

The duration and the length of the intervention took into account previous research as well as developing specific criteria for the current research (Elbaum & Vaughn, 2001). Initially the intervention was set to be 12 weeks in duration and to take place two times per week for 20 minutes per group. Activities were set to progress and increase in difficulty level. After the first week's delivery of the intervention it was decided that the total duration would be 11 weeks. This change was based on the observations of the children's performance and manipulation of the different tools used. Children were taken out of class in different times on the school day to avoid missing out the same time. More specifically, children in the first school received the intervention in the school's library whereas children in the second school received the intervention in a spare nursery classroom. Most of the existing research measures the effects of the intervention over a minimum of a six-month period. But in the current study the frequency of the intervention per week had increased so the total duration was decreased. Another reason for the selection of the 11-week period was practical purposes, for the intervention to easily fit into one term of the school year. Additionally, there were ethical reasons. Since the intervention has never been applied before its effects were not tested. Therefore, since there was no prior positive evidence that the intervention works it was not considered ethical to deliver it for a longer time. Delivering a long lasting non-tested intervention might have negatively interfered with the children's academic performance. Another criterion affecting this decision was that the six month period usually takes place with atypically developing children. Thus it was expected that TDC will progress more rapidly to reach a level that enables them to function effectively. So, in order to control for ceiling effects in the current research the duration has been decreased. According to Elbaum and Vaughn (2001) the mean school-based intervention duration aiming in improving academic outcomes among others is between two to 32 weeks with a median of 10 weeks. Additionally, a systematic review by Riethmuller, Jones & Okely (2009) presented various motor skills interventions that their total duration ranged from six to 20 weeks and the intervention's length was between 30 minutes to one hour. Conclusively, children were receiving the MSI for the Early Years two times per week, for 11 weeks and each session lasted between 15 to 20 minutes per group. In the next section the assessment tests and outcome measures are presented.

3.2.9. Assessment Tools/Measures

Among others the selection of the measures was mainly based on three factors; first to include measures of both gross and fine motor skills for the motor development section, second to include academic measures that previous research has suggested that are improved during a MS intervention and third the measures to be appropriate for the selected age of the population.

For motor development the assessment tests used tapped both gross and fine motor skills. For the academic part information was derived from the related literature review. More specifically, previous research has documented significant gains in both reading and maths (Castelli et.al., 2007; Son & Meisels, 2006). On the other hand reading was selected instead of language mainly because of the age selection. Thus since the academic assessment test designed for that age was assessing reading and maths it was decided to investigate reading as the second cognitive measure.

3.2.9.1. Assessment Tools

Children in both the experimental and control group were individually assessed in their motor skills, reading and maths. For the purposes of the current study the motor development section of the Assessment Profile on Entry for Children and Toddlers (ASPECTS) has been used as well as the Performance Indicators in Primary Schools (PIPS) PE section. Also the baseline of the PIPS test has been used for assessing reading and maths.

3.2.9.1.1. Motor Development

The ASPECTS motor development section along with some motor activities from the PIPS PE test, measured children's motor development as a baseline measure. More specifically, ASPECTS measures both gross and fine motor skills such as: static balance, walking and finger moving. The ASPECTS test is a research-based assessment, with an internal reliability of a= .66. The motor development section of ASPECTS and the PIPS PE test include the following activities: bean bag catching, leg balance, throwing to target, finger painting, walking on a straight line, ball rolling, drawing trails and finger movements. The motor skills involved in the PIPS PE measure manual dexterity and ball skills whereas ASPECTS involved both fine and gross motor skills.

Each activity on the ASPECTS test had a maximum score. For example for the static balance task the maximum score that the children could receive was 30. Children had to stand for 15 seconds on one leg and repeat the same for the other leg. They were getting one point for every second the foot remained in the air and did not touch the floor up to 15 seconds for each leg. A total motor score was then calculated for the ASPECTS motor development section and compared against other children of a similar age. Similarly, for the PIPS PE test children had a maximum score for each task. At the end a total PIPS PE score was calculated.

More details regarding the motor development measures will follow on a later section describing the assessment procedure.

Both the motor development section of ASPECTS and the PIPS PE activities were used in combination, because ASPECTS is used for the ages of three to four years and since the sample included children from the age of four onwards some of the PIPS PE activities that are addressed to older children were included. Since the measures that were used from the PIPS PE had only been developed and tried with a sample of children rather than used on a wide basis and had not been previously tested for reliability and validity there was the need to establish both. The PIPS PE was selected because it had been developed for use with TDC by a movement specialist at Durham University, had been trialled with 35 reception children in 1997 and 47 reception children in 1998. Findings looked promising in terms of its suitability for the target population and the areas assessed were relevant with the ones that the intervention wanted to improve. In a later section the extra short study that took place to establish both reliability and validity will be presented.

For the above activities scores are recorded and analysed offering a comparison against children of the same age. The ASPECTS test is research based and has been developed at the Centre for Evaluation and Monitoring (CEM), Durham University.

It is acknowledged that other motor development tests such as; Movement ABC have established high reliability and validity and are widely used as measures of assessing motor skills. Two main reasons for not using such tests were: Firstly, special training is needed in order to obtain qualification for their delivery. Secondly, one of the main purposes of the current research was to develop a pragmatic intervention that could be delivered by teachers who would also assess the children. Therefore, the decision to use the tests presented was based on the research's time limitations as well as the fact that both ASPECTS (motor development section) and PIPS PE could be provided to teachers at a later time to assess the children. On the other hand, the limitations involved in using tests that have not established high reliability and validity are recognised and further suggestions are presented in Chapter Six.

3.2.9.1.2. Reading & Mathematics

Children were assessed on their reading and maths skills with PIPS on-entry baseline test. This is a computerized version for the reception class and it takes 15-20 minutes to complete per child. The PIPS test assesses early reading and maths and uses measures that research suggests are good indicators of later progress. The early reading score is derived from the sections of handwriting, picture vocabulary, ideas about reading, letter identification, word recognition and reading. The early maths score is derived from ideas about maths, counting, sums, digit identification, shape identification and maths problems. PIPS test has very high test/re-test reliability of 0.98 and it is ideally tailored to the child's ability at the start of school and the end of that first year (Tymms et al., 2000). The overall internal (Cronbach's alpha) reliability is 0.94 (Merrell & Bailey, 2008). More specifically the internal reliability for reading is 0.97 and for mathematics is 0.90 (CEM, 2012). There is no need for a trained professional to administer the PIPS on-entry baseline assessment. It can be administered by class teachers or other competent adults. The children were assessed in the beginning of the intervention in January, and then again at the end of the intervention in June and July to attain standardised scores.

The PIPS on-entry baseline assessment provides both a total score as well as scores in early reading, early maths and early phonics. In order to make comparisons between children and classes, children's raw scores are standardised on a nationally representative number of students doing the assessment the same year.

Both ASPECTS and PIPS are tests that have been developed by CEM and are widely used in schools worldwide (www.pipsproject.org). As a result CEM has the advantage of holding a large database with children's performance scores for further testing the connections between variables and also is able to provide comparisons against a large national sample. Both tests are easy to administer, provide a reliable objective monitoring, and are administered on an individual basis.

Dividing the assessment timing in these two periods increased the soundness of the intervention outcomes, measuring the effects of the actual intervention, hence better controlling for other factors that may affect the results. In the next section the intervention measures that were used to record the activities are presented.

3.2.10. Intervention Measures

Another decision concerning the intervention was the measures by which children's performance in the various activities would be recorded or monitored. These can be called intervention measures, since their purpose was to confirm that the intervention actually works and children do get better through the course of the intervention's delivery. Additionally, it provided information that could be used to qualitatively observe children's daily progress. The two measures that were selected were either accuracy, speed or both. More specifically, for all tasks except pegboards and buckets with rice, accuracy was measured and speed was measured for the; mazes, pegboards, play buttons and bucket with rice. For the above purpose a score-sheet was designed, including all activities and setting specific time limits for the timed activities. See Appendix 4. Each task had initially five trials, but after the delivery of the first session it was decided to have three, two, or one trial, depending on the task. This decision was taken based on the observations of children's performance. For the timed activities the first two sessions acted as a baseline to set the time limits of the relevant tasks. A higher score indicated a better performance. Both accuracy and speed are two measures that are usually used to record changes in motor performance, in experimental settings (Loeb, Brown & Cheng, 1999). Accuracy was measured with either right or wrong with one and zero respectively and speed involved timed activities that if exceeded maximum time were measured as zero if not were measured as one. There was also the time measurement on the mazes activity that different times corresponded to one, two and three with three being the maximum score. The intervention measures proved to be useful in monitoring the progress of the intervention. The next section presents in detail both the assessment stage and the intervention stage by providing details on the procedures followed in each.

3.2.11. Procedure

The first stage of the intervention was the assessment of all the children with the motor and academic measures.

3.2.11.1. Assessment Procedure

First the assessment of the academic skills took place on a one-to-one basis and took between 15 to 20 minutes to complete per pupil. The first day the researcher went to the school where the teachers introduced her to the children and handed the list of the reception children along with the returned consent forms. Following that the researcher was offered a room for the administration of the assessment and the intervention later. For the assessment a laptop with the PIPS programme installed was in place, as well as white A4 paper and pencils. Each child was taken from the class to the room where he/she was sitting down and was asked to write down his/her name. Following that the researcher told the child that he/she will need to listen to the computer voice telling him/her what to do. The researcher used the computer's mouse to record the responses made by the child. The programme monitors these responses and adjusts the assessment to the child to suit the achievement of the child. All the data were automatically saved on the hard disc drive of the computer. The PIPS test involves the following sections:

- Handwriting: The child writes his/her full name on a piece of paper and I select among five scores according to the quality of the handwriting.

- Picture Vocabulary: There are three different scenes. Depending on the child scores some or all of them will appear. The audio asks the child to point with his/her finger at the screen where the object is.
- Ideas about Reading: The child is shown one or two screens asked to point at the screen.
- Repeating Words (Phonics): The child is required to repeat some words with some of them being non-words.
- Rhyming Words (Phonics): The child is asked to identify up to nine rhyming words. The section begins with an introduction which includes examples with and without pictures. Both Phonics activities measure phonological awareness.
- Letters: The child is shown a number of letters and he/she is asked to identify them with either the sound or the name of the letter.
- Words: The child is asked to identify a series of written words.
- Sentences: If the child scores sufficiently on the words sections he/she will move to this section where he/she will be asked to read a series of sentences. The number of correct words is recorded.
- Walking to School and Cats: If the child scored sufficiently on the sentences section he//she proceed to this, where the child is asked to read a story and select the correct words from the available choices to complete the sentence. All of the above tasks measure early reading.
- Ideas about Maths: The section starts by asking the child to identify the biggest cat.
- Counting: The child is asked to count items on the screen and then say how many were there after they have disappeared.
- Sums A: The child is asked to do some subtractions and additions.
- Numbers: In this section the child is asked to identify a series of numbers.

- Shapes: The child is asked to recognize the correct shapes by pointing at the screen.
- Maths One (Mental Arithmetic): If the child scores sufficiently on the Sums A section, then he/she move on this section where he/she will need to answer a series of addition and subtraction problems.
- Sums B: If the child scores sufficiently on the Sums A they move to Sums B, which involves more difficult material such as sums that use formal mathematical symbols. All of the above tasks measure early maths.

After completing the PIPS test, the child was taken back to class to continue with the assessment of the next child. The assessment was carried out through the whole school day. Once the PIPS assessment was completed the motor development assessment started. As mentioned earlier the motor development of ASPECTS test and some tasks from the PIPS PE section were used. The tools needed to carry out the motor development assessment were; finger paints, finger painting templates, stopwatch, coloured masking tape, a football, bean bags, coloured paper, pencils and chalk. Children were taken from the class one by one to perform the motor tasks. The ASPECTS (motor development section) involved the following activities:

- Finger Movement: The child was asked to touch with his/her thumb each of his/her fingers in turn for both hands.
- Finger Painting: Children were presented with a balloon template and were asked to dip each finger at a time and make a fingerprint on the middle of each balloon. One finger per one balloon. Children were losing points if they did not use all their fingers or if the fingerprint was touching the balloon's borders.
- Balancing on one leg: The child was asked to stand still in one leg while he/she had his/her arms outstretched for a maximum of 15 seconds. The task was

repeated for the other leg as well and the activity was discontinued if the child wobbled or moved his/her foot a distance more than 30 centimetres (cm) from the original point. This task measured static balance.

- Walking: The child was asked to walk straight through two lines of three meters (m) long and 15cm width made by tape on the floor. While walking the child was told not to touch the lines. This task measured dynamic balance.
- Sending & Receiving: Two squares were marked on the floor. Each square was one square metre in size and three (m) apart. I kneeled in one box and the child kneeled outside the other. I rolled a football towards the box next to the child. To be a valid roll the ball should be inside the square. The child was asked to catch/stop the ball using their hands or arms. The next stage of this task was for the child to be inside the square and rolling the ball to me aiming for the ball to go inside the square. This task measured ball skills.

The other three tasks involved in the motor development section was part of the PIPS PE test:

- Catching: In this task there was a distance of two (m) between me and the child with two points marked on the floor. The child was asked to stand behind the marked point and the task was to catch the bean bag with both hands 10 times. This task measured ball skills.
- Throwing to Target: In this task the child had again a two (m) distance from the wall. Five papers were placed on the wall with different colours and the child was asked to slide the bean bag along the ground and try to hit the centre for a number of six times. This task measured ball skills.
- Drawing Trail: In this task children were given three different papers of drawing trails and a pencil. The task was to go with the pencil through the trail first from

right to left without touching the lines or take the pencil off of the page. In the second paper the child had to do the same by moving from left to right. In the third paper the child had to move from up-down and vice versa through the last drawing trail. Different pictures were at the two ends of the drawing trails and the number of mistakes was recorded. This task measured manual dexterity.

In all tasks children were given an example before performing the task by the researcher and in some tasks they also had the chance of one practise trial. Once both the cognitive and motor development assessment had been completed data were uploaded to the system for receiving the feedback. Afterwards children were assigned to either the experimental or the control group. The children's names were assigned numbers and they were randomly selected to participate in either group. Following this, children in the intervention group were further randomly divided to groups of four to five children.

3.2.11.2. Intervention Procedure

Each group was taken from class in specific times during each day and was guided to the designated room for the delivery of the intervention. Children were given detailed instructions and also a demonstration of each task that they were asked to repeat themselves afterwards. The investigator demonstrated each task once and the instructions that were provided to the children were standardised. Each child performed three trials of each skill and could achieve a total maximum score of three if all trials were successful or zero if all trials were unsuccessful. The first sessions were important for children to get familiar with the MSI for the Early Years and also for the researcher to get valuable feedback from their performance regarding the manipulation of the various tools. During the first session, in response to both observations and experiences, some changes were implemented. For example it became obvious from the start of the intervention that having children repeat each activity five times was a lot so this was decreased to three times. Although the intervention had already all the tasks designed and advancing in difficulty level over time, it was also flexible and some extra elements were added. An example is the acceleration of speed during clapping and hand/arm rotations. Children were encouraged to give maximum effort during the intervention's tasks and were also given explicit information on their performance and the areas that needed more attention in future sessions. This information was valuable for children's learning process. Flexibility of a school intervention is a characteristic that should be present in interventions considering the groups (Oliver & Smith, 2000).

3.2.11.3 Assessment Feedback

The MSI for the Early Years was administered in two schools with a time difference of approximately one month between them. This time difference was due to delays in the return of consent forms, but it was decided that this was not an important time difference, since it was thought that children's development would not have been significantly different, so data were later analysed together for both schools. Furthermore, based on the total sample number it was decided that it was better for the data analysis to take place together for both schools, since the sample was not large enough to be analysed separately for each school. Based on the sample size if the two schools were analysed separately the power would decrease. Since the analysis was based on a small sample the different range is an advantage. Moreover, based on the pragmatic nature of the intervention the fact that there was a range of schools was desirable since the intervention was applied across all levels of attainment. Conclusively, after careful consideration of the sample size and the time difference between the two schools it was decided that analysing both schools together would better represent the research's findings and would provide coherent information regarding the intervention's impact. Both schools received initial feedback of the pre and post intervention scores of the children in the automated format that was generated from CEM's system. The pre-intervention feedback involved raw scores for reading, maths and motor development. The first two measures provided also standardised scores, whereas the motor development scores were calculated in graphs in comparison with other children on a similar age. The graphs that were generated from the PIPS test included a bar graph that provided a graphical presentation of the children's standardised scores. The graph was useful to highlight unusual data that might have been more difficult to identify in a table format. Another graph (box-whisker plot) showed the spread of ability for reading and maths within the group. Both the scores and graphical representations were given to schools along with a PowerPoint Presentation which had useful information to help teachers interpret the data. A reading scale has been constructed from the first seven sections presented in section 3.2.11.1 (except the two phonics categories) and a mathematics scale from the remaining sections. The maximum scores were 195 for reading and 69 for mathematics.

The post-intervention feedback included raw scores for reading, maths and motor development along with the pre-assessment scores for comparisons. For PIPS separate line graphs were produced for reading and maths for each intake term. These graphs showed the progress made by individual pupils and by the whole class in comparison with the national average. Furthermore, scatter plots were generated which contained the pupil's baseline standardised total scores against their follow-up assessment scores. There were additionally two box and whisker plots on the chart. One showed the distribution on baseline level for the total class scores and the other the distribution of the follow-up assessment scores. Children's progress based on the above feedback will be described in more detail in the results section.

At the end of the intervention and after the completion of the assessments the schools received a "Thank you" letter, the manual of the MSI for the Early Years and a set of detailed instructions accompanying the manual. Later on, the schools received the results of the intervention's effectiveness as well as a Poster Presentation, designed for the Developmental Section Annual Conference of the British Psychological Society (BPS) (Katsipataki, 2011) which offered a summary of the research at this point; See Appendix 5. Both the detailed manual with photos and text describing the activities and the instructions were provided as a measure of controlling and "monitoring" the intervention's delivery by others. Additionally, the researcher's contact details were provided if the school or teachers needed any help in their own attempt to deliver the intervention. The next section describes the process of data collection.

3.2.12. Data Collection

The process of data collection began before the start of the intervention, and continued beyond its completion. Data were automatically collected for each child for their reading and maths scores through the computerized version of the PIPS test. Once the assessment was completed, the researcher's task was to upload the children's files to CEM's website in order to receive feedback of both raw and standardised scores for every individual child. These standardised scores were derived from a larger sample of schools in England. The schools were a mixture of state and independent schools, with 1033 schools registered to use the computer-delivered version of the PIPS on-entry baseline and follow-up assessment in the 2010/2011 academic year. For the purposes of the current intervention study it did not matter whether the sample was nationally representative because the comparisons were between the intervention and control group rather than progress against national norms. For the motor development section individual scores were manually entered on the ASPECTS programme and then uploaded to receive the same feedback, with the exception of PIPS PE scores, which were entered on an Excel worksheet and then added to the database that was created using the Statistical Package for the Social Sciences (SPSS). Another Excel worksheet that included the daily observations of the score sheets that measured accuracy and speed was also created and updated daily; see Appendix 4. After the completion of the post-assessment the same procedure was followed for post-assessment scores, following the production of the final database with all the measures from both schools. The next step was analysing the data, which will be described in the next Chapter.

3.2.13. Extra Data Collection for Short-Term Assessment Study

After finishing the data collection for the main study, there was a need to establish test-retest reliability and validity for the PIPS PE measures, therefore a short study which involved further assessment for this purpose was undertaken. Once, Ethics approval for the additional short study was granted the researcher contacted schools to seek their participation. Both schools that had participated in the main study agreed to be part of the assessment study as well. The next step was to obtain consent from the children's parents and teachers.

Once the forms were returned the first stage of the assessment started to investigate test-retest reliability using Pearson's r between time one and time two where the children were assessed. The goal was to assess all children on the three PIPS PE measures namely; drawing trail, throwing to target and catching. The sample consisted of 28 reception class children with 15 girls and 13 boys. Children were taken from class individually and were assessed on the three motor skills measures. The duration of assessment for each child was less than ten minutes. As mentioned earlier the tasks targeted manual dexterity and ball skills. When all children were assessed (time one) a time interval of one week was provided before returning for re-testing the children. Following that, the children were reassessed (time two) on all three measures and data collection for test-retest reliability was completed. In order to control for researcher's bias and expectations for performance, the scores of the children were not summed up and calculated until the re-test period of the second phase.

In order to obtain validity of the measures the motor scores that were collected were compared against the physical development section scores of the Early Years Foundation Stage Profile (EYFSP). The EYFSP is the statutory assessment requirement for children in the Foundation stage between the ages of three to five years. The goals of EYFSP for children's physical development include the practise of fine and gross motor skills, bodily awareness and personal needs for health and safety (Department for Education and Employment, 1999). According to the National Curriculum for Physical Education children are expected to progress in four aspects within the key stages namely; "acquiring and developing skills, selecting and applying skills and tactics, evaluating and improving performance and having knowledge and understanding of fitness and health" (Doherty & Bailey, 2003). The school provided the EYFSP physical scores of all reception children who participated in the extra data collection. In the section that follows issues regarding the reliability and the validity of the whole study are discussed.

