

CHAPTER ONE: INTRODUCTION

1.1 Overview

This chapter briefly introduces the broad themes of this present study including an exploration of the theoretical and practical significance of the study, an investigation into human lateral preference, cross lateral preference and its affect on directionality and the acquisition of pre-writing skills, early handwriting skills, letter/number formation and learning in general. Also it explores the implications for children and young people who experience difficulty acquiring these skills. This chapter introduces how this study relates to education, psychology and the role of the educational psychologist. Finally, this chapter considers the use of multi-modal learning experiences coupled with the use of educational technology, and whether in this highly technological age handwriting remains a skill that needs to be acquired.

1.2 Amplification of the Title

The present study aims to determine the prevalence of cross lateral preference amongst primary aged children within a large local primary school, with a view to conducting an investigation into whether such pupils are disadvantaged in the learning environment. More specifically, the study aims to explore whether pupils with cross lateral preference also experience greater difficulty with letter/number formation due to issues related to directionality. The study investigates the use of educational technology with pupils, combined with multi-modal learning experiences to assist children in their development of motor, visual and auditory memory for letters and numbers, which ultimately should aid recognition, formation and learning in general.

1.3 Theoretical and practical significance

An explanation of the study's theoretical and practical significance will now be highlighted, taking into account the need to improve the literacy and numeracy skills of young people in the UK, and the impact of human lateral preference on the development of these skills.

1.3.1 The Programme for International Student Assessment (PISA)

Despite the UK being a relatively well developed country, with an ever evolving educational system, recently published results pertaining to the Programme for International Student Assessment (PISA) suggest as a country we could do better in terms of educating our young people. PISA is an international survey of the educational achievement of 15 year olds organised by the Organisation for Economic Co-operation and Development (OECD). Within this survey that takes place every three years, results for the UK as a whole are included in the international PISA report. The four component parts of the UK namely; England, Scotland, Wales and Northern Ireland contribute to this result in proportion to their populations.

In the 2009 survey the UK as a whole scored just above the OECD mean of 493 points for reading, achieving a mean score of 494 points, ranking the UK as 25th out of the 65 countries involved, well behind the high performing countries of Korea (539) and Finland (536). Also well below Singapore (526), Canada (524), New Zealand (521), Japan (520), Australia (515), the Netherlands (508), Belgium (506), Norway (503), Estonia (501) and Switzerland (501), who all scored in excess of 500 points on this scale. More specifically, for reading, the mean scores in England, Scotland and Northern Ireland were similar to the overall OECD mean and to each other, but in Wales the mean score was significantly lower at 481 points.

Similarly, in mathematics, the UK scored just below the OECD mean of 496 points by achieving a mean score of 492 points, ranking the UK as 28th out of the 65 countries involved. The top performing countries once again were Korea (546) and Finland (541). Further, there were no significant differences between the mean scores achieved for mathematics between the OECD mean and those achieved by England, Scotland and Northern Ireland, but in Wales the mean score for mathematics was significantly lower than the other three at 484 points.

In his speech on the 2nd February 2011, Leighton Andrews, the education minister for Wales at that time, highlighted this, stating that in both reading and writing Wales' mean score for the PISA results was significantly lower than the OECD average and our UK counterparts. A most disappointing result. He announced that all young people in Wales should be able to read and write at an age appropriate level and emphasised that

‘teaching makes a difference’ and that ‘teaching quality matters’. Amongst his twenty actions he places emphasis on the possibility of revising initial teacher training, changing it to a two year Master’s course, with additional classroom practice so that teachers become familiar with advanced teaching skills and focussing Continuous Professional Development (CPD) on system-wide needs, including literacy and numeracy.

In relation to the PISA results of 2009, the OECD Executive Summary (2010) highlights several interesting points potentially pertinent to this study namely:

- girls outperform boys in reading skills in every participating country;
- on average across OECD countries boys outperform girls in mathematics by 12 points; and
- children who have attended pre-primary education tend to perform better than those who have not.

It is interesting but not surprising to note that the PISA 2009 results show that in general, children who attended pre-primary education tended to perform better at the age of fifteen years, than those who did not. In the UK, children who attended pre-primary education for a year or less were found to have the performance advantage of 56 points on the PISA reading scale, and those attending for a year or more 76 points. In an attempt to explain the impact of pre-primary education on later school performance it has been hypothesised by the OECD directorate for education that it is the quality of this education that is important, not just the quantity. This hypothesis is supported by findings that show the impact of pre-primary education on performance tends to be greater in educational systems not only with a longer duration, but where there is lower pupil to teacher ratios and where there is higher public expenditure per pupil enabling adequate facilities and resources to appropriately address the developmental and educational needs of the child.

There is no doubt that in Wales in particular, but also in the UK as a whole there is a need to improve standards of both literacy and numeracy for all children. Given that international comparisons suggest that the quality of early educational experiences is important for future success, this field warrants further examination.

1.3.2 Early educational experiences

In recent years we have seen the introduction of a more play based approach to early education in England and Wales, with ‘The Early Years Foundation Stage’ (EYFS) becoming mandatory in England for all schools and early years providers in Ofsted registered settings, attended by children aged 0 to 5 years in September 2008, and the ‘Foundation Phase Framework for Children’s Learning for 3 to 7 year olds in Wales’ becoming a legal requirement by means of an Order made by the Welsh Assembly Government for all 3 to 5 year olds in August 2008.

Research evidence that underpinned the development and introduction of both of the above, supports the view that young children appear to benefit most when they are placed in an environment that promotes first hand experiential activities through play, freedom of choice and opportunities to socialise. The research evidence also supports the view that young children should have opportunities to learn in ways that are appropriate to their developmental stage, with more structured learning experiences introduced gradually. This echoes the view put forward by the OECD directorate, that it is the quality of the early experiences that are offered to young children that is the variable which is most likely to positively influence future academic performance.

Indeed, the revised and simpler framework for the early years curriculum published on 27th March 2012 by the UK government set out proposals for a new early years curriculum in England for 0-5 year olds which became effective in September 2012. This followed a review of the Early Years Foundation Stage by Dame Clare Tickell in 2011 who recommended less paperwork for early years practitioners and more focus on supporting children’s learning.

Furthermore, the Children’s Minister Sarah Teather in response to the review, reported that ‘The first five years of a child’s life, the foundation years, are absolutely critical.....we know experiences in these first years have the biggest impact on how a child’s brain develops’ (March, 2012). In relation to this the Government is suggesting that everyone who works with the under fives should be qualified to at least A level or equivalent standard, as presently more than 25% of those working with young children only hold GCSE level qualifications. Nutbrown (2012) in her recent independent review of early education and childcare qualifications reports that ‘the qualifications available do not always equip students to be effective practitioners in the early years sector.....Concern has also been expressed about whether qualifications equip them to

work with children with special educational needs and disabilities' (p.7). The Department for Education reports that the changes implemented in September 2012 in England help to ensure that 'parents and professionals can be confident children are developing well and any problems will be picked up early'.

1.3.3 Additional learning needs

If the aim is to improve standards of literacy and numeracy for all pupils in the UK, that will also include those pupils identified as having additional learning needs.

In the very recent SEN and disabilities Green Paper unveiled by the Children's Minister Sarah Teather on March 9th 2011, more than one in five (21%) of pupils in England are identified as having a special educational need, with similar figures being found in the rest of the UK. Such pupils need help very early on in their lives in terms of early identification of need and the implementation of appropriate interventions to help overcome their barriers to learning.

However, as highlighted in the Green Paper, teachers report that they have not always had the training to identify children's needs, and then implement carefully planned and appropriate intervention strategies. This point relates directly to those highlighted by Leighton Andrews, not only does teaching and teaching quality matter, but also the teacher's ability to recognise and appropriately address any barriers to learning.

A key question central to the current study is whether one such barrier to learning is that of confused laterality or more specifically cross-lateral preference (CLP), and the resulting difficulties with directionality which potentially might have a negative impact on learning for some young people? It would appear that not only does this difficulty remain largely unrecognised by many educators and therefore not appropriately addressed, even where this difficulty is recognised or highlighted there appears to be little that educators can access to further develop their knowledge and skills, and few resources available to use with the young people themselves.

1.4 Human lateral preference, cross lateral preference, and its impact on the development of letter/number formation/ handwriting skills and learning in general

1.4.1 Human lateral preference and the origins of laterality

For the purposes of this study, when reference is made to ‘human lateral preference’ (HLP), it is with reference to the lateral biases of the motoric/sensory system. In the study of the lateral biases of the motoric system of the human being, the preferential use of one hand over the other in a variety of tasks and activities, has been of greatest interest historically. The study of handedness and other human motoric biases such as footedness, has continued to this present time. In motor control, as in many other aspects of life, human beings generally choose the path of least resistance to achieve a desired outcome. Anatomical constraints and skill level is considered so as to incur the lowest risk of error. Ward and Cantalupo (1997) believe that this has led researchers to question the possibility of an adaptive function served by human lateral preference.

Furthermore, Ward and Cantalupo (1997) highlight that it was generally believed until the 1980s that both handedness (Warren, 1980) and cerebral hemispheric lateralisation (Levy, 1977; Luria) were unique to humans. As a result researchers did not consider other species to provide information regarding the possible adaptive significance of lateralisation. In the past two decades or more, laterality in non-human species has become an established and widely studied phenomenon in the belief that it may be relevant to the phylogenetic development (the study of the evolution of a trait or characteristic across different species) of lateral preference in the human being.

Ward and Cantalupo (1997) postulate that the origins of laterality must be very ancient due to the fact that it has been found to be very common amongst diverse animals such as fish, toads, lizards, chicks, parrots, rats, prosimians and chimpanzees. Ward and Cantalupo hypothesised that either a very ancient common ancestor developed laterality, which has then been maintained in diverse evolutionary lines or that the adaptive significance of lateralisation was so beneficial that it has been favoured many times in natural selection resulting in it appearing as a convergent characteristic.

Iaccino (1993) reports that most animals show strong and consistent paw preference when comparing individual members of the same species. However, he highlights that although preference for one limb may be considered as similar to that found in human beings, substantial variability was found to exist between animals within the same

species, with a 50/50 split between right-pawed and left-pawed, thus thought to arise by chance. Human beings, as noted by Walker (1980) appear to be the only species with lateral preferences biased towards one hand, with approximately 90% of the population being right handed. Although Rogers (1980) reported that the only other species that deviated from the 50/50 split apart from man is that of the parrot. These birds are reported to predominantly use their left claw over their right when reaching for food.

A detailed review of the lateral differences in other species is beyond the scope of this present study, but suffice to say that once advantageous asymmetries emerged at the level of an individual organism, researchers suggest that not only natural selection, but also possibly social and other pressures may have encourage population-level consistency in some species, resulting in further evolution of laterality with refinements emerging. Is this perhaps also the case for human lateral preference?

Human beings are observed to be generally symmetrical in form having a number of paired limbs and other structures. However, it might be that this symmetry is only skin deep, as despite the many paired organs, bones and structures being structurally and functionally symmetrical, beneath the surface many of these show sometimes small, yet consistent, left –right asymmetries in size and shape. For example, (McManus, 1976) highlights that the male right testicle is usually larger and higher than the left and consistent variations have also been found in female breasts.

For many decades because the cerebral hemispheres, tightly packed inside the human skull and connected by several distinct bundles of nerve fibres that serve as interconnecting channels of communication, appeared to be approximate mirror images of each other, a symmetrical brain organisation was assumed. Through developments in research and technology, it is now predominantly thought that functionally, control of the body's basic movements and sensations is almost evenly divided between the cerebral hemispheres in a crossed fashion, with the left hemisphere controlling the right side of the body, and the right hemisphere controlling the left.

Further, much accumulated evidence and research has demonstrated that the cerebral hemispheres are not identical in their capacities or organisations, and are asymmetrical in function, with differences in the ability to produce and understand language and process spatial relationships amongst others. Scientific studies of the human brain and its function show with increasing accuracy that human lateral preference and cerebral

hemispheric lateralisation are not unrelated and hence will be explored more fully in Chapter Two, when the relevant literature is reviewed.

Without doubt, the most pronounced outward human asymmetry is that of hand dominance, followed by other motoric/sensory biases of footedness, eyedness, and earedness respectively. In the context of this study, it is likely to be helpful to describe what is implied when reference is made to 'human lateral preference'. Coren, Porac and Duncan (1981) considered that there are four indices of human lateral preference namely: handedness, footedness, eyedness and earedness. These four overt indices are highlighted in this study, being the most pronounced and relatively easy to observe.

In terms of handedness, Bishop (1990) has posed the following question "why do we show a preference for one side rather than developing equal skill with both hands?" (p.1). In other words Bishop is querying why human beings are not ambidextrous. Bishop postulates two possibilities namely; handedness is advantageous over ambidexterity, leading to its evolution by natural selection, or handedness is a non-adaptive by-product of a different adaptive human characteristic.

Considering her first possibility, the notion that handedness is advantageous has been popular for many years, and the researcher herself is favourably disposed towards this notion. As highlighted previously, in terms of motor control, human beings generally choose the path of least resistance in an attempt to successfully achieve a desired outcome. Therefore, when a new motor skill is being acquired, initially performance is less polished and the execution of the action may be slower because the muscle groups involved are poorly co-ordinated and feedback is acted upon in an attempt to improve performance. Through repetition, a motor programme gradually develops and becomes embedded or learnt, as the sequence of movements becomes increasingly co-ordinated enabling better performance of the action, with less and less need for corrective feedback. Therefore it would make sense to concentrate learning on one side of the body rather than splitting it between the two, possibly 'diluting' skill level, at least initially. Bishop (1990) terms this hypothesis the "motor learning hypothesis".

To follow this through, it might be reasonable to expect handedness to be most apparent in highly skilled actions through a series of pre-programmed movements which potentially would be advantageous to an individual and favoured by natural selection. Further, Corballis and Beale (1976) suggest that handedness is likely to be beneficial in

bimanual tasks, enabling the hands to perform complementary functions, rather than duplicate functions that are not complementary.

Bishop (1990) adds to her first possibility, that handedness is advantageous through what she has termed the “interference hypothesis”. Bishop bases this hypothesis on evidence that suggests when a motor activity is learnt with one hand, it sometimes results with mirror-image movements in the other. Bishop postulates that for some human activities such as brushing teeth, this would not be a problem, but highlights for other activities, which are not ‘mirror-reversible’, for example writing, there may be a functional advantage to restricting learning to just one hand.

Many researchers e.g. Corballis and Beale (1976), Raymond and Pontier (2004) and Dinsdale, Reddon and Hurd (2011) echo Bishop’s thoughts regarding handedness being advantageous and as a result favoured by natural selection, resulting in man being able to:

- manipulate objects in a predominantly consistent way resulting in greater skill and efficiency;
- develop asymmetry in the strength of one limb in a bilateral pair, resulting in a more efficient response to stimuli; and
- develop more accurate aim-directed movements.

Bishop’s second possibility, of handedness being a non-adaptive by-product of a different human characteristic, dates back to the work of Marc Dax in the 1830s and Paul Broca in the 1860s, who found that there was a relationship between damage to the left hemisphere of the brain and loss of speech. Broca explored this further and went on to consider the relationship between handedness and speech. As highlighted by Springer & Deutsch (1998), Broca suggested that “both speech and manual dexterity are attributable to the inborn superiority of the left hemisphere in right-handers” p.13. Broca’s notion that the hemisphere that controlled speech was located on the side opposite the preferred hand remained influential well into the twentieth century. Even today the relationship between handedness and hemispheric asymmetry remains unresolved, but as highlighted previously they are considered to be related and will be explored further as part of this study in the next chapter.

Having considered the possible origins of human lateral preference, thought now needs to be given to why cross-cultural studies reveal that approximately 90% of the human population are right handed.

1.4.2 Right-sided bias of the motoric system in human beings

Many humans demonstrate a strong and consistent preference in the use of their paired limbs and sense organs, predominantly to the right, especially for handedness. Coren and Porac (1977) through examination of ancient works of art, dating back over fifty centuries, attempted to trace the origins of right handedness. Drawings on cave walls and inside Egyptian tombs typically show individuals engaged in activities involving the right hand. Further, analysis of paleolithic tools and weapons suggest that they were made with and for use by the right hand.

In addition, within language, historically the “right-hander” has been viewed more favourably than the “left-hander”. In many European languages “*right*” is not only a synonym for correctness, but also stands for authority and justice: French *droit*, German *recht*, Portuguese *direito*, and Spanish *derecho*. Indeed throughout history the right hand has been associated with skill: the Latin word for right-handed is *dexter*, as in dexterity, the Spanish term *diestro* and the Italian term *destro* can be translated as ‘right-handed’ and ‘skillful’. Further, the Irish term *deas* means ‘right side’ and ‘nice’. In contrast, left-handers are commonly referred to as “*sinistrals*” stemming from Latin word *sinestra*, which originally meant left, but later took on meanings of evil or unlucky. Roget’s Thesaurus lists left-handed as a synonym for “un-skillfulness”, the French word *gauche* translates as clumsy, *mancino* is Italian for left as well as deceitful, and the Spanish *no ser zurdo* means to be very clever, but is literally translated as “not to be left-handed”. Thus the left side is often associated with clumsiness; consider the English term “having two left feet”, for example. Even the word ambidextrous meaning “skilful on both sides” reflects the bias, given that it maintains the Latin root “*dexter*” which means “right”, it then translates as “right on both sides”!