3.2.14. Reliability & Validity Issues

Reliability can be defined as the consistency of the effects of the experiment (Breakwell, et al., 1995). Reliability is usually established by replication. If the results of the study remain the same when the study is replicated, then it is said to be reliable. Replication of results should be achieved on more than one occasion and also by using different samples to the original experiment. But researchers usually do not replicate their own studies, so reliability is mostly established by other researchers replicating the study on a later time. Reliability can also be improved by minimizing external sources of variation, standardise and control the conditions under which data collection takes place (Breakwell, et al., 1995). The above characteristics are important in an experiment's reliability.

In relation to the reliability of the assessments that are used in the current study reading and maths scores were measured using PIPS, which as mentioned earlier has high test/re-test reliability for baseline measures 0.98 (from 0 to 1). The test/re-test reliability was established by performing a correlation between an assessment on one occasion and a re-test on a second occasion approximately two weeks after the first. Also the second assessment was conducted by a researcher rather than school staff. The internal reliability (Cronbach's alpha) is 0.94 for the full scale. Cronbach's alpha is defined as "an index of reliability associated with the variation accounted for by the true score of the underlying construct". Construct is the hypothetical variable that is being measured (Santos, 1999). The higher the score the more reliable the generated scale is.

Validity on the other hand refers to the degree that a study measures what it is supposed to measure (Breakwell et al., 1995). Some ways to achieve experimental validity is by careful sampling, ensure on providing clear instructions, avoiding having too long time interval between pre-test/post-test and use appropriate statistical treatments of the data (Cohen et al., 2007). In the current research children were randomly selected and assigned to groups. Clear instructions were given and also a detailed manual of the intervention was developed to increase the intervention's clarity and replicability. Additionally, the design involved pre-test/post-test which took place without long time intervals between each stage. Based to the aforementioned criteria the current study can be characterized as having established the validity prerequisites. In the next section some of the experienced difficulties during data collection will be discussed.

3.2.15. Difficulties Experienced During Data Collection

Research that is performed in a real environmental setting and specifically in a school setting is prone to more difficulties compared to research that is conducted in a well-controlled lab setting. One of the difficulties was the delay of the parents to return the consent forms, resulting in changes in the intervention's timeline. In order to overcome this difficulty and retain the original timeline the researcher was spending the whole school day individually assessing children to complete the assessment stage on time and compensate for the initial delay.

Another problem that was experienced was the frequent absence of some children in the intervention group. This problem had possibly a negative effect to the children's progress in relation with their peers. Additionally, their absence might have also affected their performance in the post-assessment measures of cognitive and motor skills. Unfortunately, absence from school is a problem that educational research usually faces and no actions can be taken to solve it. A possible solution to this problem is a larger sample in order to compensate for the absent children but in the current research given the practical restrictions (one researcher available) this problem could not be solved.

An additional problem was that some intervention days were missed due to bank holidays or the schools' visits to museums. This problem was solved by visiting the schools another day, therefore keeping the number of sessions as initially planned.

Overall, these were the main difficulties that were experienced during the data collection stage but solutions were found for the majority of the exigencies of the current research environment. In the section to follow a summary of the chapter's main points is provided.

3.3. SUMMARY OF MAIN POINTS

This chapter described the steps followed before and after developing the MSI for the Early Years, as well as the main features of the design of the research. Also the MSI for the Early Years has been described in detail. The present research was developed by; using criteria from the experimental method, based on previous literature to create some of the tools and activities, but also introducing new tools and activities as well as different combinations of using tools as part of the intervention. One of the main goals of this research was to design a pragmatic intervention that can be easily applied in the school setting and addressed to children in the early years. The current intervention was delivered by a researcher who provided a detailed manual with visual information (photos) along with instructions to be easily replicable and monitor the therapy's standards. Some motor interventions and programmes need to be delivered by a trained specialist, while others can be delivered by either school teachers or researchers like the current one (Riethmuller, Jones & Okely, 2009; Sugden & Chambers, 2003). It is true that in many cases an intervention needs to be applied by a trained professional, but under the careful guidance of a specialist teachers or parents who see the child on a daily basis can have the role of "coaching" their children's development (Sugden & Chambers, 2005).

With this in mind the current intervention mainly combined simple tools and activities that can be found in the school setting, but that have not been used before in such combinations and patterns. Another focal point was that the intervention was planned for TDC, thus exploring the trends that exist in the mainstream. This characteristic is of great importance since introducing an intervention with potential benefits on the performance of children in mainstream schools can act as a preventative "measure" on difficulties in later years. Performing research in an educational setting is challenging and demands a well-planned design. The current research was a mixed factorial pre-test post-test control design

(Keppel, 1991). Children were randomly selected and assigned to either experimental or control group while all children were assessed both before and after the intervention. With the above design better control of confounding variables was achieved and also a more reliable documentation of the intervention's effectiveness. The total duration of the intervention was 11 weeks with each school receiving the intervention twice a week and each session lasting 15 to 20 minutes. After the intervention's and assessment's completion schools received a detailed manual of the MSI for the early years which they could use on a later time. An additional stage of the research was a first attempt to establish test-retest reliability and validity of the three PIPS PE measures. Following the end of data collection the next step was the analysis of the data to investigate the effects of the intervention. Information regarding the data analysis will be provided in the next chapter.

CHAPTER 4

DATA ANALYSIS

4.1. Introduction

The previous Chapter provided a detailed description of all the methods and steps involved in designing the MSI for the Early Years. After the completion of the data collection the next step was to analyse them. The present Chapter serves as a connecting link between the previous chapter on the methodology of the research and the next Chapter on the results of the research, and explains the rationale underpinning the data analysis. Additionally, it provides descriptions of the tests used.

4.2. Analysing CEM Data

In addition to the data collected by the researcher from the schools involved in the intervention study, a large database with longitudinal data from schools which are registered to use ASPECTS and PIPS assessments is held at CEM and was analysed as part of the current research in order to further investigate the relationship between early year's motor skills (both fine and gross motor skills) and academic skills such as; language and maths. The analysis of this database was useful in all the stages since it informed the current research and provided the rationale for the intervention. Initially, the databases had to be transformed in order to be analysed more efficiently due to their high volume. After some initial transformations (such as splitting the data into different files by year of assessment; splitting by gender; merging the files to match longitudinal data for each child; and deleting some variables that were not of interest) the first analysis started. Initially descriptive statistics were provided followed by correlational data. The next step was performing multilevel modelling. The multilevel models were used to inquire into the relationship of a set of variables that are measured at a number of different levels of a hierarchy, for example at a school or a class level (Pinheiro & Bates, 2000). The main advantage of this statistical test is that it takes into consideration the variations within the data being analysed. Multilevel modelling is also used to eliminate problems that arise from performing single-level analysis; such as oversimplifications and biased precision estimates (Hox & Kreft, 1994). Another strength of the multilevel modelling analysis is that is controls clustering which usually occurs in school environments (Goldstein, 1995). For performing multilevel model analysis the longitudinal ASPECTS data were used. The analysis involved two levels: students within schools. An important parameter that needs to be present when analysing data with this method is a high number of schools and students. For example for a two-level analysis the best scenario is that there are 25 schools or more. This criterion was met in this study. This analysis provided a contextual rationale for the actions and decisions of the current research. The statistical programme that was used for performing multilevel analysis was the MLwiN version 2.1 which has been developed by the Centre for Multilevel Modelling of Bristol University (Rasbash, Chalton, Browne, Healy & Cameron, 2009).

4.3. Analysing the Data of the Study

The above study is mainly characterised as quantitative research but it also entailed a smaller qualitative component. There are two main categories of research; quantitative and qualitative. Quantitative research involves the interpretation of data in numerical terms using statistical tests. Data are usually collected using standardised tests. This standardisation is in terms of their administration rather than standardising the scores using a representative sample (Merrell, 2012). The standardisation of assessment tests ensures that all individuals have been assessed in the same way referring to the assessment's content, scoring and interpretation. Hence, standardised assessments enable researchers to make comparisons between individuals or groups. Qualitative research involves the interpretation of data in terms of the participants, observations, categories or themes. Data are usually collected through the use of interviews and observations and cannot be transformed to numbers (Cohen et al., 2007). Sometimes they can be transformed to numerical scores but sometimes this is not meaningful. The reason is that it is not always easy to convert qualitative data to quantitative. Some of the risks involved are: researcher's bias in producing categories, difficulties in coding qualitative information and lack of collecting information in a coherent systematic way for having a valid sample for later statistical analysis. Having quantitative data the researcher is able to generalize and be more objective. On the other hand qualitative data provide detailed descriptions of the phenomena under study. Additionally, qualitative data provide rich information about context that numerical data cannot necessarily achieve. There is a strong debate on whether one research method is better than the other, but both methods provide research with valuable information giving different perspectives (Morgan, 1998). So, the use of mixed methods can be an alternative approach. By using mixed methods the researcher can draw from the strengths of both quantitative and qualitative approaches, and at the same time minimize the possible limitations of using one approach. Hence the researcher can benefit from the richness and depth that the qualitative data offer as well as using quantitative data which offer the advantage of generalisation. Mixed methods can be defined as the "class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" (Johnson & Onwuegbuzie, 2004).

Given the design of the current research, the quantitative approach was considered more efficient to obtain more generalisable outcomes whereas the qualitative aspect provided useful insight information and observations regarding the intervention. Hence the current research can be characterised as mixed methods research, although the qualitative component was not as extensive as the quantitative, and consisted of observations made by the researcher. The combination of both approaches offers a more complete approach than single method studies. For example adding observations to the statistical findings can provide important insights that could have otherwise been missed (Johnson & Onwuegbuzie, 2004).

Regarding the assessment process, the scores from children's performance (PIPS-on-entry baseline and ASPECTS scores) were held electronically within the assessment programme. After the completion of the assessment, scores were uploaded through a secure online system to CEM's database and processed to return raw scores and standardised scores. These scores were then entered in the Statistical Package for Social Sciences (SPSS) version 17 for further comparative analysis. Additionally, after the intervention had commenced, daily intervention-scores (on the measures of accuracy and speed) were kept for every activity and child. The scores were entered in a spread sheet of Microsoft Office Excel on a daily basis to have a secure back up and then these scores were also entered in SPSS.

For the quantitative part of the research, the data were also analysed using an Effect Size Calculator (Coe, 1999). After entering all data into SPSS some initial analysis started. Data were parametric, since normal distribution was assumed, which is usual for experimental studies. In order to verify this assumption, normality tests were performed on the variables within the sample. Parametric data are generally characterised by greater statistical power than non-parametric. Non-parametric data do not assume a normal distribution and are usually used with ranking data (Field, 2005). Both descriptive and inferential statistics were calculated. Descriptive statistics are used to describe the data; for example the mean is a descriptive statistic, which provides an estimate of the population from which the sample was selected. Inferential statistics are used to predict relationships between experimental variables (Cohen et al., 2007). For example a t-test is an inferential statistic which is used to measure the differences between two groups. Effect sizes were calculated using an effect size calculator. The effect size calculator is based on the following formula; *Cohen's d* = $M1 - M2 \div SDpooled.$ So instead of using this formula to calculate effect sizes by hand, an effect size calculator in Microsoft Excel was used. Effect sizes are usually applied to either replace or accompany statistical significance. The effect size is a standardised measure of the treatment's effectiveness and it is commonly used in educational research (Cohen et al., 2007). In the present study effect sizes were used to accompany statistical tests, since statistical significance among other factors depends on the sample size. Additionally, effect sizes were used to document the amount of change between measurement points for different groups. Namely the inferential tests that were used were; linear regressions, independent t-tests, one sample t-tests for calculating confidence intervals, multilevel modelling and correlations. All of the above statistical tests that were used to analyse the data were carefully selected to reflect the research's effects to the maximum and will be described in the results section.

For the qualitative component, a research diary was kept. The diary was used to examine the application and operation of the intervention, to observe children's attitudes and behaviours towards the various aspects of the intervention, to observe improvements and possible difficulties over the course of the intervention's delivery, and to ultimately use the above information in order to make any necessary modifications throughout the course of the intervention. The research diary mainly included the deviations from the original intervention (Appendix 7- Qualitative Research Diary). In addition to the intervention study data, more data were analysed that provided the contextual rationale of the current research.

4.4. Analysing the Reliability & Validity of the Intervention Assessment Measures

In addition to the aforementioned analysis, a short study to investigate the test-retest reliability and validity of the PIPS PE measures was performed. The PIPS PE measures have not established any scores of reliability or validity in the past; hence this was the first attempt to provide some initial scores that can inform future research and potentially being used to perform amendments. The short-study involved testing reception children on the three PIPS

PE measures and re-testing them again after an interval of one week. Correlations were calculated using SPSS. Additionally for investigating the validity of the PIPS PE, the children's scores on the physical section of the Early Years Foundation Stage Profile (EYFSP) were compared against the different measures of their PIPS PE scores using correlations. Additionally, the distributions of scores were plotted in order to evidence the range of scores. It should be mentioned that the EYFSP does not have any established figures for either reliability or validity.

The next Chapter provides an extensive presentation of the findings that were produced from the data analysis. Additionally, some initial interpretations of the results are discussed along with some interesting anecdotal observations.

CHAPTER 5

RESULTS OF THE STUDY

5.1. Introduction

This Chapter can be divided in six sections: The first section describes an analysis of longitudinal data collected by CEM which provided a basis for the research's expectations. The second describes the feedback derived from the children's assessment scores which comprises simple total scores and comparisons. The third section describes the analysis of the descriptive and inferential statistics. The fourth, describes the analysis performed on the intervention scores that were recorded daily during the intervention's application. The fifth section describes the qualitative part of the research. Finally, the sixth section describes the test-retest reliability short study. All of these sections are further divided according to the different measures of the study and the chapter concludes with a summary of the major findings.

5.2. CEM Database

In order to inform the current research data that were held at CEM were analysed by performing correlations and multilevel modelling analysis. Correlational longitudinal data revealed that motor development is highly correlated with academic skills such as, language in children from nursery until the end of primary school. Furthermore, multilevel modelling analysis showed that scores of motor development in the start of the academic year successfully predict language and maths performance at the end. Also, the analysis showed that motor development remains a strong predictor of language and maths performance over time as well as personal social and emotional development (PSED) for the years between 2004 and 2010.

5.2.1. Correlational Analysis

As mentioned earlier CEM is a non-profit organisation which is considered to be one of the largest independent providers of educational monitoring systems worldwide. CEM holds a large database of data on different measures such as language, maths, and motor skills that start from preschool and continue all the way to primary school years. Before the start and development of the intervention some of these data were analysed to provide a first grasp of evidence on the relationship between motor and academic performance. There was a large database holding data from the ASPECTS test[6]. As mentioned earlier ASPECTS provides age-related feedback. The database held data starting for cohorts of children from the academic year of 2003 until 2010. The analysis used data from the ASPECTS database of children's scores at the start of nursery. Data were derived from 878 schools in the United Kingdom including 122,838 children. Among this sample 65,000 were boys and 57,838 were girls. The mean assessment age was three years and eight months. Correlations were calculated for ASPECTS raw data revealing statistically significant correlations between language/maths and motor development $r = .41$ when controlling for age. The language and maths score was a single score for both areas of development. Also the correlation between maths and motor development was $r = .37$, indicating a positive relationship between these two measures. All correlations were statistically significant at the 0.01 level. Furthermore, there was no difference in the correlations between the measures for boys compared with girls. These initial findings suggested that motor performance is related with academic skills. These correlations were performed for the data obtained from the ASPECTS test rather than PIPS due to the fact that many of the PIPS data were not on a computerized form but on a paper feedback.

[6] ASPECTS: Language, maths & motor development. ASPECTS: computer delivered like PIPS & includes many of the same areas of development but at an easier level since it is aimed at younger children.
PSED: Assessed based on the practitioner's observations of their children followed by entering the scores into the program by an adult & returned to CEM.

5.2.2. Multilevel Modelling Analysis

The second analysis was performed on the ASPECTS database using multilevel modelling. Initially, the data were divided by each academic year. The academic years that had sufficient data to be included ranged from 2004 to 2010. Only the entries that had a 100% completeness of motor development (MD) were included in the analysis. The motor development section was an optional test so not all schools did it, but also if they did decide to use it there was the option to assess children with just two of the sections to check for poor development rather than to complete the full battery. Thus 100% refers to the number of schools that have assessed their pupils with the full battery. The ASPECTS database before excluding the cases with incomplete MD scores had 83,740 children whereas after the deletion the number of children decreased to 13,970. This decrease means that a large number of schools have not assessed children's MD. It might be the case that schools were assessing MD only to children who had MD problems. This tendency results in difficulties establishing baseline measures for children's motor development progress in the mainstream. The mean scores for language and maths were compared for the sample of 100% MD and the rest. The mean score for language and maths for the sample with 100% MD was 48 and for the sample without 100% MD was 28 with a maximum mean score of 82. The standard deviations were 14.29 and 15.95 for each group respectively. Once the files were created (one file for each academic year) the analysis took place. For the purposes of the current analysis, it was hypothesized that the importance of MD would remain stable over the academic years. Two analyses were performed. Firstly the analysis investigated the effects of MD, PSED, sex and gender to language and maths in the start of nursery over the academic years (2004-2010). The second analysis examined the predictive ability of MD and PSED on language and maths at the end of the nursery after controlling for language and maths development at the start of nursery for each academic year. Two-level (the student and the school) multilevel modelling analysis was conducted. From this analysis several models were created for each academic year.

A selection of these models will be presented here, based on the criterion of relevance with the current research and the more interesting observations obtained from the models. One model for each analysis will be presented. The other models for both analyses can be found in Appendix 6.

In the first analysis the effect of several controlling variables on language and maths at the start of nursery was investigated. More specifically, the research question explored to what extent do the controlling variables vary over the years? A careful examination of the models produced for each academic year revealed that MD and PSED continue to influence language and maths development over the years showing a stable pattern starting from 2004 in the start of nursery and continue until 2010. Table 5.1 represents a two level model (school and pupil level) that documents the above pattern, and has been selected to represent this relationship. This two level structure was selected since the focus of interest is the school performance and repeated measurements of this take place by assessing student performance for multiple students from each school.

Table 5.1

2008 Multilevel Models on the Effects of Controlling Variables on Language & Maths at the Start of Nursery

	NULL		**Model 1**		**Model 2**		**Model 3**		**Model 4**	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects										
Constant	0.088	0.094								
Age			0.209	0.002	0.210	0.002	0.130	0.006	0.081	0.007
Sex			0.081	0.007	0.056	0.016	0.012	0.015	0.045	0.016
MD							0.376	0.026	0.159	0.029
PSED									0.468	0.028
Random Effects										
School Level	0.484	0.096	0.062	0.012	0.061	0.012	0.046	0.009	0.027	0.006
Pupil Level	0.641	0.023	0.094	0.003	0.093	0.003	0.083	0.003	0.066	0.003

In Table 5.1 the constant coefficient is 0.088 (0.094), while age shows a coefficient of 0.209 (0.002). If we then look at the variance of intercept at a school level: 0.062 (0.012), it can be suggested that even after age is controlled the explained variance significantly decreases.

The same pattern is followed at a pupil level with a smaller decrease 0.094 (0.003). When the variable of sex is added to the second model the coefficient of age remains almost the same 0.210 (0.002), while age is still being a significant controlling variable. The coefficient of age does decrease when motor development (MD) is added in the model 0.130 (0.006), suggesting that MD can account for a variance in age. Also when PSED is added to the model, age decreases to 0.081 (0.007). As it is evident from Table 5.1 age becomes less important as further variables are added to the model but it remains a significant factor.

The sex variable also seems to be a significant variable influencing language and maths, since the coefficient is more than twice as large as the standard error. More specifically, mean scores suggest that boys perform slightly better than girls with a mean score of 29 (13.86) against a mean score of 27 (14.66) for girls which is not significant. For the variables of MD and PSED the same effects are documented with a decrease on the variance that needs to be explained after the introduction of MD 0.376 (0.026) and PSED 0.486 (0.028) and the variance of intercept at a school level being: 0.009 (0.027) and 0.027 (0.006) respectively. Another interesting observation is that when PSED is added the fourth model the coefficient of MD decreases to 0.159 (0.029), suggesting that PSED accounts for some of the variance in language and maths in the start of nursery. Additionally MD and PSED show similar decreased variances of intercept for the pupil level; 0.083 (0.003) and 0.066 (0.003) respectively.

From the above findings it can be inferred that age, MD and PSED are significantly associated with language and maths performance at the start of nursery, since the unexplained variance at the school and pupil level decreased when these variables were added to the model. Additionally, by observing the models that were created from 2004 until 2010, it can be concluded that there were minor variations on the extent that MD and PSED act as controls on language and maths. Hence cross-sectional data on MD and PSED continued to be significant factors on children performance in language and maths over a period of six years. This finding appears to have important implications in considering possible factors that influence children’s academic performance. Additionally, it comes in accordance with the literature supporting this relationship in which the current thesis was based upon.

In the next table the results from the second analysis are presented. As a reminder; the second analysis investigated the predictive ability of MD and PSED on language and maths at the end of nursery after controlling for language and maths in the start of nursery. Table 5.2 represents the analysis that took place on two levels being; school and pupil level.

Table 5.2

2008 Multilevel Models of Progress at the End of Nursery

	NULL		**Model 1**		**Model 2**		**Model 3**		**Model4**
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est. (SE)
Fixed Effects									
Constant	0.030	0.127							
Start of Nursery			0.904	0.015	0.904	0.015	0.670	0.036	0.486 0.050
Sex			-0.055	0.057	0.039	0.029	0.081	0.03	
MD					0.876	0.018	0.410	0.048	
PSED							0.566	0.048	
Random Effects									
School Level	0.486	0.130	0.487	0.130	0.163	0.043	0.116	0.034	
Pupil Level	0.639	0.031	0.638	0.031	0.170	0.008	0.115	0.007	

In Table 5.2 the progress of children at the end of Nursery has been analysed by controlling the start of nursery performance in language and maths for the year of 2008. The table shows that the start of nursery language and maths significantly affects the end of nursery scores and it continues to be significant although decreasing after the variables of sex, motor development and personal and emotional development are added into the model. As the table shows when the constant is 0.030 (0.127) and language and maths in the start of nursery is controlled then sex has a coefficient of -0.055 (0.057) and the variance intercept for the school level is 0.487 (0.130) and pupil level 0.638 (0.031) suggesting that after sex is controlled the variance to be explained does not show any significant decreases. On the fixed effects when the start of nursery motor development was added to the model there is an increase to the coefficient of sex to 0.039 (0.029) but it is not significant. From the above it can be inferred that having controlled for language and maths at the start of nursery, sex was not a significant influence on the end of year performance. Hence although differences appear to exist between the two sexes they cannot be accounted as significant for progress. On the contrary, when the variables of MD 0.876 (0.018) and PSED 0.566 (0.048) are added to the model the variance to be explained shows significant decreases in both the school 0.163 (0.043) 0.116 (0.034), and pupil level 0.17 (0.008) 0.115 (0.007) respectively, suggesting that both MD and PSED at the start of nursery are strong predictors of later language and maths performance at the end of nursery. Also when the start of nursery PSED is added to the model the sex variance shows an increase, 0.081 (0.030) and the motor development as well, 0.410 (0.048). This change in variance suggests that the children's PSED in the start of nursery is related with the changes at the end of nursery.

Both analyses provided useful insights in the investigation of the potential effects of motor development to academic skills such as language and maths. Additionally, the PSED variable has been proven to have a significant impact on children's performance which is a finding that should be investigated more thoroughly. A recent study performed with data that derived from CEM investigated the strength of PSED on predicting achievement on the early years. Findings revealed that PSED was statistically significant on predicting reading and maths achievement in four years of age. Additionally, this relationship was still strong until the age of seven years old (Merrell, 2012). Overall, multilevel analysis showed that motor development, which is the main variable of interest for the present study, continues to have an important influence on academic performance in children attending nurseries in England over a period of six years. This finding has important implications for educational policies that will be further presented in the Discussion Chapter.

In the next section the pre-intervention assessment data will be presented. These data were comprised of the scores of children in measures of motor skills (ASPECTS, PIPS PE), reading and maths (PIPS on-entry baseline) as they were collected by CEM's electronic system.

5.3. Pre-Intervention Assessment Data

As mentioned in the methodology section, after the completion of the assessment before the start of the intervention, scores were uploaded to the secure CEM website and feedback was generated. The feedback included both raw and standardised data as well as graphical representations of the children's standardised scores and spread of ability for reading and maths. Furthermore, raw scores and graphs representing the children's performance against their age were reproduced for the motor development section. Figures 5.1 and 5.2 provide the standardised plots of the scores baseline PIPS scores of the experimental and control group respectively. These are t-scores with a mean of 50 and a standard deviation of 10 and are based on both schools that were involved in the study together. Each circle represents one child and each set of scores is covered by a box and whisker plot.

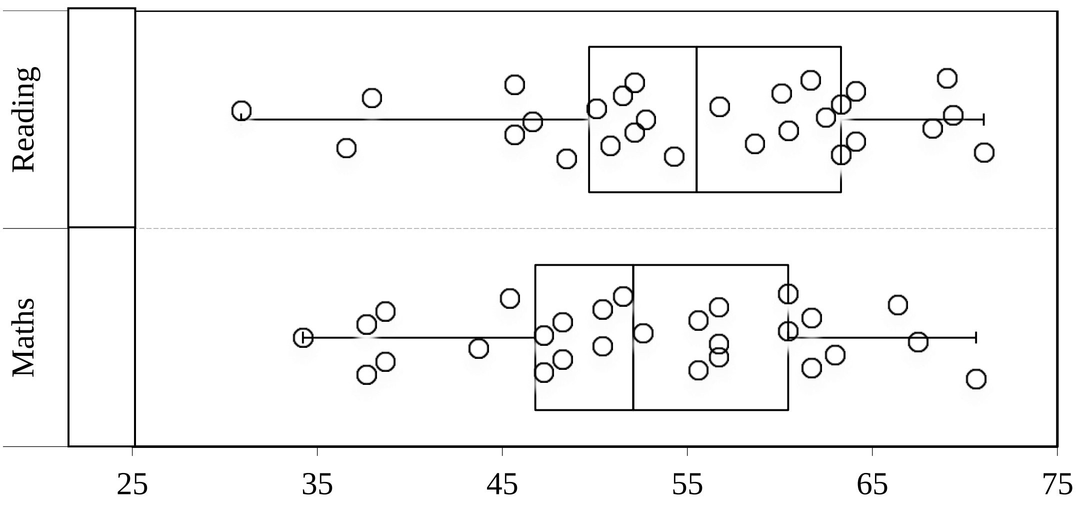


Figure 5.1: Pre-Intervention Scores of Experimental Group

Both boxes represent the spread of ability within the control and experimental groups in early reading and maths. The left whisker of the chart holds 25% of the children in the class. The box holds the next 50% and the right whisker holds the final 25%. The line in the middle represents the middle score (median). Figure 5.1 shows that the spread of ability is greater for reading than maths in the experimental group.

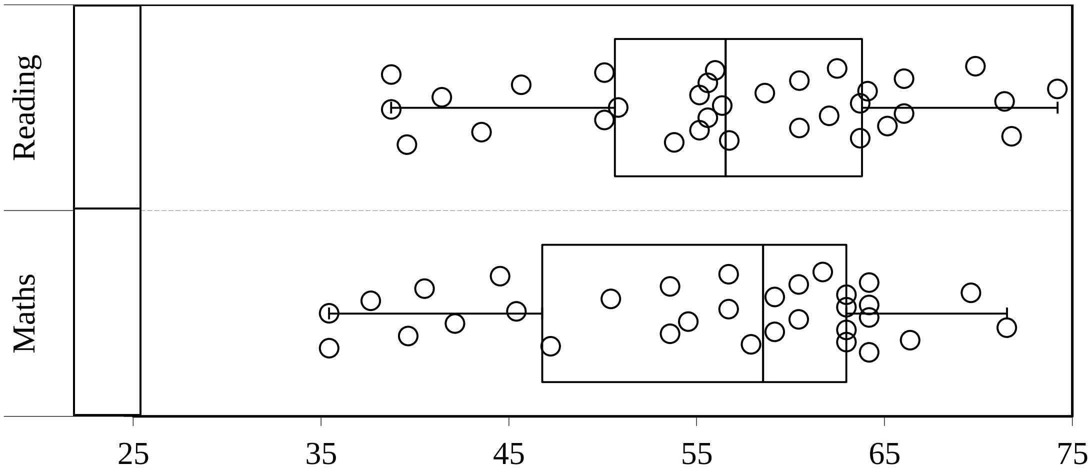


Figure 5.2: Pre-Intervention Scores of Control Group

Figure 5.2 shows that the spread of ability in the control group is greater for maths than reading. The present figures represent both schools and have been divided to either experimental or control groups, whereas schools received individualised plots representing all the children that were assessed in the reception classes. To further investigate the significance of the obtained spread of ability before the intervention, plots with 95% confidence intervals (CI) error bars were produced. Figures 5.3 and 5.4 represent the standardised mean performances of both groups before the intervention in the measures of reading and maths respectively. The scores in the current research have been standardised rather than the full PIPS sample having a mean of zero and a standard deviation of one. In order to investigate if there were significant mean differences between the groups before their intervention one sample T-tests were used. A one sample T-test showed that the differences in mean scores between the experimental and control group for both reading and maths were not significant. More specifically for the experimental group in reading t (26) = .274, *p*=.786, 95% CI [-.32, .42] and the control t (28) = -.239, *p*=.813, 95% CI [-.44, .35].

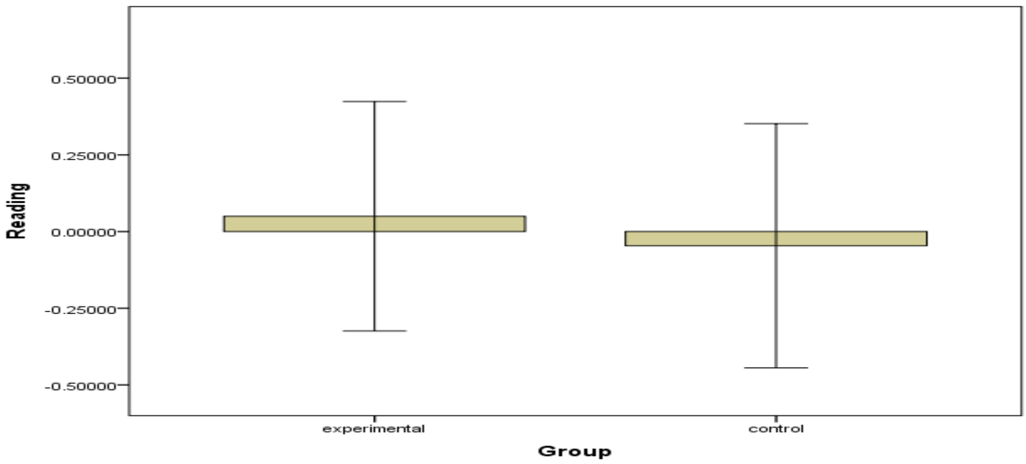


Figure 5.3: Standardised Mean Scores on Reading

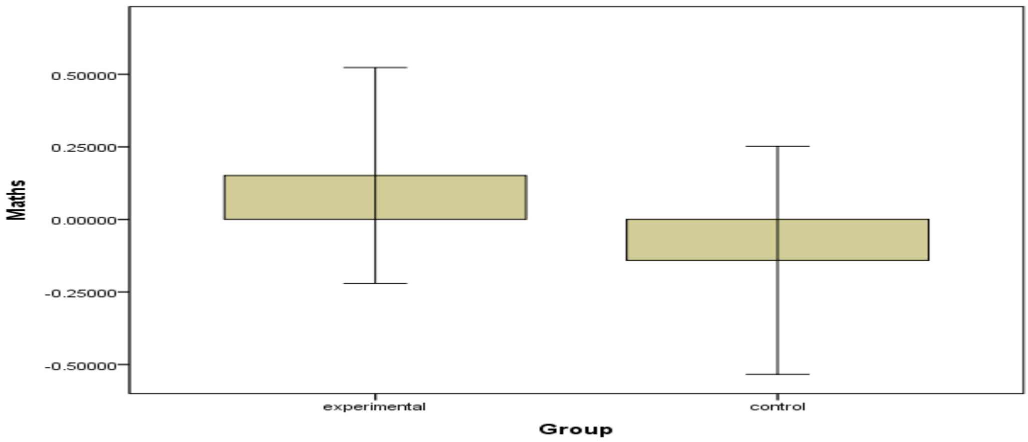


Figure 5.4: Standardised Mean Scores on Maths

Similarly the mean score differences in maths were not significant with the experimental group reporting t (26) =.836, *p*=.411, 95% CI [-.22, .52] and the control t (28) =-.735, *p*=.468, 95% CI [-.53, .25].

It is obvious as well from both figures that the error bars overlap. When the error bars overlap it can be concluded that the obtained difference in the mean performance difference between the groups is not significant. This applies both for reading and maths.

The pre-assessment feedback provided the schools and teachers with a first view of the children's progress in the measures of reading, maths and motor development in relation to their peers.

For performing the quantitative data analysis, children from both participating schools were treated as one group and further divided to experimental or control. It is interesting to view the pre-intervention differences between the two schools for both reading and maths. In Figure 5.5 the scores of the experimental group can be viewed with the dark grey dots representing one school and the light grey dots the other.

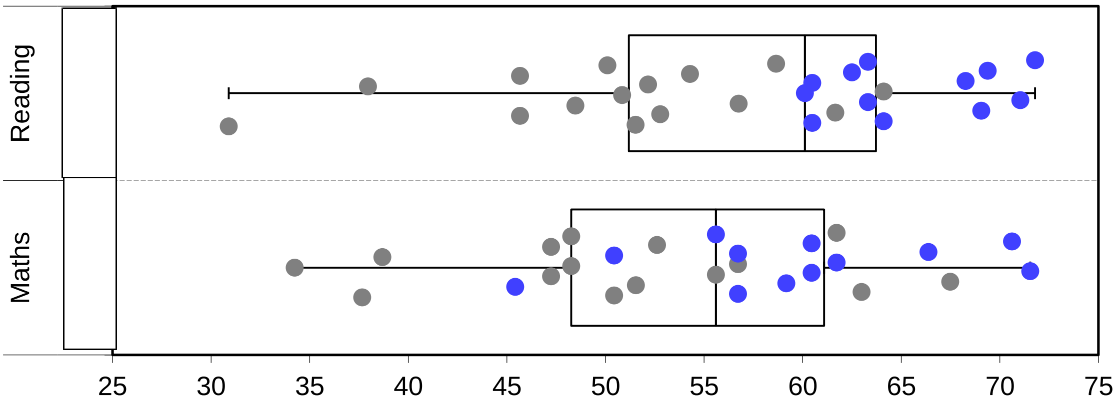


Figure 5.5: Pre-Intervention Scores of Experimental Group for each School

The first interesting observation is the differences between the two schools in reading performance. The children in the dark grey colour school show lower spread of ability for their reading and maths scores in comparison with the children in the light grey. On the other hand the majority of scores of the light grey school report higher spread of ability with the scores being below the median performance. This adds more evidence on the high academic variability between children at the start of school. Similarly Figure 5.6 shows the pre-intervention performance of children in the control group for both schools.

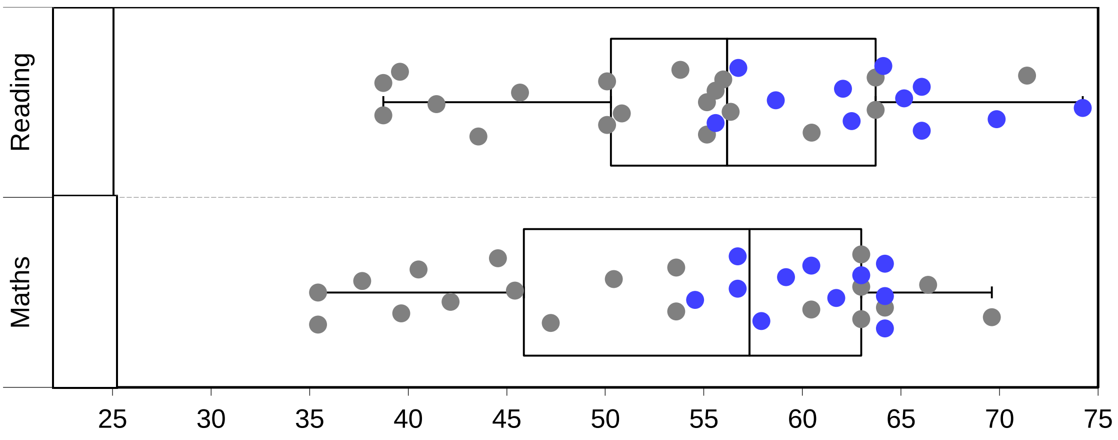


Figure 5.6: Pre-Intervention Scores of Control Group for each School

Figure 5.6 shows that the spread of ability is higher for maths than reading. Also as with the experimental group the dark grey school seems to perform higher in both measures than the light grey school.

Implications of this observed variability will be provided in the next Chapter. The next section describes the post-intervention assessment data.

5.4. Post-Intervention Assessment Data

Children were assessed after the end of the intervention in the same measures in order to observe differences in performance and record their progress. As part of being registered to use PIPS, schools receive feedback at the end of the school year (after the completion of my intervention) that once again gave standardized scores and a comparison of progress made against national norms which are graphically represented.

Coming back to the findings on the current research the post-intervention results of the first school on maths and reading were higher than the national average. A first observation of the graphs representing the standardised scores of reading and maths comparing the pre and post intervention assessment scores revealed that the majority of the children made the expected progress. For the motor scores, raw scores show that the majority of children improved their motor performance comparing the pre and post-intervention periods.

For the second school, the graphs revealed that the class average in total was lower than the national average for both maths and reading. The graphs reporting the standardised scores reveal that most children made less progress than expected. On the other hand, scores for the motor performance, revealed a trend of improvement. Both the pre and post-intervention feedback were initial indicators of the progress of the children's performance over time, but in order to compare the differences in the performance between groups further statistical analysis was performed.

5.5. Variables and Data Entry

The first step of the analysis to evaluate the effectiveness of the intervention was to enter all the variables and data in the SPSS programme in order to create the working spreadsheet of the current research. The variables that were entered in the programme are shown on Table 5.3.

Table 5.3

Explanatory & Outcome Variables on SPSS

Variables
Name
Pupil Code
DOB
Age on assessment (months)
EAL (yes, no)
Group (experimental, control)
Pre-intervention Academic scores (reading, maths)
Post-Intervention Academic scores
Pre-intervention Motor scores (motor1, motor2)
Post-Intervention Motor scores

It should be mentioned that after matching the data longitudinally, the names of the children were removed for subsequent analyses. Another category of variables included the daily scores that were recorded during the intervention on the accuracy and speed of the children.

All raw scores were entered in the database and some new variables were created. The new variables were the standardised residuals for the start and end scores of the assessment that were age corrected.

5.6. Analysis of the Outcome Measures

Both schools were treated as one single group in the analysis, since the assessment times were close enough to treat them as one large sample. Additionally, the intervention was delivered at the individual pupil level by the author of this thesis rather than a cluster design involving many people administering the intervention. Also the number of children in both schools was not big enough to treat the schools separately and analyse using multi-level modelling. As mentioned earlier the first step of the analysis was to perform several ordinary least squares (OLS) analyses in order to obtain standardised residuals. In these OLS analyses the age at test was the independent variable and the test scores were the dependent variables. The standardised residuals offer fair comparisons between subjects, since all measurements are presented on a fair scale. The next step was to perform a second regression analysis with the start age-corrected score as the dependent variables and the end age-corrected score as the independent variable. Controlling for prior attainment improves the power of the findings of an RCT. From this regression new residuals were produced. The standardised means and standard deviations of these residuals are shown on Table 5.3 and 5.4 for the experimental and control group respectively.

Table 5.4

Descriptive Statistics of Standardised Residuals Experimental Group

	Mean	SD
Maths	.09	.99
Reading	.11	1.07
Motor 1	.03	.86
Motor 2	.32	.81

Table 5.5

Descriptive Statistics of Standardised Residuals Control Group

	Mean	SD
Maths	-.08	.99
Reading	-.10	.90
Motor 1	-.03	1.10
Motor 2	-.30	1.05

A first view of the descriptive statistics reveals that there are differences between the mean residual scores of both groups. Figure 5.7 provides a graphical representation of the standardised residual mean scores of the children's outcome measures in the experimental and control groups.