A brief exploration of the most popular theories proposed to account for the right-sided bias will be explored as this is potentially pertinent to this study. Only the key features of the dominant theories are considered here as it is considered to be beyond the scope of this study and possibly unnecessary to explore these theories in detail.

1.4.2.1 Environmental Theories

Porac and Coren (1981) make reference to the *Right-Sided World Hypothesis* which suggests that it is the many overt and covert pressures, in the right-sided dominated world, that pressurise individuals to change from naturally left to culturally right. Porac and Coren use the term 'nurtural', rather than natural selection.

1.4.2.2 Genetic Theories

The classic Mendelian theory of genetics which assumed a right-hand dominant or left-hand recessive gene pattern, has been discounted as it did not appear to fit the data available. However, Annett and Alexander (1996) hypothesised that individuals probably did not carry a dominant or recessive gene for right or left handedness, rather most individuals inherit a dominant gene (rs+), responsible for the development of speech in the left hemisphere and in turn this gene increases the likelihood of the individual being orientated towards the right side. Annett termed this the "right shift factor". Annett also proposed a recessive form of the gene (rs-), which results in the absence of bias to one side. More recently researchers e.g. Van Agtmael, Forrest and Williamson (2001), McManus, Nicholls and Vallortigara (2009) believe that they have discovered a gene that is linked to increased likelihood of being left-handed.

1.4.2.3 Hormonal Factors

Possible links between hormonal factors and the body's immune system have been suggested. Geschwind and Behan (1982) proposed that at a crucial stage of pre-natal brain development, high levels of pre-natal testosterone slows the rate of growth in the left hemisphere of the brain, resulting in a right hemisphere dominance reflected in increased left handed preferences, particularly amongst males who are exposed to higher levels of this hormone than females.

Further, Geschwind and Galaburda (1987) similarly suggested that the development of the immune system is also affected by testosterone levels, resulting in increased susceptibility to immune disorders such as allergies, asthma as well as autoimmune disturbances.

1.4.2.4 Birth Stress

Bakan, Dibb and Reed (1973) have postulated that the incidence of left-handedness is greater amongst those who have suffered oxygen deficiency at birth. Further Schwartz

(1988) reported that left-handedness correlated with lower Apgar scores at birth. (Apgar scores measure the extent to which newborn babies suffer from severe birth trauma).

1.4.2.5 Twins

Historically there has been some evidence to suggest that there is an increased incidence of left-handedness amongst twins, at 15-18%, almost double that found in the singleton population, (Springer & Deutsch, 1998; Levy and Nagylaki 1972). A number of explanations have been put forward to account for this including increased perinatal risk, mirror imaging of twins, foetal positioning and delayed foetal maturation.

1.4.2.6 The Liepmann Hypothesis

Beaton (2004) reports that the most common “explanation” of right-handedness relates to the superiority of the left hemisphere of the brain over the right. Liepmann and Maas (1907, as cited in Beaton, 2004) believed that ‘manual dominance’ reflects the ability of one hemisphere of the brain being able to learn and retain what they termed “movement formulae” for motor tasks, more successfully than the other, based on the study of their patient who suffered apraxia/dyspraxia (disorders in planning, remembering, or executing voluntary, purposeful movements or sequences of movements), and agraphia (a neurological disorder involving the loss of the ability to write).

For the purpose of this study, referring back to the four indicies of human lateral preference as postulated by Coren, Porac and Duncan (1981) and highlighted previously, it is suggested that where a human being demonstrates a consistent preference for ‘right sidedness’, or ‘left sidedness’, across all four indices, these individuals be termed ‘unilateral’, either towards the right or the left, or demonstrating unilateral preference. In contrast, those individuals who consistently demonstrate a ‘mixed preference’, some right and some left, across the four indices, be termed ‘cross-lateral’, or demonstrating cross lateral preference (CLP).

1.4.3 Cross lateral preference (CLP) in humans

Orton (1937) believed that “A child was said to have mixed or crossed laterality when he deviated from the “normal” pattern i.e., showed a consistent preference for one side of his body in eye, hand, ear, and foot usage.” Orton believed that both crossed and mixed laterality were indicators of a neurological problem, and children were diagnosed (incorrectly) with minimal brain damage or delayed neurological development. Orton

postulated that this 'condition' was indicative of poorly established hemispheric dominance, resulting in amongst other things reading difficulties. A characteristic of these poorly lateralised children was termed 'strephosymbolia', which literally means "twisted symbols", or "the perceiving of objects reversed". Thus Orton suggested that both reversals in reading and associated laterality confusion were the result of incomplete dominance of one hemisphere of the brain over the other.

There remains some debate regarding the prevalence of CLP within a population. Few studies have considered all four indices simultaneously, tending to pair the limbs hand and foot, and the sensory indices, eye and ear. Within research studies it remains unclear the effects of CLP when for example a limb is crossed with a sensory index e.g. hand/eye, foot/eye. However, research by Coren, Porac and Duncan (1981) highlighted shifts in the pattern of lateral preferences as a function of chronological age, differing from early childhood to young adulthood. Data collated supported the notion of an overall shift to right sidedness and toward greater congruency across the indices. Thus individuals become not only more right sided, but also more consistently one-sided with maturity. Results obtained suggest that only 33% of the pre-school population sampled were unilateral across the four indices, suggesting that 67% of pre-schoolers demonstrated CLP. Therefore, this lends support to the notion that CLP is a developmental phenomenon and for the majority a normal stage in development. It has been reported that in general, correlations between preferred hand and foot appear to be higher than between hand-eye; hand-ear, eye-foot; ear-foot (Coren and Kaplan, 1973; Porac and Coren, 1975;1976;1979).

A greater occurrence of mixed handedness amongst children compared to adults was found by Brito and Santos-Morales (1999) in their study on lateral preferences of Brazilian children. Papousek and Schulter (1999) analysed in 1171 right handers aged 18-49 years, five behavioural laterality measures namely; degree of right handedness, ear dominance, eye dominance, line bisection performance and lateral preference as assessed by preferred direction of conjugate lateral eye movements. Nearly two thirds of the participants were observed to display left ear dominance suggesting within the right handed population the degree of CLP when the sensory index of the ear is included is relatively high. Furthermore, of the 612 participants who were tested for eye dominance within this study, 32.7% were observed to display left eye dominance. Therefore some research findings lend support to the notion that, while CLP is generally considered to be developmental, the degree of CLP amongst the adult human population when all four

indices are considered is relatively high. Potentially, given the findings of Coren, Porec and Duncan (1981) this percentage is likely to be higher amongst the pre-school population.

1.4.4 The impact of laterality on letter/number formation, handwriting skills and learning in general

The precursors to letter/number formation begin with early scribbling which gradually becomes more intentional over time. Feder and Majnemer (2007) postulate that as children develop, designs and patterns evolve into more precise shapes before letters/numbers emerge. An approximate developmental framework is suggested with children imitating geometric shapes commencing with vertical strokes (2 years), horizontal strokes (2 years 6 months), and circles (3 years), followed by the ability to copy a cross (4 years), a square (5 years) and a triangle (5 years 6 months). Feder and Majnemer state that when a child is able to copy geometric forms, particularly the oblique cross, the child is considered to display 'writing readiness'. They base this on the fact that at this point the child is able to cross the body midline, (the imaginary line that divides the body into a right and a left side) which is considered essential, as the failure to do so has been implicated as the root of many reversal problems. For example, research by Feder and Weber (1986) has shown a correlation between reversals and handedness, directionality, laterality, cerebral dominance, and visual processing.

Children who are delayed in developing lateral preference or who display CLP appear to experience greater difficulty in crossing the body midline, as a result the child may be observed to 'swap hands' to complete a task that requires crossing the body midline e.g. a child might transfer his pencil from one hand to the other at his midline when drawing a line. Such children would not display 'writing readiness' as early as typically developing children, but from a chronological age perspective are likely to be expected to start writing, as the demands for handwriting in the classroom do not always match the child's developmental level. Their teachers may notice their reluctance to cross their midline but may not understand why. Further, if the teacher did possess an understanding of potential causes, the teacher would also need the knowledge or expertise to provide appropriate strategies or interventions to help the child overcome his/her difficulties.

Some define those who do not succeed in developing proficient handwriting as "poor handwriters", others refer to such individuals as "dysgraphic" (Marr and Cermak 2003),

with dysgraphia being defined as “a disturbance or difficulty in the production of written language that has to do with the mechanics of writing” (Hamstra-Bletz and Blote 1993).

Studies have suggested that between 10 to 27 % of school aged children experience handwriting difficulties and research literature extensively documents the adverse effects of poor handwriting on future academic performance. Graham, Harris and Fink (2000) highlight that some children who experience handwriting difficulty may avoid writing, having decided that they cannot write, leading to arrested writing development. Furthermore, studies have suggested that children with writing difficulties may suffer serious consequences in terms of their emotional well-being and social functioning (Cornhill and Case-Smith, 1996; Kaminsky and Powers, 1981; Modlinger, 1983), as well as being disadvantaged in the learning environment (Gray, Dean and Seretny, 1986). Therefore it would seem that difficulties in acquiring proficient handwriting does not just result in poor handwriting alone, but can also adversely affect the individual in a number of ways as highlighted above. This serves to reinforce the importance of identifying children at risk and providing appropriate early intervention strategies.

Graham (1986) suggests that the school (educational) psychologist should be familiar with the issues and procedures that are related to handwriting assessment so that they can act as consultants to teachers advising on how to assess handwriting, help teachers to plan and evaluate interventions and/or evaluate the child’s progress themselves. The role of the educational psychologist (EP) is examined further next.

1.5 The role of the EP

In the Department for Education and Science (DFES) document entitled ‘A review of the functions and contribution of educational psychologists in England and Wales in light of ‘Every child matters: Change for children’ (Farrell, P., Woods, K., Lewis, S., Rooney, S., Squires, G., & O’Connor, M., 2006) report, based on the findings of their study and the review of the relevant literature

‘that the role and function of EPs has expanded considerably over the last 25 years despite the restrictions placed upon them by the requirements of SEN statutory assessment. They are now in a position to deliver psychological services through a variety of activities and contexts where change for children is the focus’. (p.104)

Within the report the psychological knowledge and skills EPs use in their work are acknowledged. Indeed, EPs themselves within the report have stressed that

‘their background and training in psychology provides them with a detailed knowledge of child development, social and organisational psychology, cognitive development, personality, individual differences, the psychological impact of different ‘conditions’ upon the child, family and the community, psychological therapies and interventions, and research and evaluation’. (p. 100-101)

These views were supported by teachers, local authority officers, other professionals and parents. Despite this array of skills and expertise on offer, many EPs continue to predominantly conduct individual level and statutory work, with organisational work and research only being conducted after statutory requirements have been fulfilled. Indeed, opportunities for research in particular, are often viewed as a luxury when employed as a full time EP. However, as stated by Cameron (2006), EPs should not miss opportunities for change and potentially can see the ‘bigger picture’ connecting the child’s needs and the research/theoretical base in psychology.

Thus there is a clear role for EPs to be involved in research that hopefully will lead to increased and better learning opportunities for children. Therefore in terms of letter/number formation and the development of handwriting skills, it is important that EPs understand the processes involved in the development of writing skills in order to be able to pinpoint areas of difficulty and to impart sufficient knowledge to advise/address these difficulties. This may of course include an awareness of issues relating to laterality.

1.5.1 Is there a need to increase awareness amongst EPs regarding issues relating to laterality?

EPs, despite having a common basis of psychological knowledge and skills, are nevertheless unique and ultimately are likely to approach similar concerns in a variety of ways. Research findings suggest (Coren, Porac and Duncan, 1981; Brito and Santos-Morales, 1999; Papousek and Schulter, 1999) that CLP is a normal part of the developmental process for the vast majority of individuals. However, it would be helpful if EPs are aware that CLP should diminish with natural development and maturation, but for those children where CLP persists into adolescence and beyond, there is a possibility of specific difficulties arising. Further, if a child was identified as having CLP by the EP it would be interesting to investigate the advice/range of

interventions suggested. However, it is beyond the scope of this research to investigate EP knowledge of laterality issues.

1.5.2 Early intervention

As highlighted in section 1.3.2 early educational experiences offered to young children are crucial and potentially able to influence future academic performance. Further, it has been argued in 1.3.3 that pupils with ALN, and in 1.4.4 those with delays in developing lateral preference or who display persistent CLP, need early identification of need and the implementation of appropriate interventions. There is also evidence to show that pupils experiencing difficulties with learning to write do respond to planned and targeted instruction, as long as the intervention is early enough to avoid the negative effects of failure, Tindal and Hasbrouck (1991), (Hagtvet, 1993, as cited in Dunsmuir and Clifford, 2003). Therefore, there would appear to be a need to combine all of these factors, namely to ensure that all pupils, but particularly those with delayed lateral preference and/or persistent CLP, or those experiencing writing difficulties with or without the aforementioned difficulties, are identified early and provided with appropriate interventions. The informed EP can help school staff identify and support vulnerable pupils hopefully before the negative effects of failure have become apparent. In order to do this successfully as suggested by Dunsmuir and Clifford (2003), “EPs will need to integrate an understanding of the psychological and developmental processes underpinning writing with practical supports and scaffolds available in schools when involved in intervention planning and evaluation”. (p.181)

It may also be helpful if EPs have knowledge of how technology can be used to assist and support development. There are a number of software packages available to support the writing process and a summary is provided by Dunsmuir and Clifford (2003). However, this summary does not list any software packages aimed at specifically supporting children with a combination of laterality, directionality and letter/number formation difficulties. The use of multi-modal learning experiences combined with the use educational technology to address these difficulties is now considered.

1.6 Multi-modal learning experiences and the use of educational technology/development of software

Generally, sensory modalities are distinguished on the basis of the type of physical stimulation they are most sensitive to, for example; sound for hearing, light for vision, pressure on the skin for touch and molecules in the air for smell. Within our everyday

environment usually stimulation to several modalities occurs simultaneously. Inputs to different sensory modalities that result in simultaneous information about the same external stimuli have been termed ‘valid co-occurrences’ by Bertelson and De Gelder (2004). They also highlight that unavoidably, some ‘invalid co-occurrences’ are likely to occur. However, more importantly, Bertelson and De Gelder postulate that

‘The existence of valid co-occurrences of information in different sensory modalities creates for perceiving systems, whether natural or artificial, opportunities for improved performance. Perception can fail for two types of immediate reasons-irregularities in the incoming stimulation or in the subsequent processing. Whatever the case, generally only one sensory modality will be affected, so that taking into account the evidence collected by other sensory modalities can reduce the dysfunction’. (p.141).

This suggests that multi-modal perception is beneficial and that if one mode is less efficient for any reason or fails completely, perception will be facilitated by the other modes involved. Therefore, it would seem likely that multi-modal learning experiences not only provide maximum opportunity for valid co-occurrences, but potentially could also enable a learner to develop certain skills, despite having a deficit in one or maybe more modality. Educational technology appears to offer the possibility of providing children with multi-modal experiences and therefore increased exposure to valid co-occurrences.

For this reason it is proposed that the use of educational technology may assist in the correct formation of letters/numbers for all children, especially but not exclusively for children with delayed lateral preference and/or persistent CLP, because through the use of visual effects (changing colours), auditory effects (changing sound) and tactile effects (fingers touching the surface of the table) the number of valid co-occurrences in relation to this task will hopefully be increased.

These experiences may help children to develop their motor, visual and auditory memory for letters and numbers more efficiently, which will aid recognition and formation, (furthermore, potentially the concept may be beneficial for the hearing and visually impaired population).

1.7 In this highly technological age are handwriting skills still necessary?

Not everyone values the skill of handwriting today. Silverman (2003) states that ‘keyboarding is an essential skill in this new millennium, whereas handwriting is not’. She considers that the once essential skill of handwriting is now a very inefficient

means of notetaking, with most people preferring to type. She predicts that in time each child will have their own computer and the importance of keyboarding skills will take priority over handwriting skills.

However, even in this highly technological age, it can be argued that writing remains indispensable for participation in many school activities. Handwriting is still an integral part of every child's school experience with approximately 30-60% of class time in the primary school being spent on writing tasks of some kind, despite the introduction of the Foundation Phase. It may be considered that without legible handwriting, children are denied a mode of communication that is still heavily relied on within our society.

Professor Virginia Berninger, from the University of Washington, speaking at the Department of Psychology Writing Conference in the UK in 2007, described handwriting as 'language by hand', and provided evidence detailing that it is much more than a motor skill. Professor Berninger also highlighted that her work showed that handwriting instruction may transfer to improved reading and learning in some children. She also reviewed her work showing that manuscript writing, cursive writing and keyboarding may develop independently of each other and might have different neuropsychological precursors.

1.8 Summary of the Introduction

Much of this first chapter has been devoted to exploring the origins of human lateral preference and trying to gain an understanding why human beings display a strong and consistent preference to the right, especially for handedness. An understanding of the origins and function of handedness and its relation to brain organisation may provide valuable clues to helping young children overcome difficulties in relation to this.

This first chapter has also highlighted that literacy and numeracy standards within the UK do not compare favourably to many other developed countries, and that early experiences that young children are exposed to are crucial and may influence future academic performance.

Attention has also been drawn to the potential benefits of multimodal learning experiences and how it might be possible to combine this with the use of educational technology to assist children generally, but in relation to this study specifically in letter/number formation, which could be beneficial to all children, not just those with

persistent CLP. The role of the educational psychologist has been highlighted and warrants further investigation.