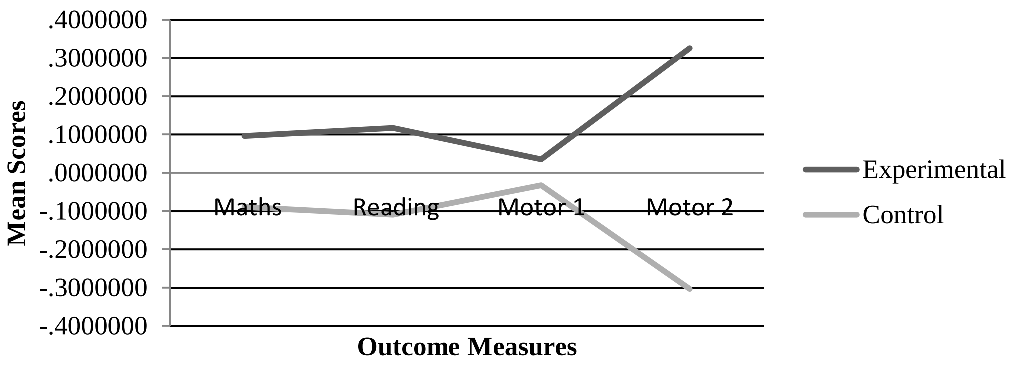


Figure 5.7: Standardised Residual Mean Scores of Outcome Measures

From Figure 5.7 it can be suggested that the experimental group had higher mean residual scores on all measures with Motor two showing the largest difference. But caution is needed because descriptive statistics such as the mean only serve to describe the data and not to infer that this observed difference is a significant one.

In order to investigate if the intervention had a statistically significant effect, independent t-tests were calculated to explore the difference between the means of the two groups. The new residuals that were produced from the second regression analysis which controlled for the pre-test score were used to perform the independent t-tests. The independent t-test was used for the analysis because there were two experimental conditions with different participants participating in each condition. Also since the sample size was relatively small *N* =56 this test is commonly used. Results from the independent t-tests are presented in Table 5.6.

Table 5.6

Independent T-Tests with p = 0.05 Significance Level

Measure	*df*	*F*	*p*
Reading	54	0.69	0.49
Maths	54	0.85	0.39
Motor 1	54	0.25	0.80
Motor 2	54	2.48	0.01

The independent t-tests failed to report significance for the variables of reading, maths and motor one scores, whereas there was a significant effect of motor two. This significance suggests that the experimental group had higher performance in motor two variable whereas in the other three no significance differences were reported.

Following the analysis of the data using independent t-tests the effect sizes were calculated for all outcome measures. Effect sizes can be categorized in small, moderate and large effects, where small is $r = 0.10$, moderate is $r = 0.30$ and large is $r = 0.50$ (Field, 2005).

Results report small effects for reading r =.19 and maths r = .25. Also moderate and large effect sizes for motor performance (measure motor one and motor two) r = .33 (ASPECTS) and r = .60 (PIPS PE) were reported respectively. From the above effect sizes the most interesting finding is the large effect size on the motor performance that suggests that the effect accounts for the 60% of the variance. Effect sizes were produced from the standardised scores of the children, where mean scores were found to be within the range, suggesting no ceiling effects. Therefore, the small effect sizes reported for reading and maths cannot be accounted for by a ceiling effect.

5.7. Analysis of the Intervention Measures

The next step of the analysis was to investigate if there was any improvement over time on the experimental group on the intervention activities. In order to investigate the experimental group's improvement over time, the intervention was initially divided in three time points: time one (T1), time two (T2) and time three (T3). These equal time intervals represented the start, middle and end of the intervention. In Table 5.7 the results from the one sample T-test present the 95% confidence intervals mean differences among the different categories and time-points. All categories showed statistically significant differences between the mean time-points with p =.000 and with no 0 value reported in the confidence intervals.

Table 5.7.

Confidence Intervals of Intervention Measures by Category based on 3 Time-Points

Time-Point	*df*	*Mean*	*SD*	*95% CI for Mean*	
				Lower	Upper
Vest.T1	26	42.63	10.8	38.34	46.92
Vest.T2	26	67.52	18.1	60.33	74.71
Vest.T3	26	93.93	23.2	84.74	103.11
Prop.T1	26	29.41	9.4	25.67	33.14
Prop.T2	26	36.41	10.7	32.15	40.67

Prop.T3	26	36.11	7.8	32.99	39.23
Tact.T1	26	14.89	4.6	13.05	16.73
Tact.T2	26	16.59	5	14.61	18.57
Tact.T3	26	17.59	7.6	14.57	20.61

*Vestibular Time-point1, Proprioceptive time-point 1, tactile time-point 1

Then the mean scores were plotted on the bar charts for each time interval with 95% confidence intervals to graphically represent each time-point for each category. Figures 5.8, 5.9 and 5.10 represent the time points for each intervention category (vestibular, proprioceptive and tactile).

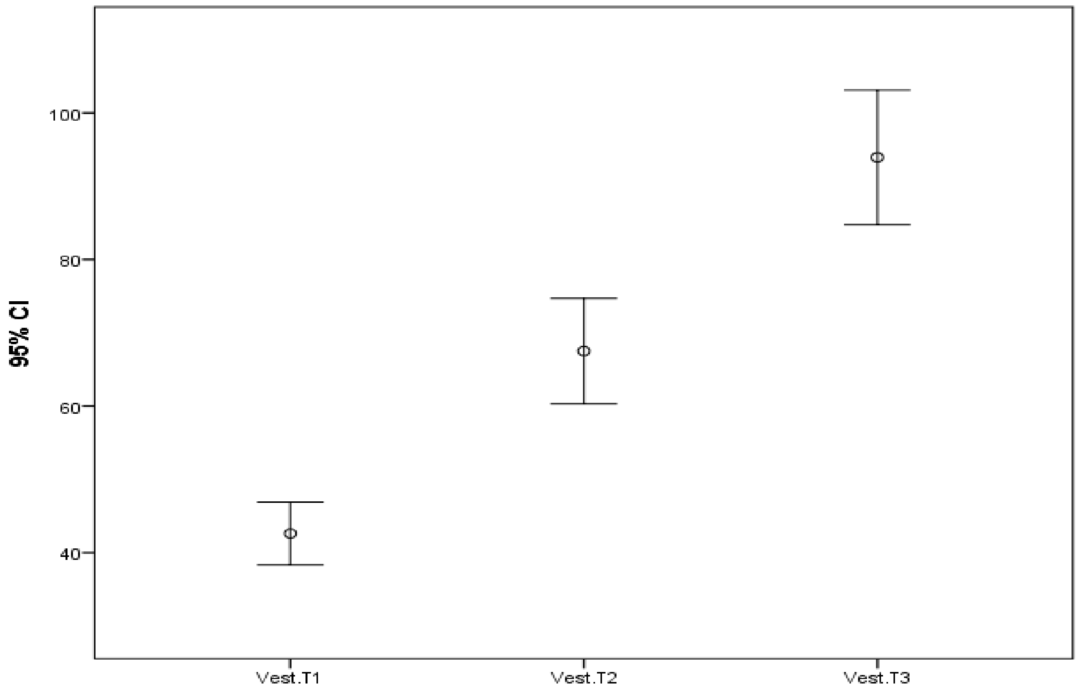


Figure 5.8: Intervention's Mean Time-points for Vestibular Category

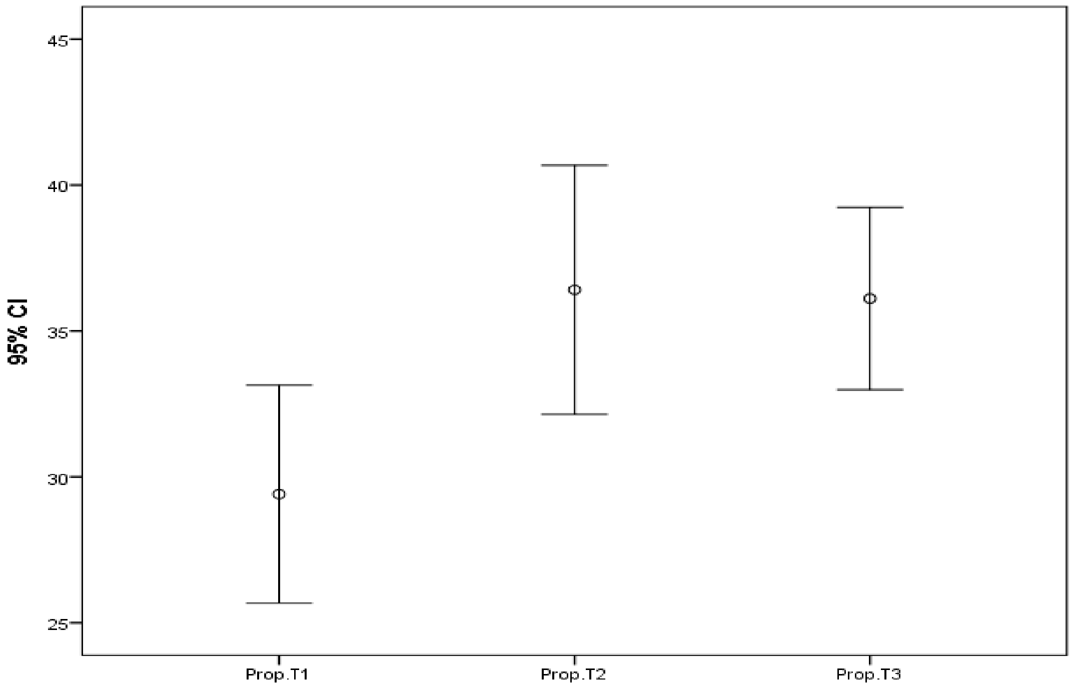


Figure 5.9: Intervention's Mean Time-Points for Proprioceptive Category

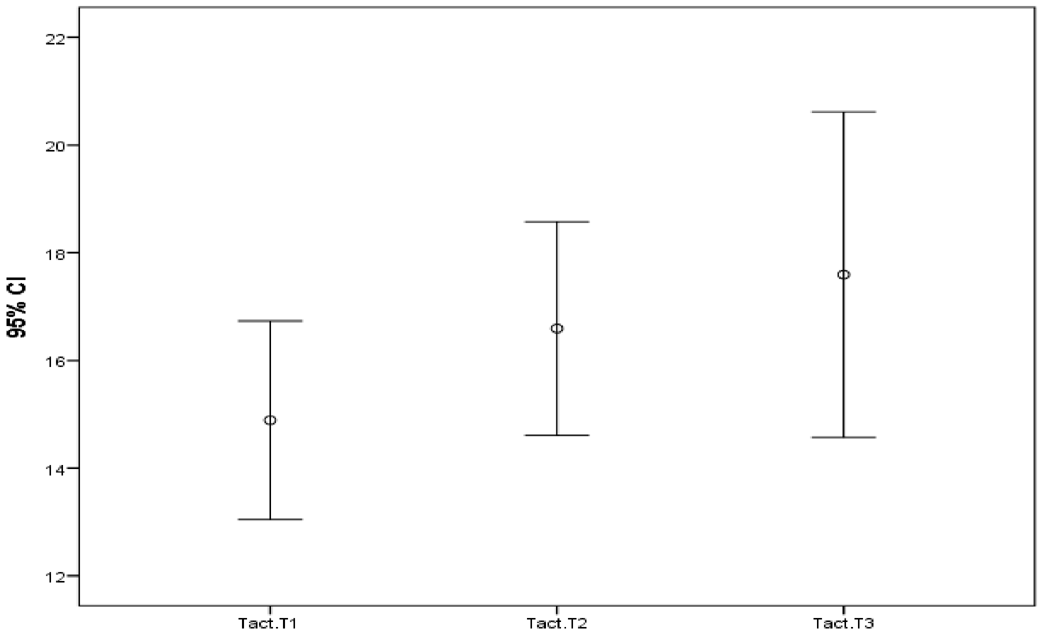


Figure 5.10: Intervention's Mean Time-Points for Tactile Category

All figures show that there was an increase in the children's mean performance over time, thus suggesting that the MSI for the Early Years was successful in improving children's performance in the various tasks.

5.8. Test-Retest Reliability & Validity Outcomes

The three PIPS PE measures that were used to assess children were catching, throwing to target and drawing trails. In order to establish the test-retest reliability and validity of these measures a short study was performed. Data were collected from the reception classes of two schools where 36 children were involved. The children's age range was between 55 and 68 months old. Once data were collected they were entered in SPSS for performing the correlations. The correlations that were performed were between the aforementioned variables on the measurements performed initially and after a gap of one week. Before the correlations the descriptive statistics were analysed and are presented in Table 5.8.

Table 5.8

Means & Standard Deviations of Test-Retest Reliability PIPS PE Scores

Measures	Mean	SD	Min.	Max
catching.T1	6.8	3.1	0	10
catching.T2	7.5	2.6	0	10
throwing.T1	7.7	4	0	16
throwing.T2	10.1	3.4	0	15
drawing.T1	15.8	7.1	0	32
drawing.T2	16.2	6.7	0	32
total.T1	30.3	9	0	48
total.T2	33.9	8	0	47

**Note: T1=test, T2=retest*

From Table 5.8 it is obvious that children's mean scores were generally close between the two time points. But it can be also observed that there were a lot of variations between the minimum and maximum scores, which can explain the correlations below. Additionally, an increase in scores in T2 can be observed which can be explained by children's having practised at T1 and therefore being more comfortable and proficient at T2.

Initially correlations were performed for each individual measure. The correlation for catching was r = .46, throwing r = .18 and drawing r = .66. Additionally, the correlation for the total scores of all three PIPS PE measures was r = .53. All correlations were positive and statistically significant, at a 0.01 level, between the test and retest period except the throwing task. Results indicate that the correlations for the catching and throwing tasks were weakest. On the other hand the drawing task reported a strong correlation and all three measures showed a significant correlation between the two time intervals. Hence, test-retest reliability for all the three measures has been partially established with an emphasis on the drawing task reporting the strongest correlation. It is being acknowledged that although the correlations were significant they are not strong enough (r close to 0.9) to suggest that the measures have established strong reliability. On the other hand, this is the first attempt to investigate the reliability and validity of these measures and it can be considered an important first step.

In order to investigate the validity of the PIPS PE measure, comparisons were made with the physical scores of the EYFSP. Teachers provided me with children's scores on the physical development section of the EYFSP and correlations were performed with the PIPS PE measures. The EYFSP scores were compared against each measure on the PIPS PE and their total. All correlations were very weak or even negative, See Appendix 7. For example the correlation between EYFSP and the first measurement phase of catching was r = -.135. In order to investigate this negative correlation the distributions of scores for both measures was plotted. In Figure 5.11 the distribution of scores for the EYFSP is represented revealing a very limited range of scores which can explain the low correlations.

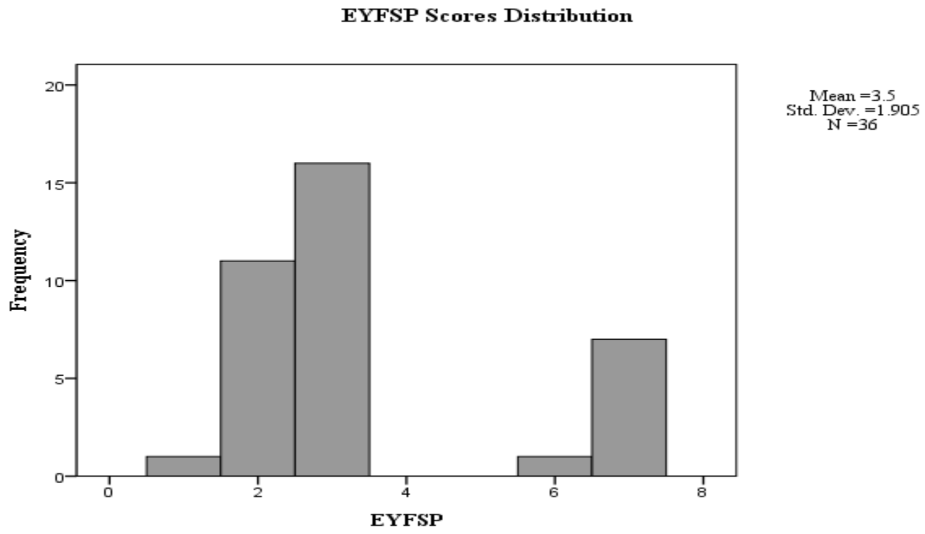


Figure 5.11: EYFSP Distribution of Scores

On the other hand, Figure 5.12 provides the distribution of scores for the initial testing of the catching task. The range of scores for the catching task is not as limited as it is for the EYFSP scores although there is a trend towards the higher end of the distribution.

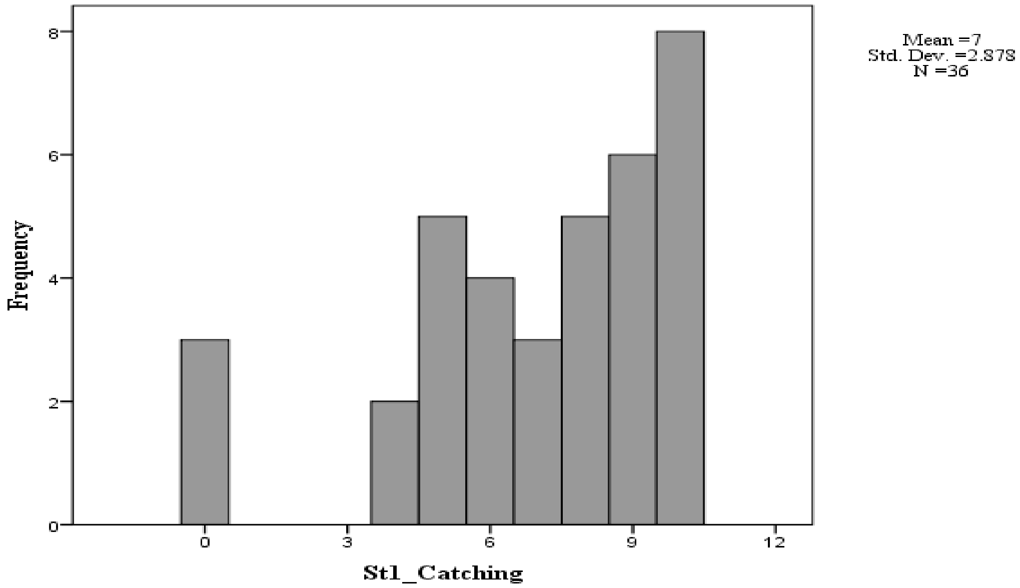


Figure 5.12: Start of Catching Task Distribution of Scores

Since the correlations between the EYFSP (physical development section) scores and the PIPS PE scores were weak or sometimes negative validity for the PIPS PE measures cannot be established. Caution is needed in the interpretation of these correlations since the range of the scores for the EYFSP was limited and also because the EYFSP has no established validity. Another query was to investigate whether the school's scores on the EYFSP were similar with the national average scores provided. A one sample T-test was performed to investigate if there were significant differences between the mean scores. The differences in the means were not significant t (5) = -1.10, p =3.19 so it can be concluded that children's scores on the EYFSP complied with the national norms.

5.9. Interpretations of Outcome and Intervention Measures

The analysis of the outcome measures revealed the effects that the intervention had upon the children that received it. The independent t-tests of the standardised residuals from a regression analysis indicated that the MSI for the Early Years had no significant effects on the measures of reading, maths and motor one. Some possible explanations of the lack of any significant effects might be the sample size, the duration of the intervention, the initial low scores in one of the schools or some of the intervention's materials. The total sample size was 56 children, of which 27 were in the experimental and 29 in the control group. Maybe the size of the sample was not large enough to document significant effects on the above measures. Although the duration of the intervention was decided upon specific criteria, it is possible that more time is needed for documenting effects on academic measures; such as reading and maths. Maybe reading and mathematics would be expected to show improvement sometime after the intervention had finished because what it might be doing is laying the foundation for the ability to read and perform maths more effectively from then onwards. If the intervention's total duration was longer maybe effects on these measures would start to develop. Furthermore, some of the intervention's materials might need some amendments, which is an issue to be considered for future research.

On the other hand the intervention showed significant gains on the motor two measures which included the activities of the PIPS PE assessment and included basically manual dexterity and ball skills. This significance has important implications since it is the first evidence that the children that received the intervention performed better in the PIPS PE drawing trail task than the children who did not receive the intervention. So, one of the goals of the intervention has been accomplished. Another interesting piece of finding can be derived from the calculation of the effect sizes. Effect sizes for reading and maths were small, but might have the potential to increase. A small effect size offers an indication that there is a relationship between the variables of interest and can indicate that the intervention laid a foundation for future larger effect sizes. The effect size for the motor one measure which included gross and fine motor skills showed a moderate effect and for motor two which included fine motor skills showed a large effect. Both effect sizes indicate that the MSI for the Early Years had considerable effects on children's motor skills. Although the significance of the motor measures appears to be promising, caution is needed since test-retest reliability was partially established for two out of three measures, and overall all measures showed a moderate positive correlation. Additionally, the validity of the PIPS PE measures could not be established and further investigation is needed on these measures. So a future step could be either the improvement of the PIPS PE reliability or the use of different assessments.

Further analysis took place on the intervention's measures of accuracy and speed that were used to indicate and ensure that the intervention works and progress is achieved. Data revealed that children improved over time on all categories but only the vestibular category activities yielded significant differences in the children's mean performance. This finding is encouraging, since it indicates that children progressed over time as was expected, and also provided information regarding the future changes on the intervention's difficulty levels especially for the proprioceptive and tactile activities. In the next section the qualitative part of the research will be presented.