The following chapter reviews the literature on human lateral preference, multimodal learning experiences, and the use of educational technology with an emphasis on previous research, which combines all three elements. More specifically, these elements will be investigated in relation to learning and the development of letter/number formation and handwriting skills in general.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

The previous chapter introduced the phenomenon of human lateral preference and highlighted that not all human beings, despite natural development and maturation are unilateral in this respect. It was also suggested that a link may exist between some who exhibit persistent CLP and difficulties in the learning environment, especially in terms of letter/number formation, and that these difficulties might be addressed by utilising multi-modal learning experiences combined with the use of educational technology. This chapter goes on to explore both the theoretical and research literature relating to the key topics and to critically examine key research studies relating directly wherever possible to these areas. Finally, the rationale for this present study and the way it will contribute to existing knowledge and understanding in relation to the development of letter/number recognition and formation skills generally, and more specifically for those with persistent CLP, will be highlighted.

2.2 Key sources

The literature cited in this study was accessed from a number of databases and sources. In terms of databases the following were used: ERIC, PsychLit, PsychInfo, The British Education Index, Cardiff University library Voyager search engine and the Association of Educational Psychologists EBSCO host database-the Psychology and Behavioural Sciences collection. The search for literature was predominantly based around the areas of laterality, multi-modal learning experiences, the use of educational technology in teaching and learning, and the development of writing skills, including letter formation. Search terminology included “laterality in humans”, “mixed dominance”, “cross-laterality”, “directionality”, “multi-modal learning”, “multi-sensory learning”, “educational technology and learning”, “the use of ICT in the classroom”, “handwriting difficulties”, “dysgraphia”, “dyspraxia”, “co-ordination difficulties”, “letter formation” and “colour and handwriting”. Furthermore, websites relating to the government departments for education and skills in both England and Wales were accessed to review up to date information: www.education.gov.uk and www.wales.gov.uk. The Internet search engines www.google.co.uk and www.scholar.google.co.uk were also utilised to access relevant websites, however the researcher checked these sources for credibility through reflecting on the reliability of their sources.

In addition, information from the BBC 2 programme Horizon “Is Seeing Believing?” screened on 18th October 2010 has been followed up and cited within this chapter. Further, information has been sourced from attendance at the BETT show (formerly the British Educational Training and Technology show) in London in January 2010, which is a leading event for educational technology where educational professionals can explore, evaluate and purchase a wide range of ICT products. Finally, conversations both telephone and face to face, were arranged with key personnel in the field of this study.

2.3 Research Studies

There is an abundance of research studies relating to the development of handwriting skills which aim to increase understanding of all the complex underlying processes involved and many offer specific handwriting interventions aimed at remediating presenting problems. Much of the research around handwriting difficulties involves children with delays in motor skill acquisition, such as ‘developmental coordination disorder’ (DCD), or those with mild neurological impairment.

There is also an increasing amount of research into the use of educational technology in the learning environment and its impact on pupil attainment and levels of engagement in learning activities, including multi-modal learning activities.

During the last fifty years or so, scientists from a range of disciplines including neurology, anatomy, psychology and psychiatry have been investigating laterality differences in the brain of humans. Results of these research studies have been published in a number of different journals and an enormous volume of literature has emerged (Tao and Walsh, 2006; Reuter-Lorenz and Miller, 1998; Lavidor, Hayes and Bailey, 2003).

Research studies into the area of human lateral preference and more specifically linking laterality with difficulties in the learning environment are less evident. Dyslexia is an exception here, as Samuel Orton as long ago as 1925 associated reading difficulties with anomalies of cerebral dominance, which he argued resulted in incomplete lateralisation at the level of the hand and/or eye. Research studies specifically investigating persistent CLP and its impact on learning are rare, however a number of relevant studies will be reviewed. What appears to be missing are research studies relating to persistent CLP and its impact on letter/number formation.

Thus the areas selected to be reviewed are those deemed most pertinent to informing this present study. These include theoretical literature relating to brain development and hemispheric specialisation and its relationship to learning, cognitive development and the impact of early educational experiences, multi-modal learning and the use of educational technology.

In terms of the research literature, studies relating to the development of letter/number skills will be examined, particularly those that involve multi-modal learning and the use of educational technology and more specifically studies that investigate CLP and its relationship with learning.

The areas of general reading development although closely linked with writing have not been reviewed, as this is not the focus of this study. Furthermore, the host of handwriting interventions available on the market have not been reviewed as the thrust of this study is looking to ensure that children are exposed to the necessary quality experiences to promote successful letter/number formation and recognition and hence reduce the need for intervention programmes.

2.4 Theoretical literature relating to the development of letter/number formation and handwriting skills and the use of multi-modal learning experiences coupled with educational technology

The skill of writing is established most readily on a foundation of good spoken language. Good spoken language in terms of use and comprehension of speech is directly related to early brain development. Furthermore, motor skills are obviously used in the production of written letters and words which form the composition of writing; these are also dependent upon brain development, involving the development of sensori-motor structures and functions enabling proficient hand to eye co-ordination as a minimum. Therefore it would be pertinent to start the review of theoretical literature by examining, although rather simplistically the development of the human brain and hemispheric specialisation.

2.4.1 Human Brain Development and Hemispheric Specialisation

The brain is a complex organ and despite many advances in this area its range of functions are not yet fully understood. The development of the brain begins in the foetus and it is believed it continues until death. Many publications (Pound, 2005; Wood and Attfield, 2005a; the Parliamentary Office of Science and Technology, POST (2000) cite

that there are around 100 billion neurons present at birth. An understanding of brain development suggests that early in the postnatal period the brain begins to form new connections, or synapses, between the nerve cells through a process termed synaptogenesis. It is stated in the POST report of June 2000 that this process lasts several months, and is then followed by a period of ‘synaptic pruning’ during which infrequently used connections between neurons are eliminated and frequently used connections are strengthened. From a physiological perspective it is believed by neuroscientists that learning occurs when synapses between the nerve cells in the brain are formed and reinforced. Research studies by Greenough, Black and Wallace (1987) and O’Connor, Bredenkamp and Rutter (1999) suggest that these neural pathways are formed most effectively through stimulation and experience, thus reinforcing the belief that children learn best through their experiences. This is a point that is returned to in the next section, (2.4.2).

As highlighted in Chapter 1, much accumulated evidence and research has demonstrated that the brain is divided into two cerebral hemispheres and connected by several distinct bundles of nerve fibres, known as the *corpus callosum* which acts as a channel of communication between them, and these hemispheres are asymmetrical both in terms of morphology and function.

Iaccino (1993) states that morphologically, both within the foetus and neonatally, the entire configuration of the human brain is asymmetrical. More specifically, within the brain itself, asymmetries have been found with the *sylvian fissure*, the *temporal planum* and the brain’s prefrontal regions. Furthermore, *venous* asymmetries have been noted along with fluctuations in blood flow through the brain tissue, because cerebral flow is responsive to changes in neuronal activity. Halsey, Blaunstein, Wilson and Wills (1979) suggest that hemispheric changes in blood flow largely relate to which hand is used in a task, with right-handed movements increasing the blood flow in the left hemisphere area and vice versa. This is likely to be directly associated with the fact that via the *corpus callosum* the left hemisphere of the brain has been shown to control the right side of the body, and the right hemisphere the left side of the body.

As long ago as 1864, Broca, a French doctor, through his involvement with a brain damaged patient, came to the realisation that for some language functions at least, a specific area in the left frontal lobe of the brain needs to be undamaged, which has since become known as Broca’s area. As highlighted in Springer and Deutsch (1998), by

1870 others came to the realisation that many types of language disorders could result from damage to the left hemisphere of the brain. For example, Wernicke (1874) identified that damage to the rear part of left temporal lobe could produce difficulties in understanding speech. More pertinent to this research, problems with reading and writing were identified in some patients and were shown specifically to be related to damage in the left hemisphere of the brain.

Almost 150 years on, largely due to advances in brain imaging techniques, there is now increased understanding of the morphology and function of the human brain. It is now considered that “a prominent characteristic of the human brain is that the left and right sides of the cerebral cortex are functionally asymmetrical” (Hellige, 2006, p.211). Studies involving brain damaged patients, and patients who have undergone ‘split-brain’ surgery, which involves sectioning the entire *corpus callosum*, as well as several smaller commissures in an attempt to help patients suffering from intractable epilepsy, along with studies of ‘neurologically intact’ subjects, suggest brain hemispheric asymmetry and hemispheric specialisation. Despite this hemispheric specialisation Hellige and others in the field suggest that both hemispheres of the brain have at least some capacity to perform tasks or engage in specific processes, even if one side displays superiority or is dominant in some way, with the exception of overt speech production which appears to be produced exclusively by the left hemisphere in most individuals. Although Hellige reports that the right hemisphere has been found capable of producing speech in unfortunate individuals who have been born without a left hemisphere, or if the left hemisphere has been removed at a sufficiently young age.

It is beyond the scope of this research to look in detail at the precise functions of the two hemispheres of the brain, but suffice to say that in its most simple form they can be summarised as follows:

Right hemisphere

- visual
- spatial
- global picture
- emotional
- abstract
- shapes and patterns

Left hemisphere

- verbal
- linguistic
- details
- practical
- concrete
- orderly sequences

Therefore, despite being described as functionally asymmetrical and displaying hemispheric specialisation, the hemispheres of the human brain are reported by neuroscientists as being complementary to each other's functioning, via the *corpus callosum*. Indeed, Hellige (1993, 2001;) and Zaidel and Iacoboni, (2003) report a complex relationship between the two hemispheres in that in addition to the transfer of information from one hemisphere to the other via the *corpus callosum*, they also report 'mutual inhibition', an inhibitory barrier acting to reduce interfering cross-talk, thus enabling interhemispheric harmony.

The brain of many mammals, including that of the human being, is considered to be largely immature and underdeveloped at birth. As highlighted previously, early in the postnatal period the brain begins to form new synapses, and learning occurs as these synapses develop and become reinforced. Indeed, educational literature frequently suggests that the period from birth to three years is crucial in terms of brain development. Wood and Attfield (2005 (b), p. 61) report 'In the early years children's brains undergo substantial and rapid growth in synaptogenesis, which appears to make this a particularly sensitive period for learning'.

However, POST (2000) details that synaptogenesis is different for different brain areas, as a result different areas of the human brain develop at different rates. Indeed, within the POST report it is reported that the synaptic density in the frontal cortex continues to increase through adolescence and does not start to decline until mid-adolescence. So it would appear that there is general agreement that the brains of young children undergo substantial and rapid changes and development but do remain malleable in some areas at least, right through to adolescence and indeed throughout life.

To an educationalist it is important to discover ways to positively influence brain development in young children, thus enabling them to realise their full potential. In general, proficient teachers/early educators are well placed to be able to identify when a child is underachieving, however, external agencies can be called upon where necessary to explore this further. However, researchers in the field of neuroscience remain reticent about making generalisations about brain development and how children should be educated.

Whilst highlighting that at least some areas of the brain remain malleable potentially right through to adolescence and beyond, the current trend of 'windows of opportunity' for skill development in young children's lives remains a crucial thrust in

educational philosophy today. For example, Meadows (1993), in reviewing the research evidence for causes in variation in cognitive development, concludes that 'there is much evidence for sensitive periods' or experience expectancy in neural pathways. In addition, within the Welsh Assembly Government document entitled 'Teaching and Learning Pedagogy' (2008) reference is made to critical periods when brain development is particularly receptive to specific types of learning, 'the first eight years of life is a critical period for language acquisition' (p. 33) and 'brain research shows that young children's minds are particularly receptive to language therefore the early years are an ideal time to introduce a new language. This supports the introduction of Welsh Language Development as an Area of Learning in the Foundation Phase' (p.35) for example.

To lend further support to the notion that the brain remains malleable and responds to instruction, the studies reported by Berninger and Shaywitz (2006) are examined. Berninger and Shaywitz firstly report the work of Fair, Brown, Petersen and Schlaggar (2006) at Washington University who studied the effect of intervention on the neural system involved in reading, using magnetic resonance techniques. They noted that the regions of the brain that increased in activation in response to the intervention continued to 'grow', whereas the regions that decreased in activation over time 'grew down' or were pruned back. Similarly, Shaywitz, Lyon & Shaywitz (2006) investigated the effects of an evidence-based reading intervention on neural systems for reading. Second and third grade pupils were in receipt of more than one hundred hours of intervention over the course of a year, and were compared to a second group of readers with disabilities who received whatever was available within the community normally. 'Typical' second and third grade pupils with no impairments acted as controls. The researchers found that not only did the pupils who received the evidence-based reading intervention improve in reading accuracy, fluency and comprehension when compared to the pupils who received the community input, but through the use of brain imaging techniques on all three groups, the group subject to the evidence-based reading intervention, were found to have 'changed' brains, neurologically. This supports the view that a relationship does exist between brain development and environmental factors in the learning process, but does not provide sufficient evidence to illuminate the relationship between brain malleability and 'windows of opportunity'.

In relation to the current study, this raises the question of whether there might be a critical period for the development of skills in relation to letter/number recognition and

formation, and indeed the skills that precede ‘letter/number recognition and formation’, and the best form of instruction/intervention to impart these skills. Indeed, Bogen (1975, 1977) has written extensively on the educational aspects of hemisphericity and suggests that the Western educational system has overemphasised reading, writing and arithmetic in the school curriculum and as a result placed too much emphasis on left-hemisphere orientated learning, and to compensate he suggests the use of different instructional techniques to help boost right-hemisphere orientated learning.

Secondly, if there is a critical period for the development of skills in relation to letter/number recognition and formation and this is missed, does the brain remain malleable in response to intervention in respect of letter/number recognition and formation? If yes, how long for? Furthermore, what format should this intervention take?

At this point it seems pertinent to reintroduce the concept of multi-modal learning. In Chapter 1, it was suggested that multi-modal perception is beneficial because if one mode is less efficient for any reason or fails completely, perception will be facilitated by the other modes involved in that particular skill. Therefore, multi-modal learning experiences potentially enable a learner to develop skills despite having a deficit in one or maybe more than one modality. Therefore if a new skill is taught initially through a multi-modal approach it may be less likely that ‘windows of opportunity’ would be missed as it is very unlikely that all the differing modes involved in the task would fail at the same time, thus enabling the learner to partially or completely acquire the desired skill at the appropriate developmental age.

Multi-modal learning experiences therefore, should potentially enable a more holistic approach to learning. It would now be useful to explore the relationship between cognitive development and early educational experiences and relate the findings to the acquisition of skills relating to letter/number recognition and formation where possible.

2.4.2 Cognitive Development and Early Educational Experiences

In Chapter 1.3.1 attention was drawn to the Programme for International Student Assessment (PISA) results of 2009 and highlighted that in relation to these results the OECD Executive Summary (2010) highlighted that children who have attended pre-primary education tend to perform better at the age of fifteen than those who have not. The OECD in its attempt to explain the impact of pre-primary education on later school

academic performance, hypothesised that it is the quality of this education that is important, not just the quantity. Quality in relation to this hypothesis was equated with adequate facilities and resources to enable youngsters to learn in ways appropriate to their developmental stage, with appropriate structured learning experiences introduced gradually.

Evidence from neuroscientists suggests that different areas of the brain develop at different rates; therefore educators need to be aware of the types of experiences that are relevant for young children, in an attempt not only to ensure that opportunities for learning are appropriate to the child's developmental level, but also to avoid exposure to potentially meaningless if not damaging tasks. To elaborate, when a child is confronted with cognitive tasks that are inappropriate, meaningless and overly repetitive or present a threat of failure, the child can become stressed, bored or fatigued. Researchers Claxton (1999), Katz (1998), Elkind (1986) and Smidt (2007) suggest that this could impede brain growth as the young child's brain is particularly sensitive to stress, as this raises the level of the steroid hormone that can destroy brain cells and neural connections needed for later learning. This point is further emphasized by Claxton (1999) who talks about a 'resilient' learner. Claxton believes that children have some innate predisposition towards resilience and adventurousness, or lack of them, and feels that 'early experience has a major influence on whether these traits are consolidated or weakened'. (Claxton, 1999, p.255).

On review of the pertinent literature, key aspects of the Foundation Stage curriculum offered to young children in England and Wales are based on a broadly developmental theoretical orientation, with play based curriculum provision and pedagogic approaches considered to be essentially informed by the child's ongoing development and interests, and most importantly their readiness for learning. Early educational experiences, in which the distinction between work and play is not clearly drawn, predominantly consists of a number of experiences within an enriched environment leading towards multiple outcomes mostly determined by the child. The pedagogical orientations of enabling and facilitating the learning of the child, along with opportunities for support and direct instruction from adults when appropriate are recognised. Pioneer educationalists Vygotsky (1896-1934) and Bruner (1915-present) both highlight the importance of appropriate adult intervention in children's learning, in the belief that children are able to perform at a higher level when they are offered help or scaffolding, than if left to struggle on their own.

Cognitive abilities associated with memory, reasoning, problem-solving and thinking emerge throughout childhood as the child interacts within the environment. Piagetian theory suggests that as a child matures and increases their capacity to understand and interact with their environment, the child passes through four stages of development. Piaget postulated that certain tasks could not be undertaken by the child until they were psychologically mature enough. Much accumulated evidence, particularly from the fields of neuroscience and evolutionary psychology, now show that his stages of cognitive development might be considered to be overly rigid (Donaldson, 1978; Meadows, 1993; Smilansky, 1990; Wood & Attfield, 2005b).