5.10. Qualitative Data Analysis

As has been already mentioned in the methodology section, the study had a qualitative component as well. The qualitative component was predominantly the use of a research diary that was kept during the course of the intervention. The main purpose of the research diary was to observe the performance of children, and to implement changes that would benefit both the children and the intervention programme. The research diary mainly included minor deviations from the original plan or format of the intervention, as well as observations of children's improvements and behaviours towards the tasks. A qualitative dimension while performing an intervention is a very important aspect because it provides the researcher with valuable daily feedback from the children that complements the quantitative part. Also, since the MSI for the Early Years had not been administered before, all observations regarding the application and manipulation of tools from the children was extremely helpful. The main changes and observations that took place can be found in Appendix 8- Qualitative Research Diary.

Overall, the major observations included the ways in which children coped with the different tasks and manipulated the tools of the intervention. The feedback of these observations resulted in changes of some points or alterations. Among others an important observation was that children seemed to enjoy the "routine" of the intervention and were keen on guessing which task comes next, since the ordering of the tasks presented was different each time. Additionally, when a new difficulty level of a task was introduced children were curious to discover how it worked, and tried to succeed. Having children in small groups was good for the intervention in general. It was obvious that many times children were engaging in a competitive behaviour; resulting in trying harder to excel on the given task. On the other hand, sometimes they were getting frustrated if they could not complete an activity as the other children in the group, and then it was the researcher's role to calm them down and praise the fact that they are trying their best. To some children the feedback that they were getting from the researcher was very important. Children needed to be treated both equally, as being part of a group but also the researcher needed to be flexible and understand the child's individuality. One of the important points of the intervention's observations was the reciprocity of the relationship between the researcher and the children. This point should be always taken into account while designing an intervention. Both the children and the researcher are influenced during an intervention. Working with children and delivering a motor skills intervention is a challenging but yet rewarding experience. Conclusively, the interpretations that can be documented from the research diary involved mainly amendments on some points of the tasks, reconsiderations on the delivery of each task and observations on the way children responded to this procedure. The qualitative component of the current research did not offer any statistical evidence of the intervention's effects but its role was still important. More detailed interpretations of the findings will be provided in the next Chapter. In the next case some observations derived from anecdotal evidence will be presented.

5.11. Anecdotal Evidence

Other than the quantitative methods to analyse data anecdotal evidence were derived from the daily observations and communication with the children during the intervention. Anecdotal evidence usually adds to the information gained from the statistical analysis (Moss & Edmonds, 2005). During the intervention the author of this thesis had the chance to personally observe each child and witness the changes on their performance over time. During the intervention there were children who were showing a stable improvement, some were showing inconsistencies on performance and some started with many difficulties in most of the tasks but improved at the end compared with their initial performance. Some information regarding the latter case will be presented documenting a child's case of improvement.

A young boy participating in the experimental group was showing difficulties in performing the tasks that involved gross motor skills from the early stages of the intervention's delivery. More specifically, on the first maze task (horizontal-vertical) where the child was asked to walk straight within the lines of the maze without touching the tape on the floor or go out of the lines, major difficulties were observed. It was hard for the child to make a step without losing his balance. Another task that the child had major difficulties with was hopping on one foot. Every time the child was attempting to hop he either fell on the floor or lost balance and touched the floor with the other leg. Although the progress of the child was slower in comparison with the other children, it was very rewarding to observe daily improvements. During the child's attempts the researcher was supporting and praising his effort, while observing that this was beneficial for the child's performance. At the end of the intervention the child was able to successfully walk through the mazes and although he was slower his performance was accurate. For the hopping task the child did manage to improve his performance by having an average of correct attempts of two out of three trials in hopping sessions involving eight successive hops.

Anecdotal data cannot be used to infer for statistical significance but they can document potential practical significance. A more detailed discussion on the interpretations of anecdotal evidence will be provided in the next Chapter.

5.12. Summary of Main Points

This Chapter provided a detailed description of the study's results. Before the analysis of the intervention's data a large database with results of both academic and motor measures was analysed and acted as a background for the current research. Additionally, further more sophisticated analysis followed which provided a contextual rational of the study's progress so far, with the use of multilevel modelling analysis. Following that, the data from the pre and post intervention were collected and initial interpretations took place. Generally, raw data and graphs might indicate trends of the relationship between variables, but they cannot indicate causality. Hence, data were entered to the statistical programme for analysing the relationship between the variables and investigating the intervention's effects. Although the intervention did not show significant effects on the academic measures and some motor variables it did show significant effects on some other motor variables suggesting a change in the children's motor skills performance. Additionally, effect sizes were calculated and revealed a range of effects from small to large on all outcome measures. These data look promising and future research is needed to further examine this relationship.

Additional analysis was performed to the intervention measures of accuracy and speed suggesting that children progressed over time showing increased mean performances on all tasks of the intervention and during the whole course. This was an indication that the intervention worked by improving the children's performance over time on the different tasks. Following the analysis performed on the measures of the main study an additional short assessment study to establish test-retest reliability and validity was conducted. Test-retest reliability for the PIPS PE measures was partially established whereas validity was not established; although caution is needed in the interpretation of this finding since the EYFSP has not got any established measures of validity. The Chapter also provided a description of the qualitative part of the research which enriched the quality of the intervention and offered valuable observations for future reference. The next Chapter will discuss the research's findings, and provide possible explanations for obtaining these results. Additionally, both the strengths and the limitations of the research will be discussed along with future suggestions for the research area.

CHAPTER 6

DISCUSSION

6.1. Introduction

In this chapter the relationship between motor skills and academic performance, as it has been expressed through the MSI for the Early Years and the course of the study up to this point is discussed. The theoretical perspectives considered earlier are discussed in relation to the findings from the current research and the original research questions revisited. Finally, the limitations and strengths of the study as well as proposals for future research are addressed.

6.2. Consideration of the Research Objectives

The main objectives of the current research were to develop a motor skills intervention which would, when implemented, lead to an improvement in young children's:

1. Motor abilities.
2. Reading performance.
3. Maths performance.

The relationship between motor skills, academic and cognitive functioning has been studied from different perspectives revealing a connection. (see for example; Etnier, et. al., 1997; Taras, 2005; Taylor, et.al., 1985; Wassebberg et.al., 2005). Based on this assumption, an intervention for young children was developed and its effectiveness on motor skills, reading and maths evaluated. Current theoretical perspectives were used to inform the development of an intervention which was then tested it in a school setting in order to find an effective way of enhancing academic skills through their motor correlates. The main hypothesis was that children receiving the MSI for the Early Years would perform better than children who did not receive the intervention in the areas of reading, maths and motor skills.

The next section will discuss the findings in relation to the area of the academic skills.

6.3. Findings on Academic Skills

Previous research suggests that physical exercise and movement is related to improved performance of reading and maths, and that motor competence can improve academic performance (Castelli et.al., 2007; Grissom 2005; Son & Meisels, 2006; Taras, 2005). The MSI developed for the current research was positively associated with an improvement in reading and maths, but the improvement did not reach a level of statistical significance. Therefore, it cannot be said with a degree of confidence that they showed a positive effect. The effect seen could have been chance.

Although these findings do not support the prediction that the intervention will improve reading and maths performance, it does not necessarily mean that the intervention was unsuccessful in this respect. While the current research was underpinned by the literature that supported the relationship between motor and academic skills, it failed to find a significant relationship between the two. The common consensus is that failing to find statistically significant results might mean either that the connection does not exist, or that the specific intervention was not able to confirm it. However, this comes in accordance with previous studies that have failed to find a significant relationship between them, when investigating the effects of structured PE programmes involving motor skills on various academic areas, including reading and maths. See for example; Daley & Ryan, 2000; Fisher, et al., 1996; MacMahon & Gross, 1987. The possible reasons include; sample size, intervention's duration, insufficient duration for changes in academic/cognitive performance to show, as well as failure to tap the true underlying processes involved in the motor areas together with creating activities which address them.

Another explanation for the lack of significant findings in the current research is the possible influence of other factors such as concentration and attention upon the children's performance. More specifically, research has documented links among attention, motor and perceptual skills. As reported earlier in the literature review, children diagnosed with ADHD and DCD often exhibit difficulties in motor coordination and academic performance (Kaplan et.al., 1998; Merrell & Tymms, 2001). The potential explanation for this might be the influence that attention has upon performance, since it is involved in both motor and academic tasks. This possible explanation comes in agreement with research supporting the links that exist between attention and motor coordination (Gillberg, 2003). In the current research the variable of attention was not measured. Hence children that might have been inattentive either during the demonstration of the tasks or during the participation in them might have had a decreased performance. Some children appeared to be inattentive during the delivery of the intervention and sometimes this behaviour was extended to the other children in the group that were attentive. Therefore, the lack of significant results in the areas of reading and maths may possibly be attributed to a lack of concentration. Also the Causal Modelling framework by Morton & Frith (1995) can explain the common symptomatology of the motor, attention and learning variables suggesting a single causal chain can be applied to different developmental disorders. Overall, problems in attention could provide a possible explanation for the findings.

Another school of thought on the research investigating the influence of physical activity to academic performance supports that this relationship might be of a more indirect nature. More specifically, research suggests that children who are physically active tend to have higher self-esteem (Tremblay, Inman & Willms, 2000). Higher self-esteem is associated with higher levels of motivation (especially directed effort, and persistency in the face of failure), and ultimately academic success. Based on this then the relationship between physical activity and academic achievement might be weaker than we thought, or the links can be of a more indirect nature. Further evidence investigating the effects of physical exercise to mental health reports that, the effect that physical exercise has on body image and social interaction is the key to a better mental health profile in adolescents (Association for Psychological Science, 2012). It would seem that physical exercise has a plethora of effects to the brain, many of them of an indirect nature. Therefore, a possible explanation of the relationship may not lie within the direct change that a MS intervention brings, but rather an indirect change of the underlying and indirect factors that improve along with physical exercise. Thus, this concept provides another explanation of the lack of significant differences between the two groups on academic performance.

The sample size of the current research was in total 56 children divided to experimental and control groups. The experimental group size consisted of 27 children which is a relatively small sample in order to find significant gains in reading and maths. A larger sample size provides less room for error and increases the reliability of the study. Many researchers have proposed a minimum of 30 as a sample size in experimental research (Cohen et al., 2007). In order to further discover the number of participants to obtain significant results a power calculation was performed based on the effect sizes obtained and using a Sample Size Calculator designed by Professor Coe at CEM (see www.cem.org for more information). Results indicated that in order to have found a significant effect in reading a total sample of 168 individuals (in both groups) would be sufficient. Similarly, in order to have found a significant effect in maths a total sample of 96 individuals would be needed. So, a possible explanation for the lack of significance might be that the study was underpowered. In a study by Ericsson (2008), performed in Sweden and testing the effects of a motor programme on various motor and academic skills including reading and maths, significant effects were documented with a total sample size of 251 children. A cluster RCT could possibly be better for the current intervention since it has been designed to be delivered by the class teacher and therefore should be analysed taking that into account. However, a large scale trial would be more appropriate for the evaluation of a more developed intervention. Considering that the current intervention was new and untested it was important for me as a researcher to implement it in order to observe its effects with a view to refining it for future use. That being the case it was not possible to handle a larger sample.

Another possible explanation for not obtaining significant results is the intervention's duration and the immediate administration of the outcome measures. Changes in the performance of academic skills such as reading and maths might need a longer time to document significant effects (Taras, 2005). The intervention lasted 11 weeks a duration period that might not be long enough to have an impact on the processes involved to improve academic performance. Furthermore, since some children were frequently absent during the intervention their performance during the assessment at the end of the intervention in the reading and maths measures could have been influenced negatively.

Additionally, the lack of significant findings may be attributed in the difficulty that lies within the process/deficit oriented approaches. More specifically, since the current intervention included a combination of underlying process-oriented tasks as well as task-oriented ones, the risk of not accessing the true underlying processes exists. The above risk is present in all approaches which have used activities which are associated with the process/deficit oriented approach and it can be considered a limitation (Cermak & Henderson, 1990). Hence, the nature of some of the tasks of the MSI for the Early Years or their intensity might not have represented the true underlying processes, failing to account for significant changes in the academic skills of interest. In the future in order to counter this limitation the addition of more task-oriented motor tasks can be considered.

On the other hand, small positive effect sizes were reported for both reading and maths. A small effect size might not provide strong evidence on the intervention's effects but it can be perceived as an indication that a positive relationship exists between the intervention and the outcome measures and thus worthy of further investigation. Additionally, the chance of having a ceiling effect explaining the small effect sizes was investigated. The scores were standardised and the mean performance in both reading and maths was within the normal range so it was concluded that there was no ceiling effect.

Furthermore, small effect sizes can further support the explanation that for changes to be significant in the cognitive or academic areas more time is needed. The current intervention might have initiated a change in children's academic performance which will develop on a later time point. Therefore, if children were assessed after a delayed follow-up following the intervention's completion some of the effects on the academic areas could have been demonstrated. Given the time limits of the current doctoral research, it was not feasible to conduct a longer-term follow-up; however this is a consideration for future research.

Another important observation about the relationship between the academic and motor skills can be derived from the findings from the multilevel modelling analysis of the CEM data set. This relationship was not only supported but it further reported that MD is associated with academic skills and has a predictive power. The findings of the analysis conducted using data from CEM echoed the findings from the study by Piek and colleagues, performed in 2008. Piek's study suggested that motor development and PSED are strong predictors of cognitive skills (Piek, Dawson, Smith, Gasson, 2008). The above relationships remained strong even after controlling for factors such as age and sex, and taking account of school membership. These findings provided a strong background for investigating the relationship between motor and academic skills. Additionally, these findings could be used to inform future educational policies because they suggest that it would be beneficial for children in the early years to engage in activities practising and improving their motor skills. Although the findings did not originate from the evaluation of the MSI intervention but from a different sample, they were findings resulting from the analysis that was part of this thesis. Thus they formed an important part of the study and provided evidence of the relationship in question. In the next section the findings on the motor skills will be discussed.

6.3.1. Findings on Motor Skills

The other areas that were investigated as part of this intervention study were fine and gross motor skills. The majority of previously published motor intervention programmes, (including PE programmes), report gains on physical performance and various motor skills (Haga, 2008; Schoemaker et. al., 2003; Tsorlakis et. al., 2004; Logan, Robinson, Wilson & Lucas, 2012). In a motor skills intervention, gains in the motor domains are considered the initial goal, with gains in other areas (i.e. academic skills) to follow. In the current research, two assessments were used to test fine and gross motor skills. The motor development section of ASPECTS test and some measures of the PIPS PE test. These two tests were used in combination to achieve a balanced motor skills assessment. The activities of the ASPECTS test were named as ‘motor one variable’, and the PIPS PE as ‘motor two variable’. Significant gains on the motor two variable were found for the intervention group compared with the control group. In terms of the size of the impact, the impact of the intervention on the motor one variable led to a close to moderate positive effect size of 0.33 and the motor two variable a large effect size of 0.60.

The above findings suggest that the intervention had a statistically significant and large effect on the PIPS PE measures which involved fine motor skills, as well as a close to moderate effect size on the ASPECTS measures, although non-significant. Results show that the MSI for the Early Years significantly improved the performance of the experimental group over the controls. This finding is of major importance, since it provides evidence for the intervention’s effectiveness, in some of the assessed areas of motor development. More specifically, the motor skills involved in the PIPS PE were manual dexterity and ball skills which are mainly associated with fine motor skills (Stafford, 2000). Additionally, these findings are consistent with the findings of Ulrich and Ulrich (1985) who found that their 10-weeks movement programme had significant effects on the children's motor skills' performance. Also current findings agree with previous research suggesting that motor training produces direct improvements in motor tasks (as cited in Reynolds, Nicolson & Hambly, 2003). Although results in the current intervention are not significant in their whole, they appear to be very promising. The MSI for the Early Years is a newly designed intervention and the above findings are a first indication of its effectiveness.

A possible explanation of the lack of significant effects on the motor one variable may be explained because the specific motor skills involved were not representative enough to document any changes. For example ASPECTS was measuring static balance whereas the MSI for the Early Years did not involve static balance as one of the direct motor skills. Therefore, there would have had to be a transfer of learning effect present. Furthermore, the fact that the motor development section of the ASPECTS test is designed for children up to four years of age might have influenced the outcome of the results by not tapping the specific motor skills involved at that age. Additionally, as was the case with the findings in the academic measures, the children in the intervention group who were frequently absent missed out on receiving the full MSI for the Early Years.

Another possible explanation for the lack of significant findings was the use of the ASPECTS test instead of another test that has established higher reliability and validity and is most widely used, such as the Movement Assessment Battery for Children (Movement ABC) (Henderson, Sugden & Barnett, 2007). As explained earlier, the main reasons of this selection was the pragmatic nature of the current research as well as the need for a trained professional to administer other motor batteries. It is acknowledged, that a more reliable measure would have made a difference by resulting in less error measurement and it will be considered in future research.

On the other hand the anecdotal evidence from the researcher's observations documented positive changes in the motor performance of some children. More specifically, the case of one boy was reported in section 5.11 on anecdotal evidence. It is known that anecdotal evidence cannot be used to support significant effects of an intervention. Nonetheless, according to the "Black Swan Theory" by Taleb (2005), since there is one black swan there should be another. This theory can provide useful interpretations on the current anecdotal data by considering that since one child improved on his performance on the gross motor tasks, it is possible that others may have benefitted similarly. Furthermore, based to the above theory "an "outlier" has the property of carrying a large impact" (Taleb, 2005). This theory has been developed by the need to provide an alternative approach to the conclusions reached by statistical tests and also consider the influence that the "exceptions" can have. Sometimes in research there is a trend towards overestimating the statistical findings and underestimating the observed findings which are usually attributed to chance. But especially in educational research, which is characterised by increased complexity and variability, the observations can complement statistical analysis or indicate a potential practical significance. Caution is needed in interpreting anecdotal data since inferences cannot be made for the intervention's effectiveness.

In the next section the findings from the short-study examining the test-retest reliability and validity of the PIPS PE measures are discussed.

Test-Retest Reliability & Validity

As discussed earlier, the reliability and validity of the PIPS PE measure had not been established prior to the current research. As part of this research, and since significant effects were reported in these measures, an additional small study investigated these properties. As reported in the Results Chapter, the overall correlations for all measures were significant between the test and retest occasions, with the 'Drawing Trail' measure itself reporting the strongest correlation. The 'Throwing to target' task required the children to stand in a distance of two meters from the target and slide a bean bag along the ground to the middle were there was a coloured paper. Children repeated the activity six times. One observation that might have caused the lower correlations on this measure was the fact that the majority of the children, although clearly instructed to slide the bean bag, just threw it to the target. Both sliding and throwing belong to the category of the fundamental motor skills, but sliding involves more advanced object control, thus this task might have been more difficult for the children (Stodden et.al., 2008). Maybe children in the age of four years have not fully acquired the concept of sliding an object with their hands, since they had difficulties performing the task. In relation to the catching task, the reason for a moderate correlation might have been that the task was too difficult for most of the children. It should be noted that the correlation was moderate but significant. In a previous pilot study on the PIPS PE measures, the catching task was reported to be too demanding for children in Reception Year (Stafford, 1998). In the future these two tasks need to be reconsidered in relation with the age of administration. In the “Drawing Trail” task children had to draw a line between a series of drawing trails without touching either of the lines. This task reported a significant positive correlation between the test and retest period, establishing a moderate test-retest reliability. Although the correlation was significant, it was not as high as it should ideally be for assessment measures. This may be explained by the speed-accuracy trade-off law developed by Fitts. According to this law the faster a person performs a movement the less precise the movement is (Zhai et.al, 2004). According to Fitts (1954) learning takes place through the stages of practise and instruction. What was observed during the assessment was that although the investigator was reinforcing children to take their time in order to avoid making mistakes, some children were trying to finish the task quickly, thus “sacrificing” the accuracy of their performance. So even under specific instructions to take their time and aim for accuracy, the children kept speeding during the drawing. A future suggestion to avoid this may be to implement a reward for accuracy. The investigator then would inform the child that he/she should not finish the task before the hourglass runs out. By including this technique the children that tend to speed would need to slow down. A future pilot study would help to observe how children perform under the above conditions and if this measure would be sufficient for decreasing or eliminating the speed-accuracy trade off. Overall, correlations between the two time-points for all measures were positive and significant but low to moderate. In terms of the validity of the measures correlational data did not reveal any relationship hence validity was not established. A closer look on the distribution of scores on the Early Years Foundation Stage Profile (physical development section) suggested that the range was limited hence that might be an additional explanation for the low correlations.

Having considered the reliability of the measures, it is important to bear these in mind when interpreting the findings from the intervention outcomes. A further set of measures to consider are the intervention measures, and so these are discussed in the next section.