Bronfenbrenner's Ecological Systems Theory (1979), more recently renamed 'bioecological systems theory' defines layers of the environment, each impacting on the child's development. This theory places emphasis on the child's own biological maturation and the interaction not only with the immediate family/community environment but also the larger societal environment. His theory proposes that change or conflict in any layer causes a 'ripple effect' in other layers, and that a child's development is not only the result of interaction between the child and the immediate environment, but also the larger environment of the child.

Both Piaget (1953) and Bronfenbrenner (1979) recognised that the child's cognitive development is largely dependent on interaction with the environment. More enriched and stimulating environments may provide increased opportunities for beneficial interactions. In differing ways both researchers appreciated the importance of the child's own biological maturation, which can be equated, if only loosely with some degree of 'readiness' for learning. Learning can frequently be viewed as incremental, each step built on the foundations of previous learning. Bearing this in mind, consideration will now be given to a developmental perspective of the skills required for letter/number recognition and formation and handwriting in general.

2.4.2.1 A Developmental Perspective of the Skills required for Letter/Number Recognition/Formation and Handwriting

Interestingly, the 'Guidance on the teaching of writing skills' compiled by the Welsh Assembly Government in March 2010 does not make reference to the developmental perspective of attaining writing skills despite highlighting its stages of development in 'Language, Literacy and Communication Skills' published in May 2008. Given the former makes reference to the *Skills framework for 3 to 19-year-olds in Wales* (Welsh

Assembly Government, 2008), whereby the importance of teachers needing to respond to ‘where they (*the children*) currently are in their learning, not where they think they ought to be according, for example, to their age’ (Welsh Assembly Government, 2010, p.5) is recognised, it could be argued that reference at least should be made to the pre-requisite skills required so that school staff reading the guidance can access this information should they need to do so.

Within the publication entitled ‘Language, Literacy and Communication Skills’ it is highlighted that ‘children should have plenty of opportunities to make marks and write in meaningful activities. Through participating in purposeful writing tasks, children will develop and improve their written skills as they move along the learning continuum’, (DCELLS, 2008, p.18). This publication highlights the stages of development in writing as follows:

- mark-making
- unexplained scribbles
- explained scribbles
- attempts to write letters
- left-to-right-orientation
- modeled writing
- making lists/notes etc.
- attempts to write simple sentences
- writing simple sentences using word books/dictionaries
- writing simple sentences with capital letters, full stops, question marks
- writing short stories/accounts using word books/dictionaries with increasing independence
- writing for a variety of purposes mainly unaided, with evidence of planning/shaping

For the purpose of this study the bullet points one to six only will be considered, given these relate to the focus of this study.

Therefore as the child develops, unexplained scribbles evolve into more precise shapes, a pre-requisite for writing. Willats (1985) states that letter shapes can often be seen in children’s drawings and can be viewed as an apprenticeship for writing. Indeed Beery and Buktenica who originally designed The Developmental Test of Visual-Motor

Integration (VMI) in 1989 have established norms for visual motor performance for children in various age groups by their ability to imitate geometric shapes, as follows:

- vertical strokes (age 2 years)
- horizontal strokes (age 2 years 6 months)
- circles (age 3 years)
- cross (age 4 years)
- square (age 5 years)
- triangle (age 5 years 6 months)

As highlighted in the previous chapter, the ability to copy geometric forms is frequently viewed as an indication of writing readiness, especially the oblique cross as it requires the child to cross the body mid-line. This latter ability has regularly been implicated as the root of problems with reversals, which are known to be common early in development, but can be problematic if they persist. This will be further discussed later in this chapter.

Visual Motor Integration often seen as the most important pre-requisite skill for writing in general, but more specifically for copying written material, may be considered as ‘the ability of the eyes and hands to work together in smooth and efficient patterns. It involves visual perception and eye-hand co-ordination’. (Sanghavi and Kelkar, 2005, p. 33). Visual perceptions need to be translated into visual-motor skills involving motor function, motor control, motor accuracy, motor co-ordination and psychomotor speed.

In addition to VMI skills, writing encompasses skills including motor planning, cognitive, perceptual, tactile and kinaesthetic. Indeed, Maeland (1992) postulated that competent handwriting depends on the maturation and integration of cognitive, visual-perceptual, and fine-motor skills. Further, Sovik and Arntzen (1991), state that fluent writing is produced by an integrated pattern of coordinated movements subject to visual monitoring and sensorimotor feedback. Volman, van Schendel and Jongmans (2006) report that many in the field (Berninger and Swanson, 1994; Graham and Weintraub, 1996; Van Galen, 1991) consider handwriting to be a complex activity in which continuous interaction occurs between lower-level perceptual processes and higher-level cognitive processes, this demands the integration of a number of component skills, which if are lacking or fail to integrate successfully can adversely affect handwriting development and performance.

Not surprisingly, many parents and adults encourage pre-school children to make letter-like forms/letters and by the time they reach school they may be able to produce letters or visual approximations of letters. However, this can have unfortunate consequences if incorrect formations have been permitted. Letter formation involves the correct ‘movement’ through the letter itself, which needs to be taught to children. If children are left to their own devices or taught letter formation incorrectly, one must take account of the words of Sassoon (2002) who rightly states ‘incorrect movements become habits that are progressively more difficult to alter’ (p. 2).

Writing is a motor skill which requires motor learning. Chambers and Sugden (2006, p.11) highlight four distinct characteristics of motor learning:

1. ‘Motor learning involves a set of underlying events or changes that occur due to practice, enabling the individual to become more skilled’.
2. ‘Learning is the direct result of practice or experience’.
3. ‘Only the results of learning can be observed and measured as the underlying processes are internal. Thus learning results in a change in performance’.
4. ‘Learning is relatively permanent’.

Translating the above points in respect of learning to write letters/numbers; the individual learns, then automates the movement of the hand and arm, which results in the production of a specific letter/number. Once a movement becomes automated and associated with a specific letter/number it becomes very difficult to alter. Therefore children’s letter/number formations should be observed carefully to ensure correct formation, scrutinizing the end result is not sufficient, for example a clockwise ‘o’ closely resembles an anticlockwise ‘o’! However, the former in the future will not join as easily and will not provide the appropriate foundation for forming letters in the same graphic family. Children need to be trained to ‘feel’ the right movement for each letter/number. However, it is not postulated that a kinaesthetic approach is used in isolation, simply as part of a multi-modal approach to letter formation.

Desai and Rege (2005) report that factors that contribute to illegible writing are incorrect letter formations or reversals, variable slant and poor alignment, and irregular spacing between words and letters. Scardamalia, Bereiter & Goleman (1982) state that handwriting is considered to be proficient when legible text is produced with minimum of effort. In this case, handwriting is automatic, and does not interfere with the content as generated by the creative thinking process. In contrast, poor handwriters are

highlighted as being unable to achieve a completely automated process”. To elaborate, Berninger and her colleagues suggested in the Handwriting White Paper of July 2007, that writing development is the process of creating a ‘functional system’ comprised of multiple components, with some components considered to be low level and others higher level. The low level skills are considered to be a good understanding of the written alphabet letters, be able to generate letter representations from memory, access these letter representations from memory before utilising motor planning and motor production to produce letters fluently. The higher level skills suggested include strategies for planning, generating language in the form of sentences and reviewing and revising written text. If the lower level skills are not firmly embedded the individual needs to devote greater attention to them which detracts from their ability to devote attention to the higher level tasks.

Thus an individual needs to develop what Berninger terms ‘writing automaticity’, the ability to retrieve and produce letters automatically, thus freeing up memory space for the higher level processes. Handwriting automaticity can be assessed by the number of correctly written letters produced within a brief time frame. Berninger promotes automaticity through the use of her handwriting intervention programme ‘Write Stuff’ (1997), which encourages a child to study a model of the target letter which has numbered directional arrow cues attached and to follow those cues as they form the letter. Children are then asked to form the letter from memory in an attempt to help create a ‘retrieval routine’. Berninger suggests that the time interval between looking at the letter and writing the letter should gradually be increased. Berninger also suggests to avoid brain habituation, a process whereby a stimulus is received but subsequently not responded to by the brain due to over repetition, children should not be asked to repetitively form single letters but write all twenty six letters in the alphabet just two or three times. However, writing is in part, a large part, a motor skill. As Chambers and Sugden (2006) highlighted, motor learning occurs as a result of practice. Young children do need frequent reinforcement and practice to learn skills, more specifically in the case of letter formation practice to learn the movement of an individual letter before moving on to the next.

In relation to automaticity, several studies have examined the impact of handwriting ability on task completion within the classroom setting. Graham, Berninger and Weintraub (1998) revealed that some pupils identified as having handwriting difficulties required on average fifty minutes to complete a task that would normally be

completed by peers in just thirty minutes. Indeed, a most interesting study by Rosenblum, Parush, Epstein and Weiss (2003) investigating human evaluation versus digitiser-based evaluation of the handwriting product, suggested that children identified as having handwriting problems held their writing implement 'in air' above the writing surface between the writing of successive character segments, letters and words for significantly longer than the more proficient writers. Rosenblum et al speculated that increased 'in air' time was directly linked to 'reduced continuity, consistency and efficiency of writing movements' (p.4).

As highlighted in Chapter 1, studies have suggested that between 10 to 27% of school aged children experience handwriting difficulties and research literature has extensively documented the adverse effects of poor handwriting on future academic performance. It is vitally important that educators appreciate the academic and psychological consequences of poor handwriting which remains an essential skill both inside and outside the classroom today, despite the now widespread use of technological devices.

2.4.2.2 Developmental Neuropsychology

Obrzut and Hynd (1986, as cited in Berninger and Hart, 1992, p. 416) considered developmental neuropsychology to be a relatively young discipline that deals with 'the struggle to acquire function, a topic on which there is comparatively little research, rather than the loss of previously acquired function' which has been researched more fully in their opinion. In particular, the concept of dissociation is considered, where one process or mode is disturbed but a related process or mode remains intact. In relation to letter formation for example, one of the component skills may fail to develop or develop adequately, yet a related component skill may develop totally adequately. As a result children can present with multiple profiles reflecting a variety of combinations of strengths and difficulties on the component skills that underlie letter formation.

This 'developmental dissociation' postulated by Berninger and Hart (1992) in which specific component skills that underlie the same outcome do not develop at the same rate results in the possibility of identifying the various separable components contributing to an integrated functional output. The developmental neuropsychological approach to componential analysis 'lends itself to individual unit of analysis, which is of critical importance for generalizing results to the individual to improve educational assessment and intervention'.(Berninger and Hart, 1992, p.417). Such an approach

might be usefully considered by educational psychologists when attempting to focus on neurodevelopmental skills related to the learning of academic skills.

This concept links to a point highlighted earlier in the chapter, namely that multi-modal perception is beneficial because if one mode is less efficient for any reason or fails completely, perception will be facilitated by the other modes involved in that particular skill. Therefore, multi-modal learning experiences potentially enable a learner to develop skills despite having a deficit in one or maybe more than one modality and as a result may reduce/remove the need for intervention.

2.4.3 Multi-modal Learning Experiences and the use of Educational Technology

2.4.3.1 Multi-modal Learning Experiences

Human beings, just like many other organisms possess multiple sensory systems. It has long been recognised that sensing the world this way is beneficial to our existence not only because each different sensory modality can sense different aspects of the environment, but also different sensory modalities can detect and respond collectively to the same stimulus. For example, from an evolutionary perspective a well camouflaged predator might be detected due to a combination of auditory and visual cues being received as the predator moves through the undergrowth. Furthermore, within a busy and potentially noisy classroom a child might hear the teacher's voice better if he/she can see the face and lip movements of that teacher.

The capacity of the human brain to synthesise the multi-modal information arising from a common source enables us to direct our attention accordingly, if however the brain receives conflicting information from the differing modalities then our perception of events will become confused and downgraded, as illustrated by the 'McGurk effect' (McGurk & McDonald 1976).

Dr Gustav Kuhn speaking on the BBC Horizon programme screened in October 2010 stated that 'We see the world through the lens of the past – we see the world in the way that is most useful', therefore we rely on previous experiences. He also stated that when the brain receives conflicting information from differing modalities then the modality providing the most information is likely to take control.

Although beyond the scope of this research a brief mention will be made of the unusual phenomenon of synesthesia, frequently described as the blending of the senses.

Synesthesia, is thought of as a cross-sensory phenomenon, where for certain individuals sounds will induce specific colours, or tactile experiences will produce a specific taste, for example. In most cases the stimuli that induce synesthesia are not sensory, but are more often conceptual categories of learned facts such as letters and numbers. The most common types involve coloured letters/numbers and mental ‘number forms’ where numbers occupy a specific position in space. For some individuals who view letters/numbers in this way, they can display extraordinary abilities. Daniel Tammet (2012) who has Asperger Syndrome and synesthesia displays an amazing talent for conducting arithmetical calculations. Having a particular colour for letters/numbers has enabled some with synesthesia to remember names and phone numbers with ease.

Research into synesthesia continues to grow and (Cytowic, 2002) believes that ‘Nature reveals herself through exceptions.....synesthesia turns out to illuminate a wide swath of mental life and forces us to think some fundamental issues regarding mind and brain’. www.lurg.org/article.php/vol2nl/synesthesia.x 26.11.11. The researcher questions whether it is possible to increase the learning capacity of young children by assigning a unique ‘multi-modal signature’ to letters/numbers, bearing in mind how the ‘blending of the senses’ has helped this population.

As highlighted in 1.6, within our everyday environment stimulation to several modalities occurs simultaneously, and the term ‘valid co-occurrences’ (Bertelson and De Gelder, 2004) is used to describe inputs to different sensory modalities that result in simultaneous information about the same external stimulus. Bertelson and De Gelder also postulate that as a result of valid co-occurrence opportunities, improved performance increases. If this theory is linked to that of ‘developmental dissociation’ (Berninger and Hart, 1992) described previously, it would appear sensible to attempt to ensure that learning/skill development opportunities for young children are presented in a format that permits the maximum number of valid multi-modal co-occurrences as possible, to increase the likelihood of success, and to minimise the effects of component skill immaturity.

Therefore, to apply this theory to difficulties relating to persistent CLP and confused directionality, and more specifically in relation to letter/number formation, it is hypothesised that the more valid co-occurrences that can be provided during input the greater the likelihood of success. The use of educational technology may assist in the correct formation of letters/numbers for all children, especially but not exclusively for

children with delayed lateral preference and/or persistent CLP, because through the use of multi-modal input, namely through visual effects (changing colours), auditory effects (changing sound) and tactile effects (fingers touching the surface of the table), the number of valid co-occurrences in relation to this task will hopefully be increased.

These multi-modal experiences may help children to develop their motor, visual and auditory memory for numbers and letters more efficiently, which will aid letter/number recognition, formation and recall. As a result the lower level writing skills as proposed by Berninger, may well be acquired more quickly, thus enhancing ‘writing automaticity’. Furthermore, potentially the concept may be beneficial for the hearing and visually impaired population, although investigating this is beyond the scope of this study.

2.4.3.2 Memory for colour, shape and sound

Colour frequently plays an important role in our everyday interactions within the environment, both natural and manmade, for example, deciding whether fruit is ripe enough to eat or stopping at red traffic lights. For most people colour is a very important property of the human visual experience, and helps to segregate the world into meaningful segments. Indeed, one only has to examine the success of camouflage in nature, where boundaries become obscured, to realise the importance of colour in segmentation.

Spence, Wong, Rusan and Rastegar (2006) report that studies (Gegenfurtner & Rieger, 2000; Suzuki & Takahashi, 1997; Wichmann et al., 2002) with natural scenes suggest that colour is a factor in visual memory. Further, Lloyd-Jones and Nakabayashi (2009, p.310) state that ‘there is general agreement that colour provides a perceptual input to early stages of visual processing’ and that events which require the perception and processing of colour also require combining colour with other forms of information associated with a particular object or class of objects, often foremost information about object shape. Not surprisingly, Lloyd-Jones and Nakabayashi identified a number of studies that have shown that colour improves identification when it is appropriate for the object. More interestingly perhaps, Price and Humphreys (1989) have demonstrated that the beneficial influence of colour on object/shape naming is only apparent when the colour occupies the internal ‘space’ of objects/shapes and is seen as belonging to the object, rather than when occupying ‘the background’ against which the object/shape appears, despite the boundary being consistently coloured/white.

throughout exposure to the stimuli in an attempt to prevent verbal recoding. The results suggested that recognition for unitary displays was superior when compared to separate displays for shape-colour association when verbal recoding was precluded, this effect was not recorded when verbal recoding was permitted.

The second experiment aimed to investigate whether participants in the suppression condition of Experiment 1 were linking colour either to letter names, or to the abstract identities of the letters themselves, by focusing on letters of the alphabet that are structurally dissimilar in their upper and lower case forms, and by utilising different case but same font probes. Walker and Hinkley (2003) hypothesised that if the superior recognition for unitary displays found in Experiment 1, reflected memory for letter names or their abstract identities, then the same effect should be observed in Experiment 2. Walker and Hinkley found that the superiority for recognition of unitary displays, as found in Experiment 1, was eliminated in Experiment 2, even when verbal recoding was precluded, and made the conclusion that visual memory for shape-colour conjunctions involves structural descriptions of the shape and are not based on letter names or the abstract identities of the letters.