6.3.2. Findings on Intervention Measures

In order to monitor the intervention's progression over time, both accuracy and speed were recorded for all activities on a daily basis. The measurements were entered into numerous spread-sheets, recording each child's progress in all of the intervention tasks. These scores were very helpful in informing the researcher whether or not children advanced on the various tasks as the intervention was progressing. During the course of the intervention these scores along with the researcher's daily observations were used to reform some of the children's groups. Furthermore, children who were performing in a lower level did not feel motivated by watching other children performing better than them. Thus two groups of children were changed after the second session of the intervention's delivery. The author of this thesis was rigorous in the methods employed to perform this change and reduce the bias as far as possible. As mentioned in section 3.2.4, the researcher was blind to children's scores and the change of groups was only based on observational information rather than children's baseline data, which had not been retrieved at the present time. The intervention was equally divided to three time-points representing the start, middle and end of the intervention in order to compare the children's mean performances over time on the three categories (vestibular, proprioceptive and tactile). The mean performances with 95% confidence intervals showed that the mean performances on all three categories were significantly different suggesting children's improvement over time. Therefore the intervention was successful in relation with the goal of improving children's performance during the MSI for the Early Years.

6.4. Qualitative Aspects of the Intervention

Other than the quantitative part which included the statistical analysis of the data, the current intervention had a qualitative aspect. This qualitative aspect did not involve questionnaires or interviews but rather a research diary, in which the researcher kept observational notes regarding the intervention. The research diary proved to be a very useful tool, providing insights for the intervention's delivery, manipulation of tasks, observations on children's improvements or difficulties and overall course. Furthermore, although the intervention's manual had been developed before its administration, some final amendments took place before creating the final copy which was distributed to schools such as, the number of trials per task. Having a newly designed intervention which has never been administered before was very challenging. Both the researcher and the children that participated in the intervention were engaging in a learning process. From the researcher's point of view this was a chance to observe in a real world context how children cope with the intervention. This environment was different to the pilot study, which provided valuable information as well, but in a smaller scale and within a shorter time length. The researcher was involved in a reciprocal learning experience because she delivered and taught the intervention to the children. In the same way, the children offered valuable feedback to the researcher. The notes and observations of the research diary involved information about the children's attitudes towards the instruments, possible difficulties, possible changes in the instructions, demonstration of the various tasks and many others. For example the anecdotal data were derived from the researcher's observations. This qualitative element of the study was an on-going process which was a valuable part of this first trial of the new intervention. The current intervention was applied in the school setting, where there is high variability among children. Therefore observations are vital, and provide useful additional information to the quantitative analysis of the intervention. It is an important aspect for an intervention to get feedback from the population that is addressed to. The above makes the intervention flexible, considering the children's responses and friendly towards them. Although the qualitative part of the current research did not involve interviews, it contributed by increasing the quality of the intervention and informing revisions in the next version. Overall, the research diary offered observations regarding children's behaviours that cannot be documented or interpreted by statistical analysis but can complement it (See Appendix-8).

6.5. What do Results Mean in Theory and Practise?

The present results have both theoretical and practical implications. Theoretically, the results add to the knowledge that a motor skills intervention cannot easily yield significant changes in children's academic skills. Some of the main reasons were described earlier. Every new attempt provides interesting information to the research field, even when not all results appear to be significant. Practically, the various characteristics of the MSI for the Early Years and its design can be considered an improvement to yield significant academic changes in the future. On the other hand, the significant results and large effect sizes in some of the motor skills appear to be a very promising finding. Theoretically, this finding adds to the knowledge that a carefully designed intervention can improve the motor skills of children and provide an advantage against children who do not engage in a structured intervention. Practically, it adds to the field of the motor skills interventions for TDC and it can be easily applied to improve children's motor skills in school. As suggested by Riethmuller, Jones and Okely (2009) the promotion of motor skills of typically developing children in the early years is critical in setting a strong basis for habitual physical activity. The research area of motor skills and its connection with academic or cognitive skills still requires additional research to formulate and support new, theoretically based interventions. Findings show that the current MSI for the Early Years can be considered a partially successful intervention, in respect to the motor area. The educational setting and more specifically primary schools in England request effective motor skills interventions and that need can be documented from the schools' willingness and interest to participate in the MSI for the Early Years. Adding to that area and offering more evidence-based options is valuable both in a theoretical and practical level. The contribution of the current research will be discussed in a later section.

6.6. What are the Key Benefits?

The current study investigated the relationship of motor skills and academic performance during development, studying previous literature, the background of motor and cognitive development, studying their interaction, finding different approaches and motor skills interventions, and designing a new hybrid motor skills intervention to investigate this relationship. The thesis involved multiple areas that were either directly or indirectly connected with each other. Consequently, the current research provides the readers with several distinct benefits which are summarised below:

- An overview of the background as well as current trends in the research area is presented and critiqued.
- Several interventions and their benefits are discussed.

- The development of a newly developed and theory based MSI for the Early Years is described and evaluated.
- The MSI offers a new perspective and approach in the research area by combining elements of the process and task oriented approaches.
- The benefits that the MSI for the Early Years had in a sample of young TDC children when used in a school setting, potentially by non-specialists makes it different to many previous interventions.
- Evidence from a RCT that a carefully designed motor skills intervention can improve the children's motor performance adds to the current published literature.

These are some of the key benefits that readers can gain from the current research. Further contributions will be discussed in a later section.

6.7. Links and Distinctions compared with Previous Research

The MSI for the Early Years has been developed from the need to investigate the relationship between motor skills and academic performance and an increase in problems arising from modern lifestyle and school curriculum. This relationship has been studied from different perspectives and several interventions emerged from the literature which was based on diverse approaches. Due to the complexity of the nature of this relationship there are still many unexplained areas. For the purposes of this investigation a review of the available approaches was the first step before deciding on the approach that would underpin the intervention. A combination of the two dominant approaches to motor skills intervention was selected as the basis for developing the MSI for the Early Years. More specifically, elements from both the process and task oriented approach to motor skills intervention have been used in the development of the intervention producing a hybrid intervention. Both approaches have documented evidence of their effectiveness in different populations and outcomes. Although they originate from different theoretical backgrounds, the combination of indirect and direct motor tasks resulted in a hybrid intervention. As it has also been suggested by Sugden in 2007 the different approaches to motor development and intervention although different are not mutually exclusive. Another area that is linked with previous research is the association between motor skills, reading and maths. Although the findings of the MSI for the Early Years did not reveal significant effects on these two areas, one of the main research objectives was the investigation of this association through the intervention. Previous research suggests that motor skills and PE in general are associated with improved performance in reading, maths and academic achievement (Chomitz et al., 2009; Haga, 2008; Trudeau & Shephard, 2008). Although this research area is considered to be fairly new, indirect associations between the two areas have emerged as early as the mind body problem of the ancient times. These associations changed over time to form the present question of whether motor skills or physical exercise are associated with cognitive or academic development.

On the other hand, the present research and intervention differs from previous research in the following points: In relation to previous research the current research is one of the limited attempts to study the relationship combining three main characteristics; involve TDC, apply a structured MSI, use a RCT design and investigate its effects on reading, maths and motor skills. Other research has mainly focused on increased PE during the school day and tested its effects on various measures both academic and physical. Furthermore, the focus of previous research lies mainly on atypically developing populations that are of immediate need for interventions. Additionally, the current intervention incorporated a RCT design which is not common in educational research, but when used it produces valuable information decreasing possible biases. Overall, the current research was inspired from previous work, but differentiated as well to create a new perspective on the research area. The next section will assert the wider areas that the current research can be connected with.

6.8. Current Research in Relation to the Wider Area

The current research can be placed under the wider fields of developmental psychology and education. Developmental psychology investigates the mechanisms that are involved in a person's development and affect it from birth onwards. "Development is a process of change with direction" (Valsiner & Connolly, 2003). The current research aimed to explore the connections between the areas of motor and academic skills in the early years. As a means to this end, a theoretical background of motor, academic and cognitive areas was provided that involved mainly a selection of relevant theories. These theories were derived from the area of developmental psychology (such as motor development theories) and many of them were used to inform the MSI for the Early Years. Some of these theories were: information processing approach, dynamic systems approach and embodied cognition presented in sections: 2.4.1.3. 2.4.1.4. and 2.8.3. By combining the knowledge from the field of human development with evidence documenting the relationship between the motor, cognitive and academic areas the MSI for the Early Years was produced. The theory of embodied cognition provided a rich background to the study of both cognitive development and motor development, suggesting that bodily experiences form cognitive ones and that the environment is part of the cognitive system. Additionally, it informed the development of the current intervention which acted as an environmental experience aiming in changing motor and academic behaviours.

The other area that this research is related with is educational area. It has been established throughout this thesis that the area of education needs new programmes that will benefit children. Materials and findings from the current thesis can be used to inform schools and the education area in general about the benefits of a MSI on children's motor skills and potentially academic skills.

Since this research investigated the relationship between the motor and academic fields it has drawn upon several areas some of them involving; sports psychology, pediatric exercise, school health, and relevant literature on motor skills. More specifically, the areas of the thesis that refer to the reported gains of exercise and motor activity are related to the wider fields of sports psychology and pediatric exercise. Additionally, the fact that the intervention focused on TDC is related with the field of school health and the promotion of the benefits of having active children. The sections dedicated to motor development, motor skills and their influence and contributions to a child's development can be placed under the umbrella of the literature on motor skills and motor learning. Finally the sections discussing the selection of the theoretical approaches that the MSI was based on, their strengths and weaknesses can be incorporated to the wider area of research on motor skill approaches as a method of improving children's skills. One of the strongest points of the current thesis was its interdisciplinary nature which offered a spherical perception and knowledge of the wider research areas. Hence the current research can be situated within a diverse variety of wider fields.

6.9. What Remains Unresolved?

Following the completion of every study, some issues remain unresolved and they also provide the basis for future research. Some of the questions that arise after completing this research are:

- Can a motor skills intervention based on a combination of process and task oriented approaches improve academic abilities at a statistically significant level?
- Will the gains currently found in the motor performance remain stable in the long-term?
- Is there a specific time frame that is needed for the MSI for the Early Years to show positive effects on academic skills?

- Are reading and maths the academic skills that are mostly affected by this interaction?
- Can there be a direct connection between specific motor and academic skills or the relationship is based on underlying factors?
- To what extend can a motor skills intervention affect motor skills and academic functioning by possibly overcoming other restricting factors such as; parenting styles, low socioeconomic status, sedentary lifestyles?

These, among others, are some of the unresolved issues that arose from the research and also provide the grounds for future research that will be presented in Chapter seven. In the next section the research's limitations are discussed.

6.9.1. Limitations

In an ideal world research would be flawless, but as with all research this study had limitations as well as strengths. The current research was quantitative, although there was a smaller qualitative aspect as well. But since the qualitative aspect was only used for observational feedback and for some of the intervention's amendments the research outcomes were explained based on statistical analysis. Quantitative analysis is widely used to measure the experimental effects on various variables. Some would argue that by applying a quantitative approach the research lacks a more in depth understanding of the phenomena studied. The best solution is to use both approaches together, although it might be more time consuming and not always necessary, depending on the nature of the research. For the present research, the quantitative approach was followed to provide more detailed and objective feedback on the effect of the intervention on the outcome variables. Furthermore, since the design of the research was experimental a quantitative approach was the best option. A quantitative approach is also free of possible researcher's bias in interpreting the data.

Another characteristic of the intervention that can be considered as a limitation is the fact that the majority of the tools and activities have not been widely used before in these combinations. Although most of the tools were familiar to the school setting, they have not been used before in such combinations so there were no established norms for their effectiveness. On the other hand, this can be considered as one of the elements of the research's originality, since it introduced a new set of activities to the intervention.

A third limitation was the relatively small sample size. The intervention included the reception classes of two schools. Although the majority of the children participated the total sample was 56 children and was further divided to experimental and control groups. Practically, it was not possible for the researcher to deliver the intervention to more than two schools. A possible reason that there were no significant effects on the academic areas might be that the sample size was not large enough to document these changes in performance. A future suggestion for further research might include more people delivering the intervention to more schools, resulting in having a larger sample size.

Another limitation could have been the duration of the intervention. Although, the total duration was selected upon ethical criteria, to easily fit to the school's schedule and also according to the duration of previous studies it might not have been long enough for the MSI for the Early Years to positively influence the academic areas.

Linked to the previous limitation, was the fact that children were only assessed immediately after the intervention's completion. If children were also assessed after a few months, maybe this follow-up would reveal significant differences on the academic outcomes that need more time to show. Unfortunately, due to the nature and time-limits that a doctorate encompasses, it was not possible to perform a follow-up.

Additionally, the lack of a high test-retest reliability and validity on the PIPS PE measures is another limitation of the current research which needs to be acknowledged. In the future the use of different measures will be considered.

Finally, although participants were tested before and after the intervention, and were randomly assigned to groups, hence reducing possible differences of the sample, there were some socioeconomic (SES) differences. One of the schools was an independent school and the other was a school in an area of lower SES status. Maybe it would be better if the schools were originally more homogeneous. On the other hand, the study served as an initial evaluation of the intervention therefore, one of the aims was to obtain a sample with a wide range of motor, cognitive and academic development, which justifies this selection. Having a wide range of schools also tests if the intervention can be applied across all levels of attainment which is of major importance based on the pragmatic character of the MSI for the Early Years.

These were the limitations that the current research had, which can be thought as points that form the basis for future research.

6.9.2. Strengths

The current thesis had also some key-points both in the research design and the intervention's delivery that will be discussed in this section and can be characterised as strong. The strengths of the thesis will be divided into two categories namely; research's strengths and intervention's strengths.

Strengths of Research Design

Some of the strengths of the current research are summarised below:

- Strong experimental design (pre-test/post-test), to control for confounding variables.

- Inclusion of a control group, to compare against the experimental group and test the intervention's effectiveness.
- Random assignment of participants to groups (intervention/no-intervention group), to achieve group's homogeneity. It is not very easy to apply a RCT in educational research, but there has been an increasing need for robust RCT evaluations of school-based interventions such as several RCT programmes funded by the Education Endowment Foundation (2011). Therefore the fact that the current study randomly assigned participants to groups adds to the overall strength of the design.
- Inclusion of a Pilot Study, to test the intervention's tasks prior to the main research.
- Mixed methods approach by combing quantitative approach with qualitative elements.
- Development and use of intervention score-sheets, to monitor progress.

The above are some of the main strengths related to the design of the research and its methodology.

Strengths of the Intervention

Some of the intervention's strengths are summarised below:

- Research-based motor skills intervention, to have a solid basis to design the intervention.
- Development of a detailed manual of the intervention, for the intervention to be easily replicated within schools in the future, and for educators to monitor the intervention's standards.
- Development of detailed instructions that accompany the manual, to ensure that the intervention is administered with the correct approach and behaviour.
- Widely affordable, to be easily included in all settings.

- Pragmatic Design, to be flexible and easily incorporated in the educational setting.
- No need for trained personnel, to lower the total costs, be administered at the most convenient time for the schools and increase the sustainability of the intervention.
- Easily fits the daily school schedule, to increase its flexibility and not causing "gaps" in children's academic performance.
- Can be administered in small groups, to save time compared with a one-to-one administration.
- Increasing difficulty levels over time, to maintain children's interest and control for ceiling effects resulting from practise.
- Weekly stage-model design, in which children can advance through stages faster, or remain to the same stage longer, according to performance.
- 15-20 minutes short and flexible duration of each session.
- Improves manual dexterity and ball skills as the current findings have documented.

The above points are some of the strengths of the current intervention. It is important to report at this point that many of the strengths of the MSI for the Early Years were created through the attempt to overcome limitations of past interventions or limitations in the evaluation of school-based interventions in general. For example the development of a manual was one of the main issues because from the previous literature it became evident that one of the major limitations of the various interventions that are delivered to schools is the lack of specific guidelines that can be followed and replicated successfully. Moreover, the need for an increase in the application of RCT designs in the educational research in order to better evaluate school-based programmes has been addressed.

6.9.3. Future Research

Suggestions for future research originate both from the research's limitations and the research's objectives and interests in the area. Future research should reduce the weaknesses of the current intervention's design and characteristics, as well as focus to provide answers on important areas that remain vague. First, the future research suggestions have been derived from the current research's limitations. Second the suggestions that follow the unresolved issues in the research area will be presented.

6.9.3.1. Future Suggestions for the Current Research

Namely the suggestions for future research include; a larger sample, a longer duration, test the intervention's effectiveness on other academic or cognitive skills, include qualitative data, some activities could be more physically intense, introduce extra difficulty levels during the course of the intervention, collect longitudinal data, perform a long-term follow-up assessment, adding a parental questionnaire measure, add measures of attention or self-esteem and the use of alternative assessment tests.

A larger sample size might obtain significant results as well as a longer duration might yield even better results that will better document the effects of the MSI for the Early Years on the various variables. Additionally, testing the effects of the intervention to other cognitive or academic areas (memory, language) might be important for the evaluation of the intervention's effectiveness in other areas that as research suggests a motor skills intervention can be influential (Iverson, 2010). Since studies report positive gains not only in reading and maths but also in other areas such as language, maybe this variable should be considered too. Success in detecting the effects of an intervention programme on academic performance depends both on the selected outcome measures and the measures' sensitivity to change. Additionally, the MSI for the Early Years might benefit from a more extensive qualitative aspect such as teachers' questionnaires or reports that will complement the quantitative data and provide a different perspective to the intervention's effectiveness. Finally, some changes in the actual intervention might prove beneficial in the future. Some of these changes might include the increase of the physical activity levels by making some activities more intense or longer. Maybe some of the tasks were not physically intense enough to affect some gross motor skills and ultimately academic skills. Furthermore, the intervention could benefit from adding additional difficulty levels during the course of its delivery and especially on the tactile activities. By progressively introducing extra levels with increased difficulty activities would be both more challenging and also would reduce the children's possible frustrations making the task more interesting. Another suggestion for future research is collecting longitudinal data. A future longitudinal study will provide a cumulative perspective to the research. In addition longitudinal research will also add to the literature suggesting that the effects of motor skill interventions appear to be long-lasting over the years (Parham, 1998; Polatajko et.al., 1991). Additionally, a delayed follow-up of the children a few months later would show if children did actually improve in academic skills as well, but the effects needed longer to show, thus no significant effects were currently obtained in the immediate post-test. Thus, testing children after a period of rest can enrich the study's results in the future. Furthermore, anecdotal data can be used to select some individual case-studies (three or four) and observe the various trajectories of different children.

Based on the extended literature identifying the significant role of parents on their child's physical activity a future study would benefit from the inclusion of a questionnaire referred to parents (Radziszewska et.al., 1996; Rhee et.al., 2006). More specifically the use of a questionnaire identifying the different parental styles as well as the parents' physical activity levels would add important information to future research. Since both parenting styles and parent's physical activity levels are so influential then receiving information on that area would provide a more comprehensive view of the child's background. Additionally, this information can be further used to develop activities tailored to help the child increase his/her physical activity levels in the house environment or add more activities for the children who will appear to receive poor physical activity levels in the motor skills intervention followed.

An additional suggestion is to include a measure of attention or self-esteem since previous research suggests that both variables can be associated in changes to children's performance. Finally, the use of different motor assessment tests with higher reliability and validity would improve the overall quality of future research.

The other category of future suggestions mainly involves the research area of motor skills and academic skills.

6.9.3.2. Future Suggestions for the Research Area

When investigating a research area, the researcher initially develops some research objectives and concepts relating to the research area. During the course of this investigation additional research questions arose and suggestions for future research. An important aspect of a motor skills intervention is to include activities that can be easily fit in a school day and have a multisensory nature to activate children's sensory systems and help them engage in adaptive behaviours. In the process of searching for schools, the above need became stronger, since schools were seeking for motor skills interventions that can be easily embodied in a school day.

Additionally, it should be noted that as research suggests when children are engaging in a programme which involves practising fundamental motor skills they can potentially become proficient in these skills by the age of six (Riethmuller et.al., 2009). Therefore, the development of more interventions targeting motor skills is essential in order to enhance children's physical activity which is advantageous in its own right.

Another important point that emerges from the current research is the need for interventions to be designed for and addressed to TDC. The preventative role of early intervention programmes is very important and can decrease other negative influences that might derive from other factors. Such factors usually are: a sedentary lifestyle, authoritarian parenting style, limited opportunities to engage into physical activities and obesity. One of the main aims was to design an intervention that can benefit all children rather than benefit only children with very specific needs. Inevitably, there will be different levels of benefits among children, but it is important to support motor skills intervention in order to help children increase their movement levels from an early age. Other than increasing physical activity levels in the school environment an important consideration for the future is the development of programmes that can be delivered within the family environment and enrich the child's time while in home. Another important finding is the fact that although the intervention did not benefit children, neither did it cause harm. Therefore, future research should consider this finding answering in criticisms suggesting that taking the groups away from their usual school activities can have a negative effect on children's performance.