The current research draws on the findings of Walker and Hinkley (2003) because, for visually similar letters, in particular e.g. b/d/p/q children frequently display confusion between these. Therefore, the current research aims to combine multi-modal experiences including visual memory for letters, taking account of shape-colour conjunctions and the inclusion of structural descriptors for letters in an attempt to aid recognition and formation and reduce confusion.

2.4.3.2.1 The use of Colour and Sound with Children with ADHD and Autism

Given that pupils diagnosed with ADHD and autism are frequently educated within the mainstream environment, use of colour with these specific groups is explored. Dr Margarete Imhof of Johann Wolfgang Goethe University investigated the use of colour stimulation on handwriting performance of children with ADHD, both with and without additional learning needs. Zentall and Zentall (1983) hypothesised that children with ADHD respond better to increased stimulation and found that both motor activity and academic performance could be positively influenced when additional environmental stimulation was introduced.

Imhof (2004) found in her study that children with ADHD took more time to complete tasks, made fewer mistakes and produced better quality handwriting when using coloured sheets of paper. No such improvement in (grapho) motor behaviour was found in the control group. Imhof (2004) hypothesised that the colour stimulation produced changes in cortical activity which influenced behavioural inhibition and facilitated motor coordination, attention regulation, and the effective monitoring of cognitive functions, including working memory and motivational regulation.

Furthermore, a study by Franklin, Sowden, Burley, Notman and Alder (2008) examined whether colour perception is atypical in children with autism. Anecdotal evidence suggests that children with autism may perceive colour differently to typically developing children, especially when one takes account of the behavioural displays in relation to obsessions and sensitivities associated with particular colours. However, Franklin et al. found that children with autism were not only less accurate at discriminating colours within a colour category, but were also less accurate at between-category discriminations when compared to controls matched for age and non-verbal cognitive ability.

However, Bonnel et al. (2003), Heaton et al. (1998) and Mottron et al. (2000) (as cited in Franklin et al., 2008) state that research has shown that people with autism generally display enhanced perception and discrimination for pitch processing, musical processing and processing of auditory stimuli. Therefore, in respect of the use of the intended multi-modal software, even if those with autism find it difficult to perceive the colour changes involved, auditory discrimination of the associated sound patterns should prove beneficial.

Stix (2011) reports that musicians perceive sound more accurately than non-musicians, as he believes that practising an instrument helps to 'train' the brain. Stix reports that monitoring of the electrical signals of the brain perception of sound reveals that musicians develop an increased sensitivity to pitch and as a result can track an incoming sound wave more accurately than a non-musician. Once again in respect of using a multi-modal approach to letter/number formation, by adding the auditory component to the learning experience, not only might it enhance auditory memory for letters/numbers, thus improving recall of correct formation, it may also in a minor way help to improve the learner's perception of sound.

2.4.4. The Use of Educational Technology within the Classroom

There is no doubt in this ever evolving technological age the use of information and communications technology (ICT) within the learning environment is on the increase. Dunsmuir and Clifford (2003) highlight that a large scale evaluation (ImpaCT2, Department for Education and Skills) was conducted between 1999 and 2002 in an attempt to identify the impact of networked technologies on school and out of school environments, and to evaluate the influence on attainment of pupils at Key Stages 2, 3 and 4.

The findings suggested that

‘...while ICT can exert a positive influence on learning, the amount may vary from subject to subject as well as between key stages, reflecting factors such as the expertise of teaching staff, problems accessing the best material for each subject, and the quality of ICT materials that are available’
(Dunsmuir and Clifford, 2003, p.172-173).

Despite this study being conducted ten years ago, these findings appear to remain largely pertinent today. Furthermore, a key question discussed across seventeen European countries at this time, and highlighted in a report summarising information from the ICT in Special Needs Education Project (2001) was ‘how can ICT give more, or add value to the educational experiences of pupils with special needs?’ Once again, this also appears to remain pertinent today and warrants further consideration.

Frequently ICT in the learning environment is equated with the use of computers and an interactive whiteboard in today’s classrooms, especially at primary school level. However, ICT is becoming increasingly commonplace within the classroom. Furthermore, the interactive whiteboard tends to be predominantly used by the teacher, with few opportunities for pupil use. In society today, many pupils have experience of using a computer even prior to starting school, including computers/tablets with touch screen facility. The current research aims to consider how ICT can be used appropriately and specifically to enhance letter/number recognition and formation for all pupils, through a multi-modal approach coupled with touch screen technology. Essentially three modalities of learning are intended, namely; visual, auditory and tactile.

Beeland (2002), an Instructional Technology coordinator, conducted an action research study in an attempt to determine the effect of the use of interactive whiteboards as an

instructional tool on pupil engagement. Within the study 197 pupils and 10 teachers participated. Pupil and teacher views were collated through the use of a survey and some were also asked to complete a more detailed questionnaire. The data collated via these means were analysed to determine the level to which pupils were engaged during the lesson being taught with the use of the whiteboard.

Beeland (2002) reported that the results of the study indicate that interactive whiteboards can be used in the classroom to increase pupil engagement during the learning process.

Some responses reported by pupils in this survey included:

- ‘I concentrate harder when we use the whiteboard. It teaches us a lot, but it’s lots of fun’
- It makes me pay attention to the teacher more’
- To some people, when you speak to them, it goes in one ear and out the other. The visuals help it to stick’
- ‘I get into learning when it is hands-on’

Some responses reported by teachers in this survey included:

- ‘It’s a tool that easily lets students actively participate and gets them involved in the lesson’
- ‘It contributes to learning because it helps to get students interested’
- ‘the use of the whiteboard contributes to learning because today’s students seem to be very visual and enjoy hands-on activities’
- ‘Of course, if there are problems with the technology aspect.....I feel very unprepared and feel like I always need a backup plan’

Beeland (2002) reports that all of the teachers felt that the whiteboard did improve pupil engagement during the lesson, and mostly attributed this to the pupils being able to see the information, touch the screen and at times hear the sounds. Beeland does not report how frequently the whiteboard was used generally within lessons prior to the study and within the report it is unclear whether the results of the findings were based on just ten observations, one with each teacher. A factor to consider would be the ‘novelty effect’ if indeed the whiteboard was used infrequently prior to the study.

According to Furner (1985), computer based instruction in teaching handwriting skills has the potential to facilitate learning in this basic skill area as it can provide accurate, immediate feedback for refined motor learning and precise letter formation, as well as enhanced motivation to learn the skill.

Macleod and Lally (1981) conducted a study to examine the teaching of manuscript letters to two small groups of mildly handicapped pupils with handwriting difficulties. Nine pupils received 3 half-hour individual computer-based exercise sessions for five weeks (experimental group), and a matched group of nine pupils received an equivalent amount of traditional instruction (control group). Teacher rankings of letter formation at the end of the intervention period suggested that more pupils in the experimental group showed improvement. Macleod and Lally reported several advantages of the computer-based exercises over more traditional approaches including ‘enhanced motivation and attention, minimisation of errors, transfer of control of movement from visual feedback to kinaesthetic feedback, and the requirement for active decision making in letter formation’ (p.119). However, it has to be noted that sample size was exceptionally small and teacher rankings can be very subjective.

Interestingly, Roberts and Samuels (1993) undertook a study to compare the effectiveness of computer-based handwriting exercises with traditional instruction in the remediation of handwriting difficulties with 36 pupils. Three methods of remediation were employed and monitored with a group of 12 pupils within seven lessons each lasting forty minutes.

- Method 1- computer-based handwriting exercises using a graphic tablet, electronic pen and a computer to track visible and invisible letters.
- Method 2- conventional instruction using paper and pencils, plastic overlays and felt pens to copy and trace letter forms.
- Method 3- conventional instruction using tracing and copying through the computer using the Touch Window (a touch sensitive surface) and a stylus pen.

The findings of Roberts and Samuels (1993) did not support their hypothesis that pupils participating in the computer-based handwriting exercises group would show superior improvement in pre-test to post-test scores than in the conventional group handwriting instruction group. Indeed, results suggested that traditional methods using paper and pencils brought about the greatest difference on a linear combination of the pre-test to

post-test variables, particularly shown through letter formation and teacher rating measures. Thus the findings of Roberts and Samuels did not echo those of Macleod and Lally (1981). Furthermore, Roberts and Samuels highlight that the small sample size and reliability problems inherent with gain scores limited their study. Sadly neither of these studies or any others examined in the literature have considered laterality as a variable.

Dunsmuir and Clifford (2003) report that in the main educational software is developed by commercial companies and designed to meet market needs and suggest that ‘those working with children need to integrate information about available products, curriculum objectives, writing development and psychology when selecting software’ (p.184). They also suggest that a closer relationship between commercial interests and researchers at the product development stage would be beneficial. In line with this suggestion, this present study utilises software development based on research and experience of working with children displaying specific difficulties around letter/number formation rather than software development being commercially led. The research attempts to devise, develop and then in light of findings modify an application of ICT to aid the multi-modal recognition and formation of letters/numbers, using touch screen technology.

2.5 Research literature relating to the Development of writing skills/Human lateral preference/Cross lateral preference and its affect on learning

In chapter 1 the terms human lateral preference (HLP) and cross lateral preference (CLP) were defined in the context of this research and the origins of laterality were explored. Some of the most popular theories proposed to account for the right-sided bias of the motoric system in human beings were presented. Research literature investigating HLP and its affect on learning, in particular the acquisition of literacy skills, and more specifically its affect on the recognition/formation of letters/numbers, is now considered.

2.5.1 The Development of writing skills

Rosenblum, Parush, Epstein and Weiss (2003) investigated ways in which evaluation of the handwriting product, both objective, using a digitizer-based evaluation tool, and subjective, using human evaluation, which lead to a greater understanding of the handwriting performance of poor hand writers. Rosenblum et al. (2003) highlight in this

study that the use of ‘conventional’ writing assessments are useful in that they have enabled the evaluation of handwriting legibility, but are limited by the fact they are dependent on subjective judgement for scoring and interpretation. However, the use of a digitizer-based evaluation tool helped to advance the understanding of spatial and temporal characteristics of children with poor and proficient handwriting. Furthermore, it has provided additional information regarding the development of handwriting skills that would not be discernible to the human eye.

In their study, two groups of 8-9 year old writers namely, proficient and dysgraphic were identified and given four handwriting tasks: writing the letters of the alphabet in order from memory, copying four words, two sentences and a 100-character paragraph. The primary outcome measures using the digitizer-based evaluation tool were total time (on paper and in air time) and total length (on paper and in-air length). Alongside these measures conventional measures of global legibility as well as analytical legibility were used.

Rosenblum et al. (2003) reported that the subjective measures did discriminate between proficient and dysgraphic writers, however, more interestingly, they found the objective measure of ‘in air time’ (the literature refers to this phenomenon as pauses, or temporary halts in the flow of writing) to be for a significantly longer period of time amongst pupils with handwriting difficulties. In fact the team found that the poorer the individual’s score for global legibility, the longer the child’s measured In Air and In Length were found to be.

Rosenblum et al. (2003) hypothesised that ‘in air’ time displayed by pupils with poor handwriting skills ‘helps them to prepare to execute subsequent characters or character segments’ p.16., and reflects a lack of writing automaticity. Rosenblum et al. (2003) also considered whether the ‘in air’ time detected reflected the time required by the individual to initiate the muscle groups in order to carry out the necessary motor movement to form characters. Rosenblum et al. do not consider the possibility of the individual ‘pondering’ over character formation due to CLP and as a result increasing ‘in air’ time. An interesting development of the Rosenblum et al. study would have been to consider lateral preference and to investigate whether a significant positive correlation exists between extended ‘in air’ time and lateral preference and CLP in particular.

Much of the research available in respect of handwriting development examines the effectiveness of handwriting intervention programmes with non-proficient compared to proficient hand writers, and then attempts to relate the findings back to deficits in underlying skills, rather than examining the individual's ability on the pre-requisite skills for handwriting as a starting point. Reference has been made to a developmental perspective of the skills required for letter/number recognition/formation and handwriting (2.4.2.1.), it is argued that due consideration of these skills prior to any intervention wherever possible is undertaken, in an attempt to ensure that the individual is provided with the most appropriate intervention, which may not be a handwriting intervention programme at all!

Chang and Yu (2010) investigated handwriting difficulties in children with or without developmental coordination disorder (DCD), and highlighted that the attainment of automated handwriting was markedly slower in children with handwriting deficits and DCD because when learning to write more complex characters as the stroke velocity of this group was found to be significantly slower and weaker than that of typically developing children.

Chang and Yu hypothesised that the disautomation in the learning process coupled with the slower rate of writing the more complex characters displayed by this group, interacted with each other during the learning process that occurs during the act of handwriting. Although a number of screening measures were used including the Chinese Handwriting Evaluation Questionnaire, the Movement Assessment Battery for Children, the Beery-Buktenica Developmental Test of Visual-Motor Integration and the child's preferred hand was noted, but no consideration was given to the possibility of CLP. However, Chang and Yu did highlight that 'the correct identification of motor deficits in children is an essential prerequisite for an effective clinical intervention' (p.249). This is heartening as very often this is not evident and children are involved in handwriting intervention programmes when motor control programmes might be much more beneficial, enabling the child to acquire or improve the necessary underlying motor skills before embarking on a handwriting intervention programme.

Volman, van Schendel and Jongmans (2006) investigated the contribution of perceptual-motor dysfunction and cognitive planning problems to the quality or speed of handwriting in forty nine children identified as having handwriting problems. A number of instruments were used to gain data including subtests from the Movement

ABC test (Henderson and Sugden, 1992), more specifically two subtests from the Manual Dexterity category: unimanual speed and unimanual spatial accuracy, to form a Unimanual Dexterity measure, which was used as the first measure of fine motor coordination. A third measure in this category, namely bimanual coordination, was disregarded for use due to the fact that the researchers were ‘not interested in bimanual coordination ability’ (p.454). A second measure of fine motor coordination was derived from the motor coordination subtest of the Developmental Test of Visual-Motor Integration (VMI) (Beery, 1997).

In this study the researchers highlighted a number of interesting points which are summarised below:

- the HWP (handwriting problems) group scored significantly lower on the Unimanual Dexterity and VMI motor coordination subtests than the control group (no handwriting problems) group.
- the HWP group scored significantly lower on the VMI-visual perception than the control group.
- both HWP and control groups had significant Pearson correlations between writing quality and Unilateral Dexterity.
- HWP group only displayed a significant correlation between quality of handwriting and VMI-integration.

Given the points above, coupled with other factors in their research findings, the researchers concluded that two different mechanisms underlie the handwriting performance in both groups. The researchers concluded from this study that the underlying mechanism responsible for poor quality of handwriting (equated with letter formation) in the HWP group is related more to visual-motor integration processes than to fine motor processes. The researchers report in their research paper that this finding is in agreement with findings from a study by Maeland (1992), in which a similar correlation was reported between quality of handwriting and visual-motor integration amongst a group classified as clumsy/DCD. Furthermore, it is reported that in Maeland’s study, no such correlation was found between visual-motor coordination and the quality of handwriting amongst the group classified as non-clumsy with handwriting difficulties.

Neither Maeland (1992), or Volman, van Schendel and Jongmans (2006), took into account the lateral preferences of the participants. As highlighted previously, VMI in its most simple format may be viewed as the ability of the eyes and hands to work together in smooth and efficient patterns. It involves visual perception and eye-hand co-ordination. Therefore, the findings of Volman et al. study may be suggesting that the children in the HWP group are those who are experiencing greatest difficulty in their ability to use their eyes and hands together in a smooth and efficient manner, such as those described in Maeland's DCD group. It is distinctly possible that for some of the children at least that problems relating to CLP were present but not recorded, and as a result overlooked as a factor.

2.5.2 Human lateral preference/Cross lateral preference and its affect on learning

Tan (1985) investigated the hand preference of 512 four year olds using the McCarthy Motor Scales and a fine motor scale designed by the researcher in an attempt to establish whether handedness was related to motor competence in preschool children. From this population 448 children were identified as right-handed, 41 were identified as left-handed and 23 as lacking definite hand preference. Tan found no evidence to support the notion that left-handed children are poorly coordinated and inferior to right-handers in respect of motor abilities. Tan postulated that because left-handers' mode of action looks different to the right-handed majority it may be considered to be awkward and less skillful.

Tan (1985) did however find that those children who lacked a definite hand preference obtained significantly lower scores on the motor abilities tests. This finding concurs with the normative sample of the McCarthy Scales studied by Kaufman, Zalma & Kaufman (1978) where the 'dominance not established group' of 2-4 year olds also scored lower on the McCarthy motor index. Tan concluded that children who establish hand preference early are better co-ordinated than those who establish hand preference late or not at all.

Tan (1985) reported that the lack of hand preference found amongst the experimental group should serve as a marker indicating that these children need special assistance to help further develop their motor skills and to help them avoid confusion with particular skilled tasks which might impact on their learning.

In this study no reference is made to human lateral preferences other than for handedness, therefore it cannot be said with certainty that the children who lacked a definite hand preference would have displayed CLP, but it is a possibility.