Another suggestion is to investigate further the exact connecting link and mechanisms that are involved between motor academic and cognitive development. Many theories have emerged-but none has fully explained this relationship. A possible scenario might be that the link between the two is that of attention. Attention is associated with reading accuracy (Fuchs, Fuchs, Hosp & Jenkins, 2001). At the same time children with ADHD can also have difficulties in their motor skills as it has already been established. The role that attention plays in this relationship should be further studied. A future study should consider the effect that attention can have on a child's performance on both motor and academic tasks and should monitor this variable before and after an intervention. If attention is measured and controlled then it may be possible to discover its effect on motor skills school-based interventions.

Finally, any future studies should use a well-designed intervention, based on theoretical constructs and measure its effectiveness with standardised tests for better evaluations and valuable feedback. The current area of research is still developing and due to its complex nature further research is needed to shed light to this controversial relationship and add to the current knowledge.

CHAPTER 7

CONCLUSIONS & IMPLICATIONS

7.1. Introduction

The previous Chapter discussed the findings of the research offering several interpretations. Additionally, the limitations and strengths of the research were acknowledged and future suggestions were proposed.

This study set out to investigate whether there is a connection between motor skills and academic performance. The relationship between the mind and the body emerged as early as the ancient years of Greek philosophical enquiries, followed by more contemporary theories such as the one of embodied cognition discussed in earlier sections of chapter two. As part of this goal, a theory based motor skills intervention was designed to further investigate the connection between motor and academic skills that as relevant research suggests it is strong. More specifically, the academic areas under investigation were reading and maths and the motor skills involved both fine and gross motor skills. Research findings suggested that children who received the intervention improved on some aspects of their motor performance, but failed to find a similar statistically significant improvement for reading, maths and some motor skills. Some possible explanations for the above findings have been already addressed in previous sections of this thesis. The following sections will present the contributions of this thesis to the wider research area, the implications that derive for both the educational and research fields and will conclude with some final remarks.

7.2. Contributions to the Research Field

This thesis was of a multidisciplinary nature, encompassing different research areas and trying to unite fields that previous research has suggested are related. Although the exact nature of this connection has not been fully understood yet, every new study contributes to the process of gradually revealing the origins of this connection and explaining which motor areas affect the academic and cognitive areas. Every research problem has a background which encompasses both indirect and direct connections with the research questions. More specifically, for the current research the indirect areas that were involved included: an overview of the nature-nurture debate, a presentation of some of the most prevalent of motor development, and some more specific theories on the connection between motor and cognitive development. Some other areas presented that were considered to be directly linked with the thesis in question included: previous research derived from different research fields that has provided supporting evidence for the relationship between motor skills, academic performance and cognitive functioning, the presentation of some of the other interventions that have been used to improve academic or motor performance, the approaches that the current intervention was based upon and the detailed presentation of the MSI for the Early Years. These areas can be considered to be directly linked with the research problem, since they address the most contemporary views and research on the area and present the newly developed MSI for the Early Years. Therefore, before presenting the contributions of the thesis to the research area it would help to identify the areas that have been influenced by the current research.

The areas that have been influenced involve the research field that investigates the relationship between motor and cognitive functioning, the area that designs and develops motor skills interventions, and more generally the literature involving research in the educational setting. These influences have been discussed in the form of the original contributions that the current thesis provided to the aforementioned areas.

This thesis provided original contribution to the literature and research area in general in several ways:

- The thesis showed that some areas of motor performance (manual dexterity and ball skills) can be increased during an 11-week period using a research based motor skills intervention.
- It provided evidence that the MSI for the Early Years can have a positive effect on the motor skills of typically developing children.
- It used a RCT with pre-post design, which is not frequently done in the educational settings but it is advantageous in order to document the real intervention effects.
- It also suggested that changes in academic skills might need more time than 11 weeks to show in TDC.
- It proposed that changes in academic skills might happen when children engage in more intense physical activities or when the intervention is administered more than two days per week.
- It provided further evidence that taking children out of class for specific time periods during the school day does not negatively affect their academic performance.
- It was the first study that used tasks and activities from both process and task oriented approaches with groups of children rather than individuals.
- It designed a new hybrid intervention with tools and activities that had not been used before in such combinations.
- It introduced an intervention of a pragmatic nature that could be easily administered in the school setting as well as measured for effectiveness.

The research area of the relationship between motor and cognitive skills is characterised by a lack of widely recognised motor skills interventions. Furthermore, there is no robust evidence of their impact using randomised control trials. This gap was a challenge and an opportunity for the current thesis to develop a new intervention and make an original contribution to this fast growing research area. The next section is a discussion of the implications of the current research to both the research and the educational fields.

7.3. Implications for Research & Educational Fields

The current research originated from the enquiry of the relationship between motor skills and academic performance. Generally, previous research can be characterised as controversial, since there are studies providing evidence that support the relationship; see for example; (American Academy of Pediatrics, 2011; Washington 2005), and on the other hand there are studies that fail to support the relationship, or results are inconclusive (Coe et.al, 2006; Grissom, 2005). Over the years several motor skills programmes have been developed to further test this relationship, but results are yet controversial. The main reason for this “phenomenon” is the complexity of the area that makes it harder to document the potential significance of the effects. One of the explanations might be that while the previous motor skills programmes did improve cognitive or academic skills, the tests used were not sensitive enough to document these effects. Additionally, other factors such as, research design, sample size and duration can influence research findings. Although the relationship between motor skills and cognitive development seems difficult to study the findings of the current thesis offered implications for the research and educational areas.

The findings of the present research showed significant improvements in the performance of some motor skills namely; manual dexterity and ball skills. At the same time findings failed to find significant gains in the academic skills in question. Starting with the significant findings in motor skills it is being revealed that a hybrid intervention such as the MSI for the Early Years can improve the performance of TDC in reception class in 11 weeks duration. Comparing with other therapies that are usually delivered in an individual level the current intervention attempted to administer the programme in small groups and achieve the same positive results in the area of motor skills. The above was accomplished in a motor but not in an academic level. Since the MSI for the Early Years was a combination of process and task oriented approaches, it can be inferred that such an intervention positively affects the aforementioned motor skills in reception classes.

Furthermore, another important implication can be derived from the fact that the intervention was administered to TDC. Traditionally, motor skill interventions are being developed for atypically developing children but the current research provides supporting evidence of the effectiveness with TD populations as well. Moreover, the current findings further support the idea that a structured motor skills intervention can increase specific motor skills of school aged children (Deli et.al, 2006). This finding has important implications suggesting that a structured motor skills programme can improve physical performance on TDC. Overall, findings can be used as a future reference in the research areas exploring motor interventions and their effectiveness on improving specific motor skills in the mainstream.

The importance of the non-significant findings is also significant, since they inform the research area about steps or characteristics that should be avoided or need to be altered in the future. It is always preferable to find significant results that provide evidence for the area of study but non-significant ones can have important implications too. Current results failed to find a significant relationship between the MSI for the Early Years and the skills of reading and maths as well as some of the motor measures. Regarding the academic skills this can add to the research supporting the need for a larger population as well as either longer duration of the intervention in total or increase of the weekly sessions (Strong et.al, 2005). Additionally, findings reported some small to moderate effect sizes in other areas of motor skills as well as reading and maths. These findings although non-significant may be used to inform the research area that a motor intervention inspired by both the process and task oriented approach can potentially improve the remaining motor areas and academic performance.

Regarding the motor skills that did not report significant findings such as; static balance and walking, it can be implied that these motor skills cannot be easily tapped through the underlying processes involved in process oriented activities. Therefore, future research should acknowledge this during the selection of the motor measures. Overall, the non-significant findings can inform the areas that investigate the effects of motor programmes on reading, maths and some motor skills on which intervention elements should be given more attention.

Other than the implications that this thesis appears to have in the research area, there are implications relating also to the educational settings. From the current findings it can be inferred that a structured motor skills intervention with pragmatic nature can improve children's motor skills. Some very important characteristics that an intervention should have in order to be easily accessible from schools are: affordable, not time-consuming, to have the option of being administrated by non-trained stuff such as teachers and to have research evidence of its effectiveness. Findings show that the MSI for the Early Years improved motor performance while using widely affordable tools, needing a short time to be administered and without the need of trained staff for its delivery. Also, findings did not report any decrease of the intervention group to either reading or maths performance, indicating that the time children spent out of the class did not negatively interfere with their academic performance. This finding provides implications to schools that if children spend time engaging in a motor skills intervention rather than being in class then their academic performance is not negatively affected. This finding also comes in agreement with previous research suggesting that time spent in physical exercise does not negatively affect academic performance (Castelli et.al., 2007). Many studies have reported that gains in physical activity have important health implications (Donelly & Lambourne, 2011; Stone et.al., 1998). There is growing evidence to suggest that being physically active promotes healthy behaviours whereas physical inactivity can be a risk factor for several unhealthy conditions. The MSI for the Early Years showed improvements in some of the motor skills of children which have similar positive implications for promoting motor skills programmes. Additionally to the findings that derive from the statistical analysis, the researcher's observations showed that children enjoyed the MSI for the Early Years in general, but they mostly enjoyed the fact that the intervention was changing during its course and was becoming more challenging. The above observation although it cannot be grouped together with the quantitative findings has important implications for the educational settings, suggesting that children are open to challenge and enjoy change over time. Conclusively, present findings can help schools to establish criteria that future motor skills interventions should involve.

Another important finding that has implications for the educational setting was derived from the multilevel modelling analysis that took place using the database from CEM. More specifically, during the multilevel modelling analysis motor development appeared to be a significant predictor of academic performance and its effects remained stable over a period of six years. This finding has important implications for the development of school policies. Since motor development can predict aspects of academic development while having long-lasting effects the importance of the role of motor activities in the school setting should be re-considered. A possible future scenario is the inclusion of structured motor programmes within the school day. In the vast majority research in this area documents positive gains on children who engage in motor activities both in their motor and academic performance. Hence it would be beneficial for future policies to re-evaluate the school curriculum while adding additional motor tasks.

Overall, the present thesis provided implications for the areas of; process and task-oriented approaches to intervention, the research areas investigating motor skills interventions and its effects, schools criteria and standards regarding motor skills intervention and children's needs.

7.4. Concluding Remarks

It has been established that early years continue to be a milestone for later development. Therefore, the role of researchers in the investigation of possible connections among the various developmental pathways in order to produce structured interventions is vital. Human development is a complex process which involves the participation of multiple systems that act both individually and in collaboration with other systems affecting progress over time. Research in this area is essential since the typical development of a child is strongly connected with every aspect of a person's life. For that reason researchers should continue to explore the undiscovered areas of human development and help creating a better future. Future research may lead to significant discoveries of the complex relationships between psychology, cognition, neuroscience and pedagogy. Since the positive impact of having physically active children can be traced back to the ancient years researchers need to help children achieve their full potential. The importance of non-academic components such as motor development in the early years should not be underestimated compared with the development of academic skills such as reading and maths. As this positive impact is receiving growing support, the future role of the researchers in the area is to combine today's knowledge with the knowledge of the past to shape the future.

Appendices

Appendix 1- Nature-Nurture Research

Plomin & Asbury, 2005: This study suggests that nature and nurture are in a continuous interplay with each accounting for about half of the variance. An interesting example is schizophrenia which was considered to be the result of poor parenting up until the 1960s, where twin and adoption studies found evidence to change this view. These studies made it clear that schizophrenia has a strong genetic background. On the other hand twin studies showed that only the 45% of identical twins were concordant for schizophrenia. This discordance can only be explained by the influence of environmental factors.

Plomin 1989: The focus of this study was the research on the heritability of intellectual, personality factors and psychopathology. This interest is described in detail by providing evidence of the strong genetic basis for: IQ, specific cognitive abilities, academic achievement, reading disability, mental health problems, personality factors (neuroticism) and psychopathology (schizophenia). Data indicate that genes influence behaviour and development but also indicating that the environment is responsible for the other half. An interesting aspect of research that is discussed is the findings which show that siblings brought up in the same family show greater differences than similarities. These findings imply that environmental influences differentiate children in the same family. Therefore, they act on an individual-by-individual basis rather than on a family-by-family basis. To conclude, behavioural genetic research clearly shows that nature and nurture act together.

Thompson et.al, 2001: the focus of this research was the investigation of how genetic influences are expressed by the brain and the heritability of both cognitive and linguistic skills. Some of the cognitive skills which are highly heritable are: IQ, verbal, spatial abilities, perceptual speed and also personality qualities such as: reactions to stress. In the current study the researchers aimed to map specific brain regions which are under significant genetic control and how these are expressed through several cognitive functions. These brain maps showed significant relationships among genes, brain structure and behaviour. Therefore the highly heritable parts of the brain structure can be fundamental in finding individual cognitive differences.

Appendix 2- Consent Form

EXAMPLE CONSENT FORM (Teachers Format)

Investigator's Name:

Maria Katsipataki

E-mail: maria.katsipataki@durham.ac.uk

Title of Pilot Study: Can Motor Skills Training Improve Cognitive Functioning? An Evaluation of Structured Interventions for Young Children.

Brief Description of Pilot Study:

This research project aims to explore the relationship between motor skills and cognitive abilities. Children will either be participating in the motor intervention programme that has been developed by this research group or continue with their daily school activities. Both programmes are comprised of tasks that are enjoyable for children of this age. Children will also be tested on their reading, maths and motor development skills, using curriculum assessments and tasks from the PIPS test. The information and explanation given will be in such a way that the children will perceive the testing as a game and not as a strict test, although they will be aware that some scores are recorded. The information gained will be of great value in helping the research group to design an intervention that will help children further develop and improve their skills.

The members of staff responsible for this project (research supervisors) are:

Pr. Joe Elliott, Dr. Christine Merrell & Dr. Susan Bock *from the University of Durham.*

Contact information is available upon request.

<u>Declaration of Consent</u>

I have been informed about the aims and procedures involved in the research project described above. I reserve the right to withdraw any child at any stage in the proceedings and also to terminate the project altogether if I think it necessary. I understand that the information gained will be anonymous and that children's names and the school's name will be removed from any materials used in the research.

Name:

Signed:

School:

Date:

Appendix 3- Intervention's Instructions

SAMPLE DELIVERY INSTRUCTIONS FOR THE "MOTOR SKILLS INTERVENTION FOR THE EARLY YEARS"

ACTIVITIES

(EXAMPLE OF SESSION ONE)

MARACAS: Have you seen these before? These are called Maracas. We are going to play with them in a while. Let me tell you what we are going to do: First we are going to hold one Maraca tight with both our hands (like that: visual aid) and then we are going to move the Maraca. I will count until 3: 1, 2, 3 and then we will move the maraca up to the sky (like that: visual aid) to make them light.

Okay? Let's try it together now. (Giving the maracas to the children) Ready? Hold the Maraca tight with both hands: 1, 2, 3: up to the sky. Well done. Now try it yourselves.

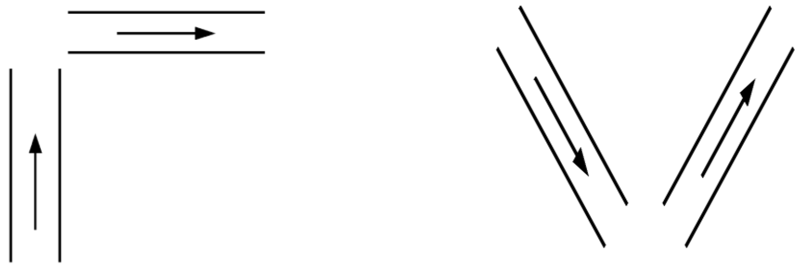
(The same procedure will be repeated by moving the Maracas down, right and left).

TUBE WITH BALL: Now we are going to "play" with this. Let me show you what we are going to do: This tube has a red ball inside. We are going to hold the tube from the two ends (like that: visual aid) and we will try to make the ball stop in the middle of the tube (like that: visual aid).

Okay? Let's try it together now. (Giving the tubes to the children) Ready? Shake the tube first and now hold the tube as I showed you and try to move right and left and hold steady when it goes to the middle. (Children will be able to try this activity with my help first and then by themselves) (this will involve the first level).

HOPPING ON EACH FOOT: Now we are going to do some hopping. Okay so we are going to hop on one foot counting 3 times: 1, 2, 3. Now let's try it together and try not to touch the floor with the other foot. Good, now let's do the same with the other foot: 1, 2, 3.

MAZES: Do you see the mazes on the floor? Let's make a line behind me one after the other and start walking inside the maze, but be careful not to touch the ropes/tape. Good, now you can try it without me (this will involve the 1st two mazes), (timed activity).



**Mazes sizes:* (Mazes will be 2.50cm length & 30cm width, when mazes become narrower, tape will be put in the middle and the width will become 15cm}.

METRONOME: (optional) Now you will start moving your legs and hands like I do counting to 4. Watch what I am doing and then we are going to do it together. Clapping and moving hands counting to 4 (1, 2, 3, 4)-(repeat the activity 3 times). Great now let's do it together.

CLAPPING: Now we are going to try different ways of clapping. Can everybody see the upper part of their palm? Good only the part with the fingers. Let's touch it together good. Now we are going to start clapping slowly like that: 1, 2, 3. (1 time together) Now can you try to do it without me? (repeat 3 times).

HAND ROTATIONS: We are going to hold our hands in front of our face like that (visual aid) and start moving them like a circle. Let's try together: 1, 2, 3, 4. (clockwise). Good, now you try to do it without me.

PEGBOARDS: Can you see these colourful pegs? (provide children with 15 pegs). Let's all take one pegboard and try to put the pegs inside the holes. We can each make a nice pattern (sun-flower) and see how fast we can do it. You need to be as fast as you can and put the pegs before time runs out. I will tell you when to stop. (timed activity)

PLAY BUTTONS: Take the string, choose a button that you like and try to put the lace into the button's holes (like that: visual aid). Let's try together to put 2 buttons. Even if the button has more than 2 holes, you need to thread only 2 and then move to the next button. Make sure you do it before the time runs out. I will tell you when to stop. (timed activity)

BUCKET WITH RICE: Let's all take a bucket with rice. Inside the rice there are small balls hidden. We have to try and find the balls putting both our hands inside the bucket and search for them. We put both hands together in the bucket and try to find the balls. There are 6 balls that we need to find. Let's see how fast we can find them. (timed activity)

Before children start the 3 last timed activities, it is useful if we ask them to put their hands on their knees for example, we count 1, 2, 3 and say go. In this way all children start at the same time and get prepared.