De Agostini and Dellatolas (2001) argue that the presence and type of correlations between laterality and cognitive skills in normal adults and children remains controversial. Their study examined the relationships between the human lateral preferences of handedness, footedness and eyedness, parental left-handedness, asymmetry of hand skill on a computerised task and a number of different verbal and non-verbal skills assessed by thirteen tasks amongst 254 children aged three to eight years. It may be helpful to note that psychometric measures to obtain an Intelligence Quotient were not undertaken. Their work was part of a longitudinal study on normal child development in pre-school and school aged children in France.

Interestingly no evidence was found for any deleterious effect on children's cognitive performance in relation to inconsistent lateral preference of hand, eye or foot, or parental sinistrality. Furthermore, results showed a trend towards a slight advantage amongst right handers. De Agostini and Dellatolas (2001) reported that they found no evidence of any disadvantage for children showing approximately equal dexterity with either hand as reported by Crow, T., Crow, L., Done & Leask (1998). However it must be noted that the manual dexterity tasks utilised in each study were very different with; a pencil and paper exercise (Crow et al., 1998) compared to a computerised peg moving task (Agostini and Dellatolas, 2001).

Both Crow et al. (1998) and De Agostini and Dellatolas (2001) found a relationship between increasing cognitive abilities with increasing dextrality. Furthermore, De Agostini and Dellatolas reported variation of performance on the different cognitive tasks presented appeared to be related to hand skill; namely strong right-hand advantage to strong left-hand advantage, but highlight that further research is needed in this area to confirm and further interpret these findings.

However, in contrast, Whittington and Richards (1987) analysed data from over 11,000 children in the National Child Development Study which began in the UK in 1957 and argued that 'variations revealed in the pattern and rates of development of handedness, coupled to certain ability and attainment deficits, suggest that for a substantial number of children left-handedness and lack of consistent handedness may be associated with processing difficulties' (Beaton, 2004, p.163). Furthermore, Briggs and Nebes (1975)

reported that full scale IQ scores amongst undergraduates were lower in left-handers and mixed-handers than in ‘fully dextral’ individuals.

As highlighted in Chapter 1.4.3 and again in Chapter 2.3, the notion of incomplete cerebral dominance resulting in associated laterality confusion and difficulty learning to read and write including the production of reversals was popularised by Orton as long ago as the 1930’s. Orton believed that letter reversals (strephosymbolia) and mirror-writing were especially common among poor readers. Beaton (2004) reports that we now know that mirror reversals are found in a great many children, though these difficulties may persist for longer amongst younger dyslexic children. However, Orton based his notion of strephosymbolia on the belief that children displaying dyslexia were also more often left-handed or displayed crossed hand-eye dominance. Beaton (2004) reports that Orton’s theories were adopted enthusiastically and as a result some children displaying the aforementioned characteristics were labelled as dyslexic. Beaton (2004) believes that this has resulted in confusion and misinterpretation in the subsequent research literature.

Extensive searches for research studies pertaining to CLP and the development of writing skills have been undertaken and, although a number of related studies have been sourced and discussed, nothing specific to this area has been found.

2.6 Summary of findings from the literature and research evidence

Research to date indicates that the human brain is functionally asymmetrical and displays hemispheric specialisation, but appears to possess an ‘inhibitory barrier’ that enables interhemispheric harmony. A number of researchers (Berninger and Shaywitz, 2006; POST, 2000) report that the human brain remains malleable, at least in some areas, and responds to instruction right through to adulthood. Furthermore, it is considered that the brain undergoes synaptogenesis at critical periods, especially during the early years making this time a particularly sensitive period for learning.

Bioecological systems theory, which considers that the child’s own biological maturation and interaction with their family, the immediate environment and the larger societal environment in general have been discussed and all shown to significantly impact on the child’s cognitive development. This emphasises the need for a rich and stimulating environment in which young children can develop, thrive and reach their potential at their own rate. As highlighted previously, proficient teachers/early years

educators are well placed to identify if a child is fulfilling their developmental potential, and if they consider this is not the case can organise appropriate early interventions.

The concept of providing the learner with multi-modal learning experiences, enabling a more holistic approach to learning has been explored, placing emphasis on the learner being able to adopt their preferred learning style. Furthermore, the possibility of a pupil experiencing ‘developmental dissociation’ (Berninger and Hart, 1992), was highlighted and the potential for multi-modal learning experiences enabling a learner to develop skills despite having a deficit in one or more modalities.

In terms of findings from literature and research evidence in relation to the development of handwriting skills there appears to be an agreed ‘natural’ progression of skills which a child is expected to acquire, and these can roughly be equated with developmental stages. Visual motor integration along with skills including motor planning, cognitive, perceptual, tactile and kinaesthetic are seen as essential by many researchers to enable writing skills to develop to automaticity.

There appears to be conflicting research findings and practice as to whether the use of computer based instruction/use of an interactive whiteboard in the teaching of handwriting skills is advantageous over the traditional methods involving paper and pencils. However, there does seem to be a consensus of opinion that the use of an interactive whiteboard in teaching increases pupil motivation and enhances learning, as evidenced in 2.4.4.

Studies investigating human lateral preference and its affect on motor skills were examined. Not surprisingly, children who lacked a definite hand preference scored lower on tests of motor abilities. Studies pertaining to human lateral preference and cognitive ability appeared to show a general positive correlation between increasing cognitive ability with increasing dexterity, amongst both right and left handers.

Although consideration should be given to the possibility that potentially some tasks may be easier to complete with increased dexterity and therefore the results could be misleading.

There appears to be an absence of research pertaining to human lateral preference and the recognition/formation of letters/numbers, and for this reason this current study attempts to explore the use of educational technology to assist in the correct formation

of letters/numbers for all children, taking into account the lateral preferences of the sample population.

2.7 Summary of rationale for present study

This section will outline the rationale for this study.

A number of studies have indicated that handwriting dysfunction amongst school aged children is a widespread and significant problem, e.g. Smits-Englesman, VanGalen and Michelis (1995), Rubin and Henderson (1982). Furthermore, studies have suggested that children with writing difficulties may suffer serious consequences in terms of their emotional well-being and social functioning, e.g. Cornhill and Case-Smith, (1996), Kaminsky and Powers, (1981), Modlinger, (1983), as well as being disadvantaged in the learning environment, e.g. Gray, Dean and Seretny (1986). Furthermore, handwriting is a very complex task demanding the integration of a number of component skills, which if are lacking or fail to integrate successfully can adversely affect handwriting development and performance.

In addition, Rosenblum and Livneh-Zirinski (2008) found that children with a developmental co-ordination disorder produced slower handwriting movements. They were unable to conclude from their research whether this was due to slow movements in general or due to difficulties with motor memory for letter formation and /or in visualising the letters when needed to form them rapidly.

Despite the major advances in technology, the ability to form letters/numbers and to be able to produce legible script remains essential to all.

Furthermore, it has been highlighted that many humans demonstrate a strong and consistent preference in the use of their paired limbs and organs, predominantly to the right. A much lesser number demonstrate the same for their left side. Some individuals display CLP, but there remains much debate about the prevalence of this within the population. As highlighted in Chapter 1, it has been suggested that as many as 67% of the pre-school population demonstrated CLP when assessed for the indices of hand, foot, eye and ear, and as such is considered to be part of the normal stage of development of the human species.

Research studies (Kaufman, Zalma and Kaufman, 1978; Tan, 1985) highlighted previously suggest that children who lack a definite hand preference scored lower on

tests of motor abilities. Similarly research findings (Crow et al., 1998; De Agostini and Dellatolas, 2001) suggest that cognitive ability shows a general positive correlation with increasing dexterity. Therefore, it is a possibility that young children who display CLP might lack a definite hand preference and/or display reduced dexterity and as a result be disadvantaged in the learning environment, particularly in relation to letter/number formation due to confusion regarding directionality.

2.8 Aims of present study

This present study aims to investigate whether the use of educational technology in the form of an interactive table can assist young children in the development of early letter/number formation and handwriting skills. The researcher intends to commission a programmer to develop the software under her direction to provide young pupils with multi-modal learning experiences through incorporating the interaction of visual, auditory, and tactile modalities, utilising sound, colour and touch. The use of the software is intended to assist all pupils, but especially those displaying CLP which sometimes results in difficulties with laterality and directionality. Therefore the researcher will also be exploring the prevalence of CLP amongst the sample population and the relationship of those displaying CLP with the development of early letter/number formation.

It is hypothesised that through the implementation of this newly developed software for use on an interactive table or tablet, young pupils will improve their ability to ‘visualise’ letters/numbers and their motor memory for correct formation. Furthermore, it is hypothesised that young children will ‘hear’ correct letter/number formation, as the software attempts to promote the motor, visual and auditory memory for letters and numbers through the associated use of changing colours and sounds.

The researcher hypothesises that educators have limited knowledge of human lateral preference, CLP and mixed dominance. Therefore, research findings hopefully will inform all those involved in the education of young people.

2.9 Summary of literature review

This chapter has discussed both theoretical and research literature relating to brain development, the development of letter/number formation and handwriting skills and the use of multi-modal learning experiences coupled with the use educational technology.

The rationale for the present study and the way in which it further develops existing knowledge and understanding of letter/number formation taking into account human lateral preference has also been discussed. Finally, the aims of the present study have been discussed and outlined.

CHAPTER 3: METHODOLOGY

3.1 Overview

This chapter outlines the methodology employed in this study. The rationale for the chosen research paradigm will be explored and the procedures, sample population, data collection, data analysis and ethical considerations will be discussed.

This present study attempts to explore whether through the vehicle of educational technology combined with multi-modal learning experiences young children can benefit from positive learning experiences that will assist them with directionality and laterality, particularly in respect of letter/number formation and recognition.

The software development was commissioned for use with an interactive touch screen table/board/tablet in an attempt to promote the development of motor, visual and auditory memory for letters and numbers, which may then aid formation and recognition, based on the reviewed research.

Furthermore, this present study attempts to assess the lateral preference of young children across four indices namely: hand, foot, eye and ear, in order to measure the establishment of laterality at age 4 – 5 years.

Finally, this present study attempts to assess the understanding of those involved in educating our young of human lateral preference/cross lateral preference and its potential impact on learning, both in the short and long term.

The following research questions were formulated:

- What is the prevalence of CLP amongst young children?
- Does the use of educational technology and multi-modal learning experiences provided by the software produced, assist children in the development of early letter/number formation and handwriting skills?
- Is a child displaying CLP disadvantaged in the learning environment, especially in terms of letter/number formation?
- What level of understanding do those involved in early years education have of HLP/CLP?

How each of the above will be assessed is now considered.

3.2 Research Paradigm

The Oxford English Dictionary's definition of 'research' as cited in Barker, Pistrang and Elliot (2002) p.10 states that 'A search or investigation directed to the discovery of some fact by careful consideration or study of a subject; a course of critical or scientific enquiry'. As Barker et al highlight there are five aspects to this definition these include:

- (i) a 'methodical' aspect is stressed, suggesting that research has to be careful and disciplined.
- (ii) a 'critical' stance is suggested so that any conclusions should be evidence based.
- (iii) no research methodology is postulated, hence the value of both *rational and empirical* is recognised. Psychology is generally considered to be an empirical science, concerned with the systematic gathering and analysis of data to test and develop theories.
- (iv) the term *discovery* in relation to research highlights the distinction between exploratory research, research that aims to find out something new, and confirmatory research which seeks to evaluate existing theory.
- (v) the 'discovery of some fact' the Oxford English Dictionary defines a fact as 'something that has really occurred or is the case'. This part of the definition is a little more challenging in that we have to consider what evidence actually supports the notion that a fact is actually proven. Furthermore, this can be challenged by other researchers.

Educational research is vitally important because it has a very important role in contributing to the development of theory and professional knowledge that will impact upon the development and education of our young.

The essence of this research design is to measure the lateral preferences of the sample population and to test whether those individuals who display CLP to a greater or lesser degree, are disadvantaged in the learning environment in relation to the recognition and formation of letters/numbers and handwriting skills.

A second aim of this study is to assess whether multi-modal learning experiences provided through the use of newly designed software for use on an interactive table assist individuals with directionality especially in relation to letter/number formation.

A third aim of this study is to evaluate the level of understanding of those involved in educating our young of HLP and CLP.

3.2.1 Rationale for utilising quantitative methods of data analysis

The majority of current research studies in psychology tend to involve at least some element of numerical measurement. Measurement is defined by Fife-Shaw (2012) as

‘assigning numbers to objects, events or observations according to some set of rules. Sometimes these numbers will be used to indicate that an observation belongs to a certain category or has a certain quality; at other times these numbers will mean that the observation has more of some property than an observation given a lower number. These observations could be generated directly by the research participants ... or by the researcher by, for example, observing the participants’ behaviours in different situations’ (p.25-26).

Whilst many established tests exist, in research, psychologists are frequently required to devise their own measures, or modify existing measures, in order to measure specific phenomena, as is the case in this research design (please see below).

Any characteristic of a population which differs from person to person, or object to object is called a variable. In some instances it is possible to assign numbers or values to certain variables, thus enabling the researcher to measure population characteristics. The measures which describe population characteristics are called parameters.

Data consisting of numerical scores generally reflect more or less of some underlying dimension. Data with interval level measures, which are numerically equal distances on the scale, generally reflect equal differences in the underlying dimension being measured. These data are termed interval data. Manipulation of these scores to find for example, the means and standard deviations, presupposes that the structure of measurement used is isomorphic to the numerical structure of arithmetic. Thus the researcher assumes that the variable being scaled is normally distributed in the individuals being sampled.

As it is not always practical to obtain measures from a total population, the researcher collected data from a sample of the population, assuming that the data were representative of the total population. (Please refer to 3.2.1.1.1 regarding the sample population who participated in this study). On the basis of sample population measures, a ‘probable’ measure for the whole population is assumed. Thus inferential statistics are used to predict population parameters from sample measures. For the purpose of this

study the researcher will employ the use of parametric inferential statistics. All the common parametric statistics are applicable to data in an interval scale.

3.2.1.1 Validity and Reliability of Quantitative methods of data analysis

An attempt was made to ensure that the research design is robust enough to produce results that are reliable, valid and that contribute to new knowledge. Simply stated, reliability means that the results obtained are ‘reproducible’, they are consistent. Therefore it is predicted that other researchers should be able to repeat this study and get similar results.

Hole (2012, p.52) describes validity as ‘the results are measuring what we think they are measuring and not something else’. Hole points out that this is quite a separate issue from reliability. Two types of validity are considered in relation to this study namely:

Internal validity may be considered as the extent to which the researcher can be sure that the changes in the measurements recorded, have been produced in relation to the intervention, rather than by other factors.

External validity may be considered as the extent to which the results obtained in this study have any real relevance to the field of educational psychology and beyond.

Ideally, the research design should incorporate experimental and control groups of participants, and participants should be assigned at random. Campbell and Stanley (1963) highlight the difficulties of achieving a valid research design which minimises the threats to valid inference. For this type of study the researcher should have ideally adopted what Campbell and Stanley term ‘the Pre test-Post test Control Group Design’. Here equivalent experimental and control groups are achieved by randomization. The design neatly controls for the factors of history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality and selection maturation interaction thus giving the design internal validity.

3.2.1.1.1 The Sample

Within this study, two existing Reception classes within the school were used to act as the sample population. The individuals within this sample were already assigned to their classes previously, with two different class teachers, so it was not possible to assign individual sample members randomly at the time of the research study. However, these classes were generally matched for gender, age and ability (as evidenced from the

gender balance, age range within each class and monitoring/assessment results obtained by their respective class teachers) and individuals had been randomly assigned to the classes at the beginning of the year. The status of Experimental and Control groups were randomly assigned. (please see 3.5.2 bullet point 4).

A major factor to consider when drawing conclusions from the data collected is that the Experimental and Control groups although following the same early years curriculum, were taught by different class teachers and supported by different teaching assistants, thus internal validity is not guaranteed.

3.2.2 Rationale for producing Software

As highlighted in Chapter 1.8, the researcher has encountered and continues to encounter a high percentage of pupils being referred for involvement of the Educational Psychologist due to continued ‘learning difficulties’, despite exposure to a number of intervention programmes in school. On closer examination, a large proportion of these referrals when screened, are found to display CLP. This CLP may be part of their normal development, or in the case of older children, persistent CLP. Frequently, it has been found through the use of consultation with school staff and parents that many of these youngsters also experience difficulty with directionality, more specifically confusing left to right orientation. The researcher has attempted to discover specific interventions used to help such pupils, which were found to be very few in number. Most of these interventions were practically based, for example, putting a ‘green for go’ and ‘red for stop’ marker on the child’s page on the left and right respectively. Whilst such interventions help with directionality in respect of reading and writing, such practical measures do not help with letter/number formation. Obviously there are products on the market that help to address letter/number formation which can be used alongside the practical measures and varying degrees of success can be achieved. However, there appears to be a gap in the market for the use of a product that will address these issues simultaneously and hopefully in a way that is more meaningful and helpful to the child.

It is considered therefore that through the vehicle of educational technology a programme could be produced for use with an interactive table, screen or tablet that would provide multi-modal learning experiences that would benefit all children with directionality and more specifically letter/number formation, but those displaying persistent CLP in particular.

Furthermore, as highlighted in 2.2 the BETT show was attended in London in January 2010 to explore the range of new educational ICT products to check to see whether there was any product available that would help to address the difficulties associated with CLP. This proved to be negative. Hence a decision was made to produce software via a commission with a view to trialling it within a school in an attempt to determine its effectiveness.

3.2.3 Rationale for ascertaining Human Lateral Preference (HLP)

The term ‘human lateral preference’ (HLP) has been clarified in respect of this study (in 1.4.1), and the term ‘cross lateral preference’ (CLP) (in 1.4.3). There remains some debate regarding the prevalence of CLP within a population, and few studies have taken account of all four indices of hand, foot, and eye and ear simultaneously. Where a pupil displays CLP there is a possibility that this can have a negative impact on learning for some youngsters. Research evidence (Tan, 1985; Kaufman, Zalma and Kaufman, 1978; suggest that children who lack a definite hand preference score lower on tests of motor abilities. Similarly research findings (Crow et al., 1998; De Agostini and Dellatolas, 2001) suggest that cognitive ability shows a general positive correlation with increasing dexterity. Therefore, it remains a possibility that children who display CLP/ lack a definite hand preference and/or display reduced dexterity might as a result be disadvantaged in the learning environment, particularly in relation to letter/number formation which requires motor abilities as well as robust skills in relation to directionality.

Therefore, in an attempt to quantify the establishment of laterality and the prevalence of CLP amongst 4-5 year olds and its impact on learning, the incidence of HLP/CLP amongst the sample population was measured and this measure was used as an independent variable within the research.

3.2.4 Rationale for using Standardised Measures of Assessment

Standardised measures of assessment were used wherever possible because such assessment tools have been devised for sampling a defined population and valid norms and standard scores can be produced, which permits more reliable comparisons between specific groups, and between pre and post measures. Thus, the use of standardised measures permits the use of norm-referenced judgement. The use of standardised measures of assessment increases the likelihood that the scores obtained are reliable and

valid measures. This is obviously dependent on the use of the standardisation procedures of the individual assessment tool.

3.2.5 Rationale for use of Questionnaire with Staff

A questionnaire was used to assess the knowledge of the staff, both teachers and support staff, in the Key Stage 1 phase of the sample school of human lateral preference, cross lateral preference and the potential effects of CLP on learning. No ‘ready made’ questionnaire was available that probed the appropriate areas, so a questionnaire was constructed for this aspect of the research.

3.3 Imported Research Instruments

3.3.1 The Wechsler Individual Achievement Test, Second UK Edition (WIAT-11UK).

Two sub-tests from this standardised assessment tool were utilised to assess the skills of letter/number recognition and formation of the sample population both pre and post intervention. It was standardised on 892 individuals, aged between 4 and 16 years 11 months in the UK in 2004, using a stratified sampling plan to ensure that representative proportions of children from each demographic group were represented in the validation sample. The sampling plan defined a cell structure that identified the appropriate number of children for each cell. The cells were defined in terms of 12 levels of geographic regions in the UK, 2 levels of gender, 33 levels of age, 4 levels of race/ethnic group and 5 levels of parental education level. Data collated from the 2001 Census provided the basis for the stratification by geographic region, gender, race/ethnicity and parental education level. Use of this assessment tool provides age-based standard scores, percentiles, stanines, normal curve equivalents, and age equivalents for each of the sub-tests.

Assessment features of the sub-tests to be administered

Word Reading (Start age: 4 years)

Assess pre-reading (phonological awareness) and decoding skills.

- Name the letters of the alphabet when presented visually
- Identify and generate rhyming words
- Identify the beginning and ending sounds of words
- Match sounds with letters and letter blends

- Read aloud from a graded word list

Written Expression (Start age: 4 years)

Measure the child's writing skills at all levels of language.

- Write the alphabet (timed)
- Demonstrate written word fluency
- Combine and generate sentences
- Produce a rough-draft paragraph (8-11)

The full assessment potential of each subtest is provided and will be administered in strict accordance to the age appropriate start and finish points. It is anticipated that these 2 subtests will take approximately 15 minutes per individual to administer.

In addition, each participant will be asked to sequence the alphabet verbally, and to record the numbers 1-10.

3.4 Research Instruments constructed for this study

Techniques used to assess lateral preference vary amongst researchers. Most researchers seem to utilise questionnaires because of the ease of testing and the ability to expediently assess the lateral preferences of large populations of individuals. Given that lateral preference of limb or sense organ is going to be considered as an influential factor when drawing conclusions in this study, and that the sample size is relatively small, it was felt that it is important that the data collection in relation to this is reliable. Therefore it was decided not to utilise a questionnaire given the age of the sample population in the study and the potential for unreliable results.

Although more time consuming it was decided to assess the lateral preferences of the sample population individually. A screening tool was constructed and applied drawing upon some of the measures utilised by Coren and Porac (1978), when testing the behavioural validity and reliability of self report items for the measurement of lateral preference. The criteria used for selection for this study included developmentally appropriate tasks with easily observable responses. A scoring mechanism was established and then applied in an attempt to establish 'degrees of laterality' amongst the target population.

3.4.1 Human laterality screening tool and continuum

The lateral preferences of each participant will be determined as follows:

HAND PREFERENCE

- child to pick up crayon from table top and draw a circle
- child to unscrew a bottle top
- child to throw a ball with one hand

FOOT PREFERENCE

- child to kick a football
- child to hop on one leg
- child to stamp on a small item on the floor

EYE PREFERENCE

- child to look through a cardboard tube at target item
- child to look at the researcher through a 2cm hole cut in a piece of cardboard
- child to look into an opaque bottle and report the contents

EAR PREFERENCE

- child to hold talking telephone to ear
- child to listen to ticking clock within a shoe box by placing an ear near the box
- child to listen to quiet music emitted from a small portable radio by holding it up ear

Three measures of laterality for each of the four indices highlighted above have been created, resulting in a total of 12 items. Each measure will be scored L (left) or R (right), and recorded on a laterality continuum ranging from 0 – 12, with 0 representing totally unilateral to the left and 12 representing totally unilateral to the right. Therefore if a child performs each measure with a right bias he/she scores 12, for each measure performed on the left, 1 point will be deducted from the total of 12. Therefore if all 12 measures were performed with a left bias, the results would be $12 - 12 = 0$.

Use of this continuum permits the establishment of laterality to be explored and enables 'degrees' of laterality/ CLP to be recorded within the target population. The use of this

continuum will be piloted amongst pupils and with a group of teachers in a different school to ascertain ease of use and understanding.

3.4.1.1 Piloting of Laterality Continuum

This was piloted in a Primary school in the same local authority as the research school. Through the piloting process it was found that it was imperative to place items centrally to the child, otherwise some had the tendency to use their hand/foot that was closest to the item, thus invalidating the results. The use of the laterality continuum itself was clearly understood by those participating in the pilot study.

3.4.2 Questionnaire for staff

3.4.2.1 Construction of the Questionnaire

On designing the questionnaire consideration was given to the topics to be covered within the questionnaire, their sequence, the questions to be posed, the number of questions posed, and the format of the response. A major aim was to make the questionnaire as easy and free of frustration as possible. Consideration was given to the following in an attempt to ensure that the responses obtained were valid and reliable:

- *Item wording*
Much consideration was given to question wording as the researcher believes that the way a question is phrased can to a large extent determine the kind of response that is given.
- *Neutrality*
An attempt was made to ensure that the language used in the questions was neutral and did not suggest an answer.
- *Clarity and simplicity*
An attempt was made to ensure that simple, clear, everyday language was used and deliberately avoided the use of psychological jargon.
- *Specificity*
An attempt was made to ensure that the questions posed were specific and not open to misunderstanding or ambiguity.
- *Brevity*
An attempt was made to ensure that questions were kept short by avoiding multiple phrases, in an attempt to aid processing and understanding.

- *Response Scale*

It was decided not to make use of a rating scale simply because the area under investigation, according to literature searches is relatively unknown.

- *Questionnaire layout*

An attempt was made to ensure that the resulting questionnaire was coherent and engaging, enabling the respondent to work through it easily, thus minimizing the possibility of exhausting or irritating the respondent.

3.4.2.2 Piloting of the Questionnaire

The questionnaire was piloted amongst Key Stage 1 teachers and support staff in a primary school within the same local authority as the research school. The same school had also been utilised to pilot the laterality continuum. Ten out of twelve, (83%) of the sample population responded.

On examination of the responses, it was considered that the questionnaire had ‘validity’ whereby it measured what it intended to measure. As a result no adjustments were made to the questionnaire. (Please refer to Appendix L).

3.4.2.3 Interpretation of the Questionnaire responses

Neither numerical values nor a Likert scale were assigned to the responses on this questionnaire, as it was anticipated that if the questions were left open ended more in depth information would be obtained. Therefore as a result of this, analysis of the results generated by the responses on this questionnaire will be in the form of analysis of general trends or themes as they emerge.

3.4.3 Commissioning of the software

As highlighted in Chapter 2, based on experience of working with children displaying specific difficulties around letter/number formation, one of the aims of this research study is to investigate whether software devised and developed for use on an interactive screen, would help young children with these specific difficulties. As the researcher did not have the expertise herself to produce this software, it was necessary to commission a software producer.

3.5 Procedure

3.5.1 Sample Selection

The sample selection was restricted by the availability of specialist equipment within the school. Only three schools within the experimental local authority possessed the specialist equipment required, namely an interactive table. Two of these tables were located within specialist provisions, namely an autistic base and a school for pupils with profound and multiple handicaps. The use of these two schools was rejected on the basis that additional variables relating to specific needs of the population within these schools made the target population less 'typical' of the general population. The third table was located in a large mixed ability primary school in the city; therefore it was felt that the population here would be more typical of the population as a whole, given that the sample population should represent a subset of the larger population to which findings can then possibly be generalised.

3.5.2 Recruitment

- Contact was made with the head teacher of the proposed experimental school and explained the research project in full, both verbally in a face to face meeting, and subsequently via letter. The head teacher provided informed consent permitting the research study to be conducted within the school. (Please refer to Appendix A).
- Parents of all pupils within the two reception classes in the school were provided with a letter, outlining the rationale of the research project and requesting permission to screen all pupils within these classes in order to determine lateral preference across all four indices, in order to measure the establishment of laterality. Simultaneously, parental consent was requested to administer a two of sub-tests from the Wechsler Individual Achievement Test – Second UK Edition (WIAT-11UK) to assess the skills of letter/number recognition and formation, pre and post intervention. (Please refer to Appendices C and D). The contact details of the researcher, the supervisor and the Ethics Committee were provided so that any parental concerns could be addressed if they arose.
- Those parents who provided consent allowing their child to participate in the study then formed the sample. In fact the response was exceptionally positive with a 100% consent rate.

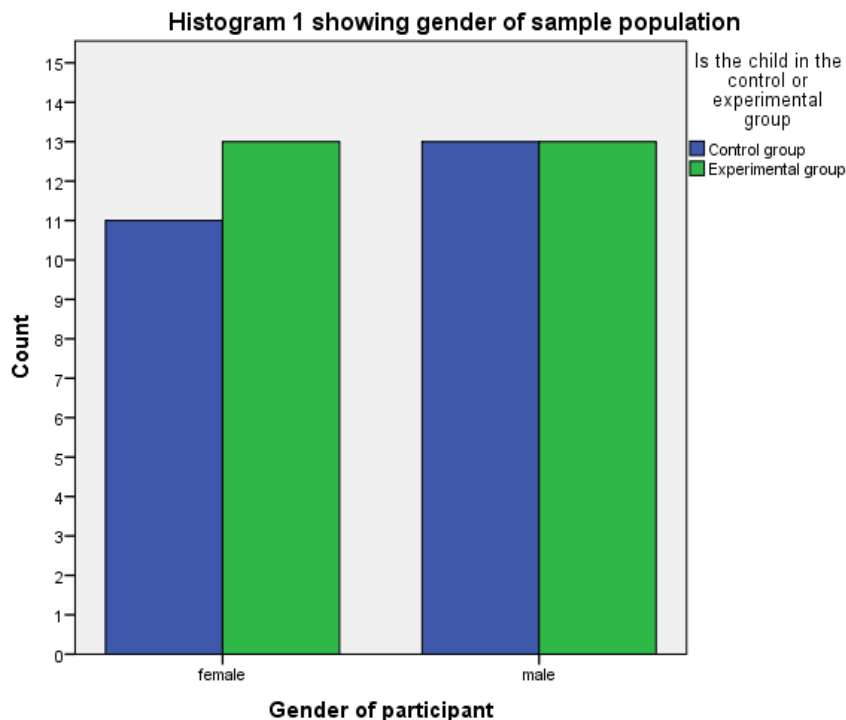
- The two classes were randomly assigned the numbers 1 and 2, and then a die rolled until a 1 or 2 appeared, with the proviso being that the first appearance of a 1 or 2 would identify the Experimental class, and the other class would be identified as the Control class.
- At the end of the intervention period a debriefing letter was sent to the parents of all pupil participants providing further details about the research study itself, and highlighting that a further letter will be sent once the data had been analysed. Parents were also reminded that all data will be anonymised and destroyed after a period of one year (please see Appendix K).

3.5.3 Description of the Participants

3.5.3.1 Pupils

The pupils within the two reception classes of the sample school are drawn from an urban conurbation, containing, in the main, owner-occupied housing. Within the school catchment there is also a relatively large social priority area of terraced houses forming an estate. The majority of the houses within the catchment are owned by white, working class citizens, however within the area there are a minority of professional people and people from minority ethnic groups. Free school meals data highlights that 23% of the school population receive free school meals.

The sample consists of fifty mixed ability reception pupils in two classes.



The chronological age of the sample population at the start at the intervention ranged from 4 years 4 months to 5 years 2 months, with the Experimental Group ranging from 4 years 5 months to 5 years 2 months and the Control Group ranging from 4 years 4 months to 5 years 2 months.

Table 3.1: The Sample by Mean Age (in years and months) in Experimental Group prior to Intervention

CASES					
INCLUDED		EXCLUDED		TOTAL	
N	%	N	%	N	%
26	100	0	0	26	100

N	MEAN	SD
26	4.22	0.34

SD= Standard deviation

Table 3.2: The Sample by Mean Age (in years and months) in Control Group prior to the Intervention

CASES					
INCLUDED		EXCLUDED		TOTAL	
N	%	N	%	N	%
24	100	0	0	24	0

N	MEAN	SD
24	4.35	0.44

SD= Standard deviation

Table 3.3: The Total Sample by Mean Age (in years and months) prior to the Intervention

CASES					
INCLUDED		EXCLUDED		TOTAL	
N	%	N	%	N	%
50	100	0	0	50	100

N	MEAN	SD
50	4.28	0.39

SD= Standard deviation

3.5.3.2 School Staff

All of the staff, both teachers and learning support assistants, (n=16) within the Key Stage 1 phase of the research school were approached to request that they complete a questionnaire. All of the staff within this cohort are female.

3.5.4 Screening/Assessment of Target Pupils

- All pupils within the Experimental and Control groups whose parents had provided written consent to be part of the research project were screened in order to determine lateral preference across the four indices. On entering the room the child was asked their name and if they are willing to participate in a number of brief activities to help the researcher with her work about how people perform certain tasks. If the child did not wish to participate at this point despite the parent agreeing, he/she was returned to the classroom.
- At the end of the screening session the child was debriefed by the researcher who explained in age appropriate language the purpose of the screening. The session ended with a positive interaction between the researcher and the participant, whereby the participant was asked if they would like a sticker as a reward for helping the researcher with her work, and permitted to choose one from the sheet (please refer to Appendix E).
- Results of initial screen were recorded confidentially and stored within a locked filing cabinet. Examination of the results of the initial screen will enable the researcher to quantify the establishment of laterality and the prevalence of CLP amongst the sample population.

- Once the screening to determine lateral preference of the pupils within the two groups was complete, and prior to the start of the use of the software with the Experimental group, the researcher collected baseline data from both groups relating to:
 - ability to discriminate between letters and numbers
 - letter and number recognition
 - letter and number formation
 - reading skills
 - ability to verbally sequence the alphabet

by administering the WIAT-11UK sub-tests as on p.60. These sub-tests were administered as follows on a separate occasion to avoid participant fatigue. All baseline data collated including lateral preferences of the sample group and assessment results were copied to the Head Teacher of the school, so that it could be added to their existing monitoring and assessment data. Further if parents requested this information the Head Teacher was able to provide it. Should clarification regarding this data be sought by the parent, the researcher agreed to make herself available to provide this clarification.

- The child's positive verbal consent was obtained before he/she was taken from the classroom. On entering the testing room the child was asked their name and told that they have been chosen to do some activities to help with a study that was being conducted within the school. If the child was reluctant at this point further explanations were given regarding the nature of the task. If the child was in any way distressed he/she was returned to class without undergoing assessment despite written parental consent having been obtained.
- At the end of each assessment, the child was debriefed in age appropriate language, explaining the purpose of the assessment. The session ended with a positive interaction, whereby the participant was asked if they would like a sticker as a reward for helping with the study, and permitted to choose one from the sheet (please refer to Appendix F).
- As it was intended to collect data both prior to the Experimental group being exposed to the software and following its use, initially use was made of a coding system to label data. Following collection and analysis of the post exposure data, all data was then anonymised.

3.5.5 Use of Questionnaires with School Staff

- All teaching and support staff within the school were provided with a brief information sheet about the research proposal (please refer to Appendix H), along with a consent form (please refer to Appendix I) highlighting that participation in the research was voluntary and if they agreed to participate by completing the questionnaire they may omit any questions they did not wish to answer. The questionnaire had been specifically devised to investigate staff awareness of issues relating to CLP (please refer to Appendix J).
- Each participant was asked to indicate whether they are a teacher or LSA.
- A debriefing paragraph was added to this questionnaire explaining the potential value of their responses to the research being undertaken.
- It was requested that all completed questionnaires be posted in the post box provided located within the staff room.