Appendix 4- Intervention's Score-sheet

Scoring Sheet/ Vestibular Activities							
1.					**4.**		
2.					**5.**		
3.					STAGE 9 & 10		
MARACAS TWO							
	No.of Children	**1.**	**2.**	**3.**	**4.**	**5.**	**Accuracy**
UP		TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
		TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
		TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
	TOTAL						
DOWN		TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
		TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
		TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
	TOTAL						
LEFT		TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
		TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
		TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
	TOTAL						
RIGHT		TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
		TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
		TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
	TOTAL						

TUBE WITH BALLS						
	1.	2.	3.	4.	5.	Accuracy
HANDS IN MIDDLE	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
TOTAL						

HOPPING						
	1.	2.	3.	4.	5.	Accuracy
HOPPING ON RIGHT 8 TIMES	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
TOTAL						

Scoring Sheet/ Proprioceptive Activities

MAZES

	1.	2.	3.	4.	5.	Accuracy & Speed
SNAIL	|	|	|	|	|	
	|	|	|	|	|	
TOTAL						

MIMING-HAND ROTATIONS

	1.	2.	3.	4.	5.	Accuracy
1 HAND CLOCKWISE 1-ANTI	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
TOTAL						

MIMING-CLAPPING

	1.	2.	3.	4.	5.	Accuracy
WHOLE PALM	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	TRIAL 1	
	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	TRIAL 2	
	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	TRIAL 3	
TOTAL						

Scoring Sheet/ Proprioceptive Activities

PEGBOARDS

	1.	2.	3.	4.	5.	Speed
PEGBOARD 2 5 PEGS (45'')						
TOTAL						

PLAY BUTTONS

	1.	2.	3.	4.	5.	Accuracy & Speed
6 BUTTONS	|	|	|	|	|	
TOTAL						

BUCKET WITH RICE

	1.	2.	3.	4.	5.	Speed
2 BALLS HIDDEN (25'')						
TOTAL						

Appendix 5- BPS Conference-Poster Presentation

Appendix 6- Multilevel Modelling Analysis Models

Tables from 1st Analysis:

School Year: 2004	**NULL**		**Model 1**		**Model 2**		**Model 3**	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects								
Constant	-0.017	0.056						
Age			0.255	0.003	0.101	0.008		
Sex					-0.09	0.023	0.010	0.019
Motor Development							0.602	0.028
Random Effects								
School Level	0.062	0.025	0.031	0.009	0.032	0.009	0.026	0.007
Pupil Level	0.94	0.044	0.119	0.006	0.117	0.005	0.078	0.004

School Year: 2005	**NULL**		**Model 1**		**Model 2**		**Model 3**		**Model 4**	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects										
Constant	-0.023	0.052								
Age			0.245	0.002	0.108	0.008	0.009	0.010		
Sex					-0.064	0.013	-0.024	0.012	0.002	0.019
Motor Development							0.552	0.03	0.332	0.035
PSED									0.621	0.038
Random Effects										
School Level	0.174	0.035	0.032	0.006	0.033	0.006	0.024	0.004	0.02	0.004
Pupil Level	0.839	0.028	0.072	0.002	0.071	0.002	0.061	0.002	0.047	0.002

School Year: 2006	NULL		Model 1		Model 2		Model 3		Model 4	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects										
Constant	-0.055	0.057								
Age			0.195	0.002	0.194	0.002	0.106	0.004	0.053	0.005
Sex					-0.078	0.014	-0.038	0.013	-0.001	0.015
Motor Development							0.446	0.021	0.225	0.024
PSED									0.508	0.024
Random Effects										
School Level	0.276	0.046	0.046	0.007	0.044	0.007	0.038	0.006	0.02	0.004
Pupil Level	0.666	0.019	0.097	0.003	0.095	0.003	0.081	0.002	0.057	0.002

School Year: 2007	NULL		Model 1		Model 2		Model 3		Model 4	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects										
Constant	0.002	0.086								
Age			0.186	0.002	0.186	0.002	0.099	0.005	0.045	0.006
Sex					-0.074	0.013	-0.038	0.013	0.011	0.015
Motor Development							0.454	0.026	0.238	0.030
PSED									0.511	0.025
Random Effects										
School Level	0.575	0.094	0.068	0.012	0.068	0.012	0.059	0.01	0.033	0.007
Pupil Level	0.571	0.016	0.113	0.003	0.112	0.003	0.1	0.003	0.08	0.003

School Year: 2009	**NULL**		**Model 1**		**Model 2**		**Model 3**		**Model 4**	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects										
Constant	-0.042	0.074								
Age			0.122	0.001	0.123	0.001	0.075	0.002	0.042	0.003
Sex					-0.025	0.007	-0.007	0.006	0.013	0.007
Motor Development							0.388	0.02	0.216	0.023
PSED									0.487	0.027
Random Effects										
School Level	0.338	0.063	0.014	0.003	0.014	0.003	0.011	0.002	0.006	0.001
Pupil Level	0.459	0.014	0.023	0.001	0.023	0.001	0.02	0.001	0.016	0.001

School Year: 2010	**NULL**		**Model 1**		**Model 2**		**Model 3**		**Model 4**	
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)
Fixed Effects										
Constant	-0.034	0.078								
Age			0.207	0.002	0.207	0.002	0.131	0.006	0.066	0.008
Sex					-0.036	0.015	0.002	0.014	0.042	0.015
Motor Development							0.363	0.026	0.192	0.030
PSED									0.473	0.035
Random Effects										

School Level	0.224	0.056	0.026	0.006	0.026	0.006	0.019	0.005	0.016	0.005
Pupil Level	0.766	0.03	0.065	0.003	0.065	0.003	0.057	0.002	0.048	0.002

Tables from the 2nd Analysis:

School Year: 2004	**NULL**		**Model 1**		**Model 2**		**Model 3**
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est. (SE)
Fixed Effects							
Constant	-0.044	0.084					
Start of Nursery			0.792	0.017	0.594	0.054	0.5990.053
Sex			-0.074	0.061			
Motor Development					0.744	0.018	
Random Effects							
School Level	0.197	0.058	0.196	0.059	0.305	0.077	
Pupil Level	0.843	0.039	0.842	0.039	0.277	0.013	

School Year: 2005	**NULL**		**Model 1**		**Model 2**		**Model 3**		**Model4**
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est (SE)
Fixed Effects									
Constant	- 0.005	0.062							
Start of Nursery			0.873	0.018	0.868	0.018	0.502	0.060	0.405(0.059)
Sex			- 0.213	0.063	- 0.075	0.033	-0.019	0.027	
Motor Development					0.884	0.018	0.441	0.069	
PSED							0.51	0.068	
Random Effects									

School Level	0.246	0.054	0.258	0.056	0.508	0.075	0.541	0.083	
Pupil Level	0.798	0.039	0.785	0.039	0.198	0.01	0.107	0.006	

School Year: 2006	**NULL**		**Model 1**		**Model 2**		**Model 3**		**Model4**
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est. (SE)
Fixed Effects									
Constant	0.002	0.073							
Start of Nursery			0.922	0.020	0.926	0.020	0.721	0.047	0.582 0.064
Sex			-0.081	0.059	0.062	0.039	0.104	0.043	
Motor Development					0.893	0.022	0.285	0.060	
PSED							0.746	0.062	
Random Effects									
School Level	0.231	0.055	0.233	0.055	0.267	0.056	0.194	0.047	
Pupil Level	0.783	0.032	0.781	0.032	0.326	0.013	0.242	0.012	

School Year: 2007	NULL		Model 1		Model 2		Model 3		Model 4
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est. (SE)
Fixed Effects									
Constant	0.019	0.11							
Start of Nursery			0.873	0.016	0.871	0.016	0.658	0.035	0.640 0.047
Sex			-0.156	0.044	0.006	0.027	0.036	0.031	
Motor Development					0.846	0.018	0.445	0.049	
PSED							0.451	0.048	
Random Effects									
School Level	0.552	0.12	0.551	0.12	0.152	0.034	0.15	0.037	
Pupil Level	0.619	0.024	0.613	0.024	0.233	0.009	0.22	0.01	

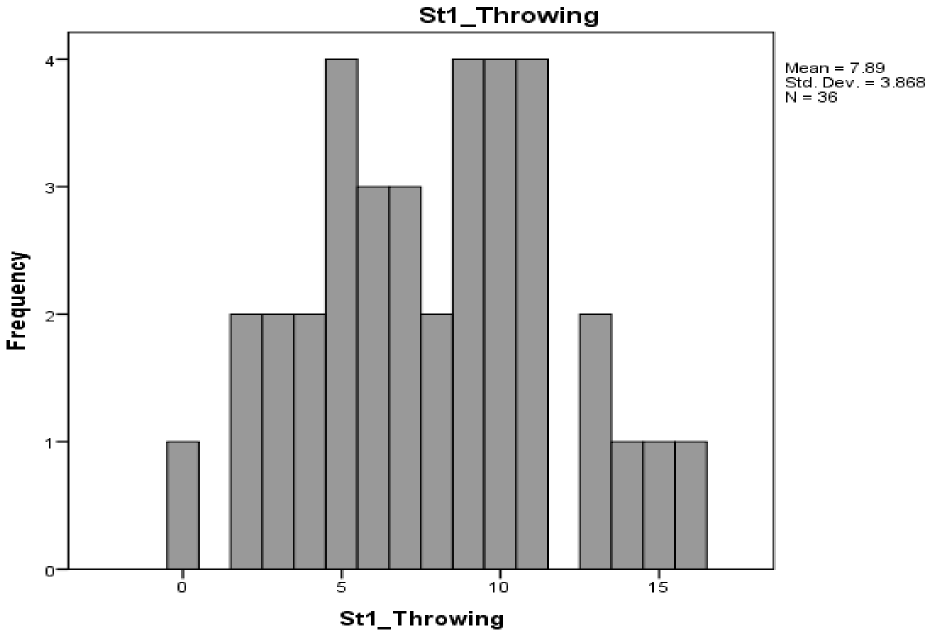
School Year: 2009	NULL		Model 1		Model 2		Model 3		Model 4
VARIABLE	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est.	(SE)	Est. (SE)
Fixed Effects									
Constant	-0.019	0.105							
Start of Nursery			1.697	0.019	1.694	0.019	1.344	0.050	1.210 0.067
Sex			-0.081	0.053	0.027	0.023	0.058	0.021	
Motor					1.606	0.024	0.631	0.067	

Development									
PSED							1.118	0.074	
Random Effects									
School Level	0.341	0.091	0.329	0.087	0.126	0.032	0.102	0.028	
Pupil Level	0.648	0.029	0.637	0.029	0.114	0.005	0.089	0.004	

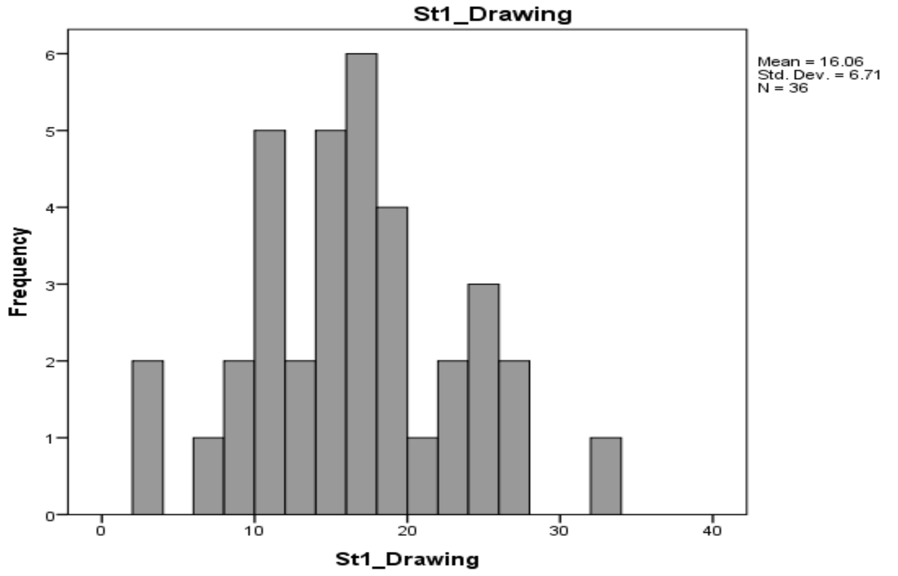
Appendix 7-Validity Correlations & Distribution of Scores for PIPS PE & EYFSP

Correlations between EYFSP scores & PIPS PE scores							
Measure	St1.Throw	St1.Draw	St2.Catch	St2.Throw	St2.Draw	Total.Start	Total.End
EYFSP	0.081	-0.344	0.109	0.207	-0.369	-0.311	-0.224

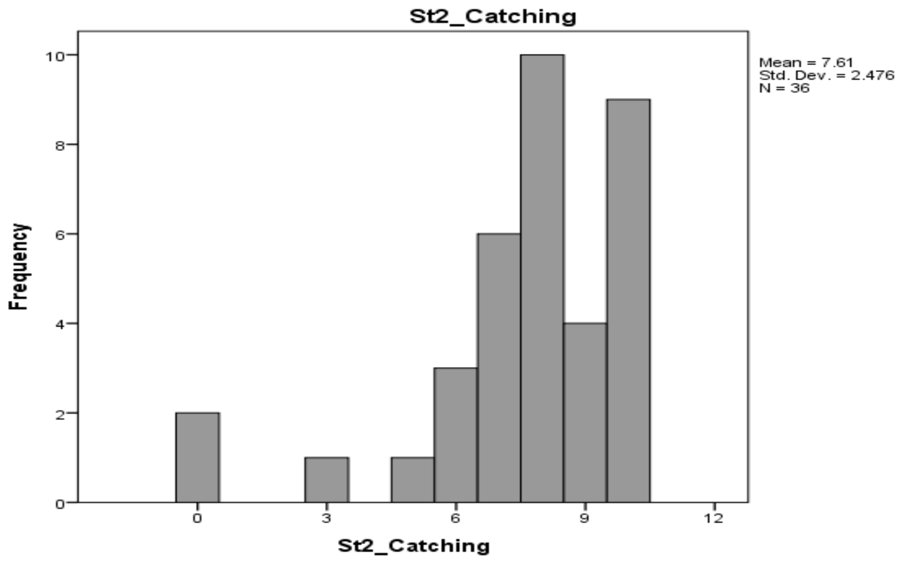
St1.Throwing Distribution of Scores



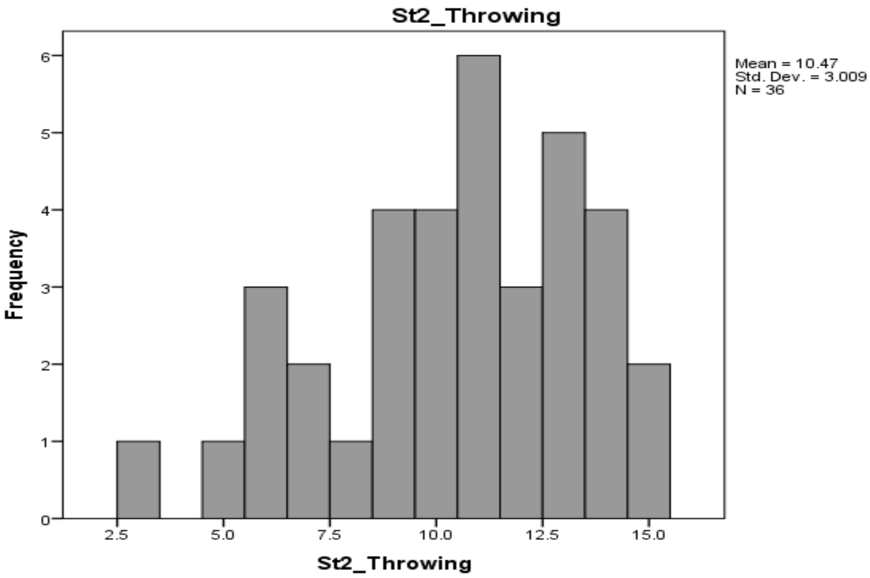
St1.Drawing Distribution of Scores



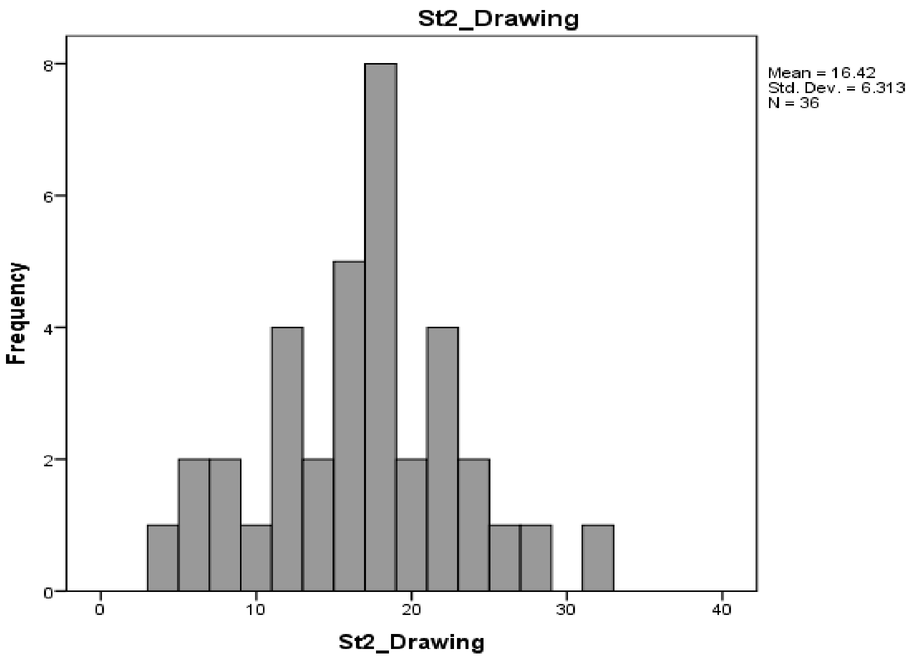
St2. Catching Distribution of Scores



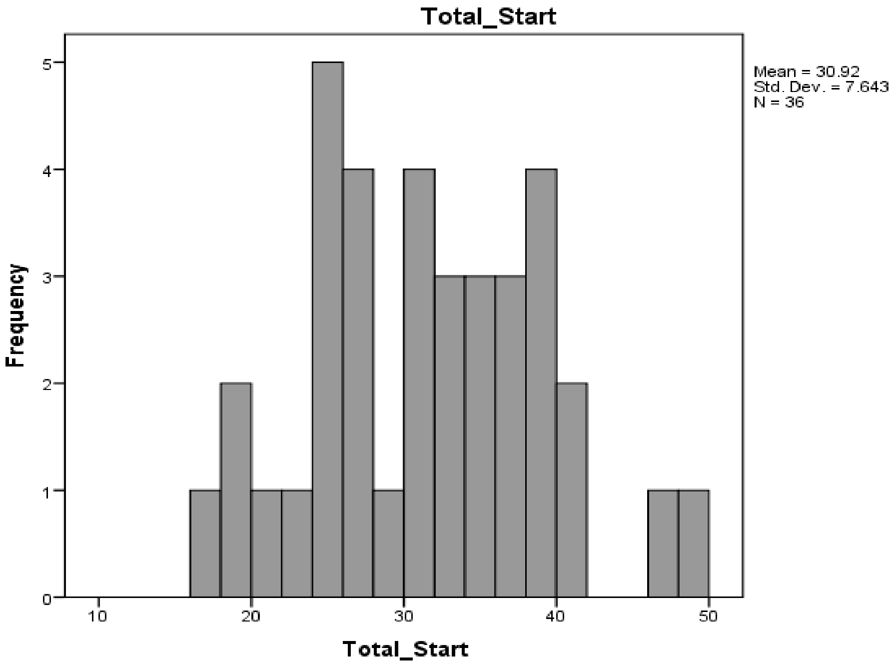
St2.Throwing Distribution of Scores



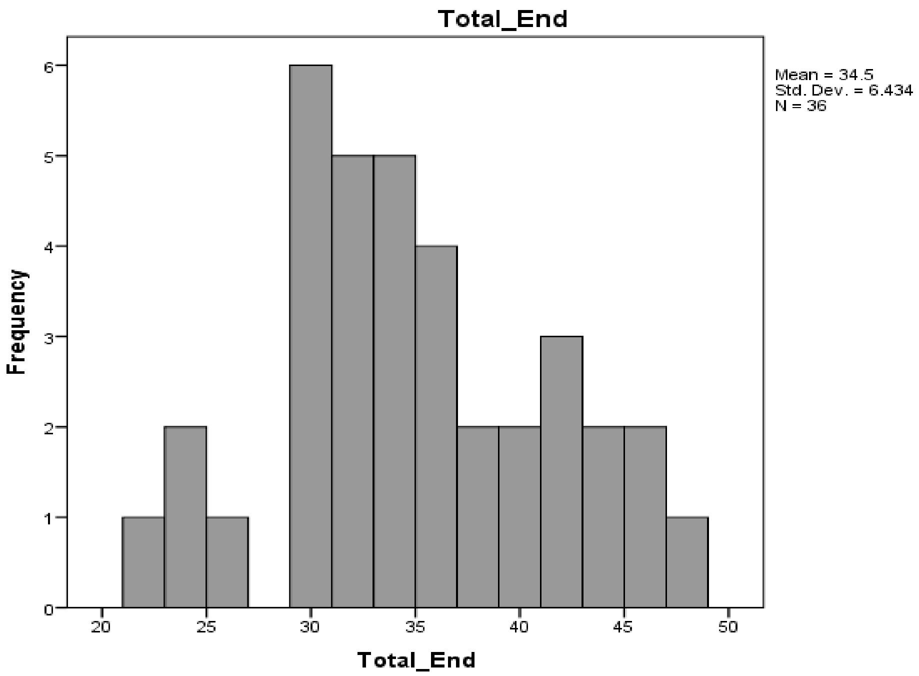
St2.Drawing Distribution of Scores



Total Start Distribution of Scores



Total End Distribution of Scores



Appendix 8- Qualitative Research Diary

- Initially there were 5 trials for almost all tasks. After the delivery of the 1st session it was decided to decrease the number of trials, to 3, 2 or 1 depending on the task.
- After the continuous absence of a randomly selected child (4 sessions) in the experimental group, another child was randomly selected and replaced that child.
- Timed tasks were revised, with the first 2 sessions acting as a baseline to set the time limitations of these tasks.
- Observation that children overall are gradually improving.
- Observation that some children were advancing faster than others. So after half-term some of the groups changed to become more homogeneous and receive the intervention at the appropriate difficulty level.
- In groups that appear to advance faster there is the option to move more levels than the ones that do not advance in the same pace.
- Tasks that children showed more improvement from their initial performance are: tube with balancing ball, hand-rotations and hopping.
- Changes took place in some tasks: (a) Introduction of different speeds (slow-medium-fast) to the maracas, clapping and hand-rotations. (b) Mazes: pausing points while walking on the butterfly and snail maze, which keeps children more focused. (c) the metronome task was originally in the intervention, but after the first session the activity was excluded because it was too easy for the children. (d) in the buckets with rice activity the small balls were substituted with buttons (the same buttons from the threading task), and when children found the buttons they were allowed to continue to the threading task. (e) maracas: cross their hands as well while moving the 2 maracas.
- One of the Stages (stage 8) was skipped due to the children’s general performance.

- A future suggestion that was recorded was for the hopping task, on a higher difficulty level children might try to change legs while hopping (e.g. left leg 1-2, right leg 3-4).

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