3.5.6 Exposure to the Software

- The Experimental group were given their usual access to the interactive table, plus additional daily individual access for ten minutes to use the newly designed software to practice letter/number formation and recognition and basic writing activities such as writing one's name, initially under the direction of a Teaching Assistant (TA) for a period of eight weeks. The Control group were given their usual access to the SMART table, but initially no access to the new software. Following the completion of the research project the Control group will be given an opportunity to utilise the new software. This will not contribute to the research study but is a means of thanking the class teacher and pupils for their participation in the project and also considered to be ethical.

3.5.7 Statistical Procedures Employed for Data Analysis

As highlighted above in 3.2.1.1, the 'pre-test/post-test control group' experimental design has been adopted. Here, for the purpose of this study, both the Experimental and Control groups will be subject to a number of pre-intervention assessments to ensure that the two groups are initially comparable before the intervention is introduced to the experimental group.

Firstly, a repeated-measures Analysis of Variance (ANOVA) will be utilised, as the same participants, namely the Experimental and Control groups (Between subjects IV – Group), have been assessed on two different occasions. Hence the same participants have contributed to the different means obtained at pre and post assessments (Within subjects IV –Time).

In a repeated-measures ANOVA the effect of the intervention will be highlighted in the interaction between the Group and the Time variables (Group x Time). A significant interaction indicates that changes across time observed for the Experimental and Control groups are significantly different. Repeated ANOVAs will be performed for the four dependent variables (DVs) considered in the study: Word Reading, Written Expression, letters sequenced and numbers correctly formed.

ANOVA will inform whether the intervention was generally successful, however it will not provide specific information about how each group was affected. The ANOVA produces an F-ratio, which compares the amount of systematic variance in the data to the amount of unsystematic variance. Therefore the F-ratio will highlight that the intervention has had some effect, but it does not specifically illustrate what that effect is. If the F-ratio is large enough to be statistically significant, it will be necessary to conduct *post hoc* tests to further analyse how the groups differ.

Post hoc tests are utilised when a significant interaction is identified and consist of ‘pairwise comparisons’ and as such are designed to investigate mean group differences from the pre to post intervention moments, separately for each group, the Experimental and Control group.

In educational research it is generally accepted that if a difference or a relationship between two variables has only a 5 in a 100 ($p < 0.05$) chance of being due to sampling error, or a 95 in a 100 ($p = 0.95$) chance of not being due to sampling error, then the results are taken to be statistically significant. The probability level associated with each result will be indicated, so that the reader may utilise his/her own judgement in deciding whether or not the results are significant.

Use of the dependent t-test, also referred to as the paired samples t-test, will be employed as a *post hoc* test, in order to check for statistical significance between pre and post intervention measures obtained by the experimental group and control group respectively.

This test compares the mean difference between the samples to the difference that one would expect to find between population means, and then takes into account the standard error of the differences. If the null hypothesis is true, then no difference would be expected between the population means.

Finally, an exploration of whether there is a quantifiable relationship between specific pairs of variables will be conducted. The statistic that provides an index of the extent to which any two variables are related is called the correlation coefficient. In the case of parametric statistics the usual measure of correlation is the Pearson product moment correlation coefficient, r , devised by Karl Pearson (1857-1936).

The values of a correlation coefficient may vary only between +1 and -1. Interpretation of a correlation coefficient involves the consideration of the numerical value itself and whether that correlation is positive or negative. The numerical value represents the strength of the relationship between one variable and another, the closer the value to +1 or -1 the stronger the relationship. Obviously 0 represents no correlation at all. Values that are positive suggest a positive correlation, as one variable increases the other also increases. Values that are negative suggest a negative correlation, as one variable increases the other diminishes.

All calculations were executed using the Statistical Package for Social Sciences 20 (SPSS).

3.6 Ethical Issues

The British Psychological Society in its publication 'Code of Ethics and Conduct' (2006) recognises 'its obligations to set and uphold the highest standards of professionalism and to promote ethical behaviour, attitudes and judgements on the part of psychologists' (p.4).

The BPS guidelines specify the responsibilities of the researcher in needing to:

- obtain informed consent from participants
- ensure participants are not deceived in any way
- debrief the participants after the research
- ensure participants are aware of their rights to withdraw from the research at any time
- protect participants from potential risks

- ensure confidentiality of information provided by the participants.

It was ensured that all the above principles were adhered to throughout the research process. In addition, ethical approval was sought and given for this present study from the Ethics Committee for the Psychology Department of Cardiff University.

One local authority was approached with information pertaining to the role of the researcher, the aims of the study, details relating to the confidential nature in which the data collected would be stored and debriefing procedures for those involved. Once consent from the local authority had been given, consent was then sought from the head teacher of a suitable primary school. The primary school was deemed suitable if it had a minimum of two parallel reception classes and the school already possessed an interactive table for use in the study.

On identification of an appropriate primary school, particular consideration was given to the ethical issues specifically pertinent to school-based research.

3.6.1 The Informed Consent Process

As pointed out by Felzman (2009), a significant complication of school-based research can be the involvement of ‘multiple stakeholders’. Felzman highlights that research with children has to meet both the legal and ethical requirement of obtaining assent, not just from the participants themselves, namely the children, but also from their parents/legal carers, in the form of informed consent. For this reason, all parents of pupils in the two reception classes within the school will be sent a letter outlining the rationale of the research project and requesting *active consent* or *opt in* for their child to be involved. The letter will clearly explain exactly what they will agree to in terms of involvement of their child. Absolute regard will be given to the fact that refusal on behalf of the child participant overrides consent by the parent, and no child would be coerced to be involved if they were unwilling for any reason. Furthermore, due regard is given to the fact that participants may assume that the research activities are a continuation of their normal studies and that participation is expected of them in the same way as applies to their normal studies. This would be the case for the intervention activities overseen by the class teacher, but not for the screening and assessment of the participants both pre and post intervention.

Regarding gaining informed consent from the adults participating in the research project in terms of completing a questionnaire anonymously, all teaching and support staff

within Key Stage 1 of the school will be provided with a brief information sheet about the research proposal along with a consent form, highlighting that participation is voluntary.

3.6.2 Confidentiality

As stated by Felzman (2009) ‘confidentiality requires the researcher not to divulge information from research activities without the express agreement of the research participant’ or in the case of the pupil participants their parents.

As it is intended to collect data both prior to the Experimental group being exposed to the software, and following intervention, use will be made of a coded system to label data. Following collection and analysis of the post exposure data, all data will then be anonymised to ensure confidentiality. As highlighted in 3.5.4 all pre and post data will be copied to the Head Teacher for their school records, therefore should a parent request access to data following anonymisation this would be available from the school, with added clarification from the researcher if required.

In terms of the staff responding to the questionnaire the researcher will ask each participant whether they are a teacher/LSA but will not ask for personal identification. Therefore any information imparted will not be traceable to the participant.

At the end of the research project all data collated will be destroyed.

3.6.3 Harm and Benefit

In the main research in school settings is devoid of significant physical risk, but as highlighted by Felzman (2009), psychological and social risks are not uncommon.

In an attempt to ensure that participants are not harmed in any way, all pupils whose parents have provided informed consent, on entering the room will be asked their name and if they are willing to participate in a number of activities to help with a study being conducted in the school. The nature of the activities will be explained. If the child does not wish to participate at this point ‘refusal’ or even unwillingness will result in the child being returned to the classroom immediately.

At the end of the session the participant will be debriefed in age appropriate language regarding the purpose of the screening/assessment. The session will end with a positive interaction between the researcher and the participant, whereby the participant will be

asked if they would like a sticker as a reward for helping the researcher with her work, and permitted to choose one from the sheet.

In terms of the adult participants a debriefing paragraph will be added to the questionnaire explaining the potential value of their responses to the research to be undertaken.

3.7 Hypotheses to be Tested

The following hypotheses have been formulated:

- H1 – CLP will be observed in the sample population within the range indicated by previous studies.
- H2 - Multi modal learning experiences, incorporating the use of educational technology in the form of a touch screen software program which utilises changes in colour and sound to help emphasise directionality, along with tactile experiences, will help all children with letter/number formation and handwriting skills, but more specifically those with CLP.
- H3 - Individuals who display CLP experience greater difficulty with letter/number formation and handwriting skills than those who do not.
- H4 - Educators have little knowledge or understanding of HLP/CLP within early years settings.

CHAPTER 4: STATEMENT OF THE RESULTS

4.1 Overview of the Chapter

This study aimed to explore the following research questions:

- What is the prevalence of CLP amongst young children?
- Does the use of educational technology and multi-modal learning experiences provided by the software produced, assist children in the development of early letter/number formation and handwriting skills?
- Is a child displaying CLP disadvantaged in the learning environment, especially in terms of letter/number formation and handwriting skills?
- What level of understanding do those involved in early years education have of HLP/CLP?

4.2 Introduction to the Results

For convenience the presentation of the results has been divided into a number of sections, they are as follows:

- 4.3 The production and description of the software
- 4.4 Description of the intervention
- 4.5 Histograms showing the lateral preferences of the Experimental and Control groups
- 4.6 Statistical analysis
- 4.7 School staff questionnaire
- 4.8 Key Findings

4.3 The production and description of the software

As highlighted in 3.1 the development of software for use with an interactive touch screen was commissioned. It was exceptionally difficult to locate a person with the appropriate skills to translate the ideas into practice and this process took a lengthy period of time. Once identified it was possible to liaise with the software developer to enable the initial production of a prototype, which was then subsequently modified through consultation in an attempt to satisfy the demands of the research project.

It was requested that the software have two modes, Basic and Level 1. The Basic mode simply consists of a colour changing surface with associated change in sound as one

moves one's finger across the interactive table/screen. Specific use of colour was requested along with the pitch of sound increasing as one travelled from bottom to top and left to right of the surface. This Basic mode function is intended to be used by young children to 'mark make' and produce unexplained scribble, progressing to more precise shapes before they can practice their letter like forms, using 'big' movements more appropriate to their developmental age. In addition it is expected that young children will move their fingers across the screen to deliberately produce certain preferred colour and sound changes.

Through using this Basic mode it is anticipated that the users will incidentally familiarise themselves with the colour and sound changing properties of the software, predominantly via the vehicle of play, exploration and inquisitiveness.

Level 1 consists of three sub-modes

- lower case letters
- upper case letters
- numbers

On selecting one of the above options, either lower/upper case letters or numbers appear on the perimeter of the screen. On selection of a specific letter/number a sensitive oblong shaped area appears on the interactive screen with the appropriate starting point for the selected letter/number. The user then 'draws' the selected letter/number in the sensitive zone.

In order to ensure correct formation it is expected that the child will initially be taught by an appropriately trained adult, namely a Teaching Assistant already assigned to the class, either individually or within small groups, using the software and simultaneously be given the opportunity to see and hear the visual and auditory properties pertaining to a specific letter/number, thus increasing the number of valid co-occurrences, as previously highlighted in 2.4.3.1. In addition, experiencing tactile feedback once they utilise the touch screen themselves, thus aiding the development of motor memory for specific letters/numbers. Having seen and heard correct formation demonstrated by the tutor, it is hypothesised that the child will utilise multi-modal learning strategies and incidental learning experiences and be more likely to see or hear and ultimately feel correct/incorrect formations, thus better developing their motor, visual and auditory memory for letters and numbers more efficiently.

It is possible to add additional levels where no prompting regarding the correct starting place is given, but this was felt to be an unnecessary addition at this time.

4.4 Description of the intervention

It was ensured that the software was correctly installed on the interactive table prior to use. A meeting with the class teacher and supporting teaching assistant of the Experimental group was convened to demonstrate the use of the software and to discuss the progression of skills envisaged. The use of the software was also modelled with a child, so that the staff involved could hear the sort of language that was being used and the types of instructions and questions posed to the child, and the responses given to the child's questions.

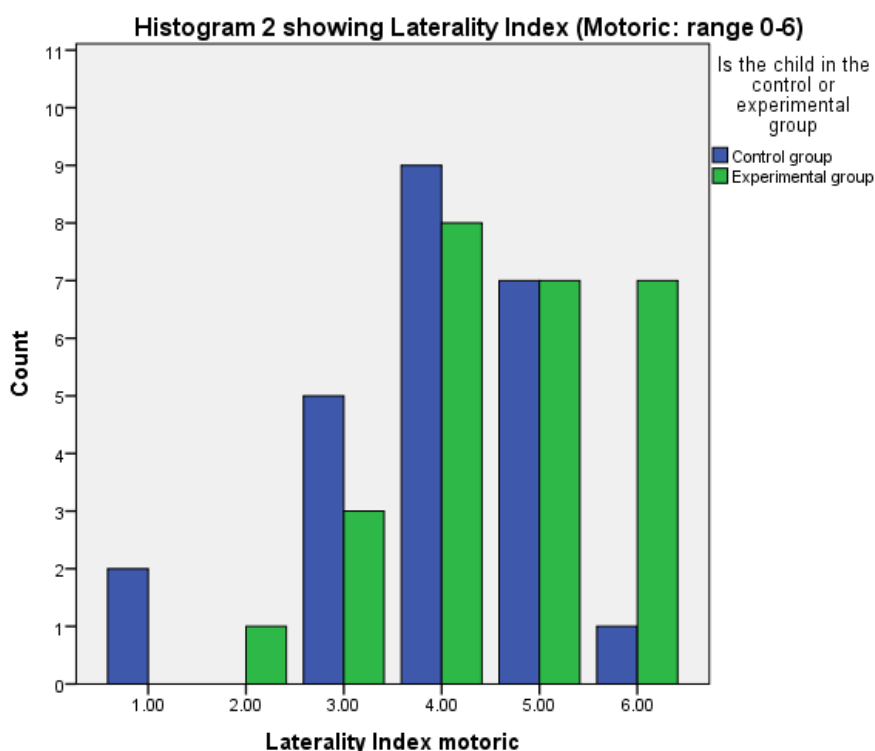
As highlighted in 3.5.6 in addition to their usual access to the interactive table, each member of the Experimental group were given an extra ten minutes daily to access the new software individually, to practice their letter/number formation. Prior to this individual access each participant had been tutored on its use by the teaching assistant. This daily individual access to the software extended for a period of eight weeks.

In contrast, the Control group were given their usual access to the interactive table but no access to the new software.

Data pertaining to Research Question 1: What is the prevalence of CLP amongst young children?

4.5 Histograms showing the lateral preferences of the Experimental and Control groups

Based on the raw data collated regarding lateral preference, prior to intervention, which can be found in Appendix N, four histograms to summarise the results of the laterality assessments conducted have been produced.



0 signifies totally unilateral to the left

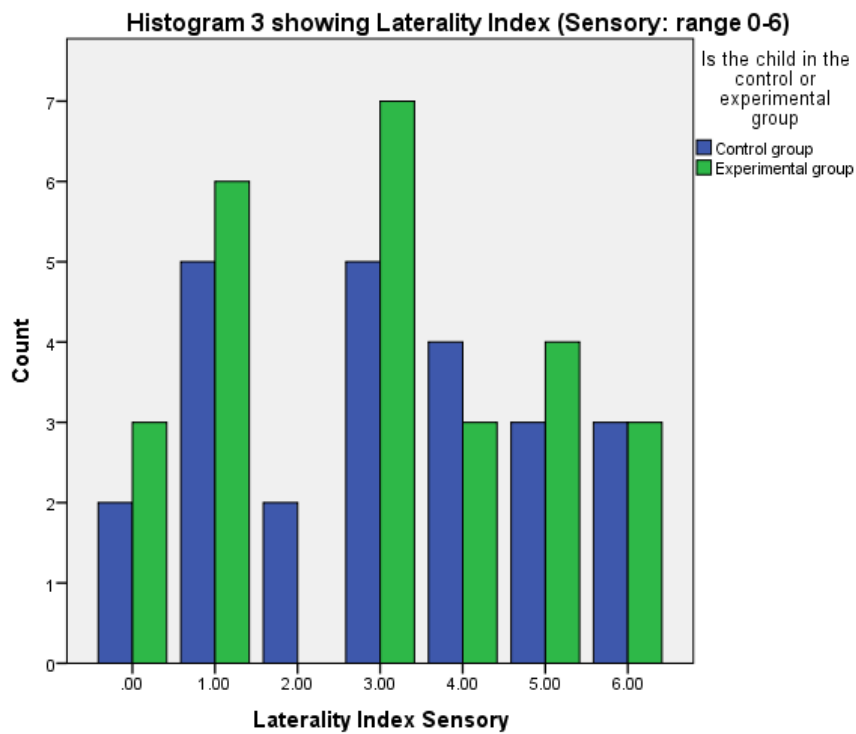
6 signifies totally unilateral to the right

Table 4.1 Showing Percentage of Sample Population Assessed as Unilateral or Displaying CLP on Motoric Laterality Index.

% unilateral to left		% displaying CLP On 1 measure or more		% unilateral to right	
Control	Experimental	Control	Experimental	Control	Experimental
0%	0%	96%	73%	4%	27%

In terms of the motoric Laterality Index (hand and foot preference), histogram 2 shows a definite shift towards the right, with 27% of the Experimental group and just 4% of

the Control group displaying unilaterality to the right. Neither group displayed unilaterality to the left.



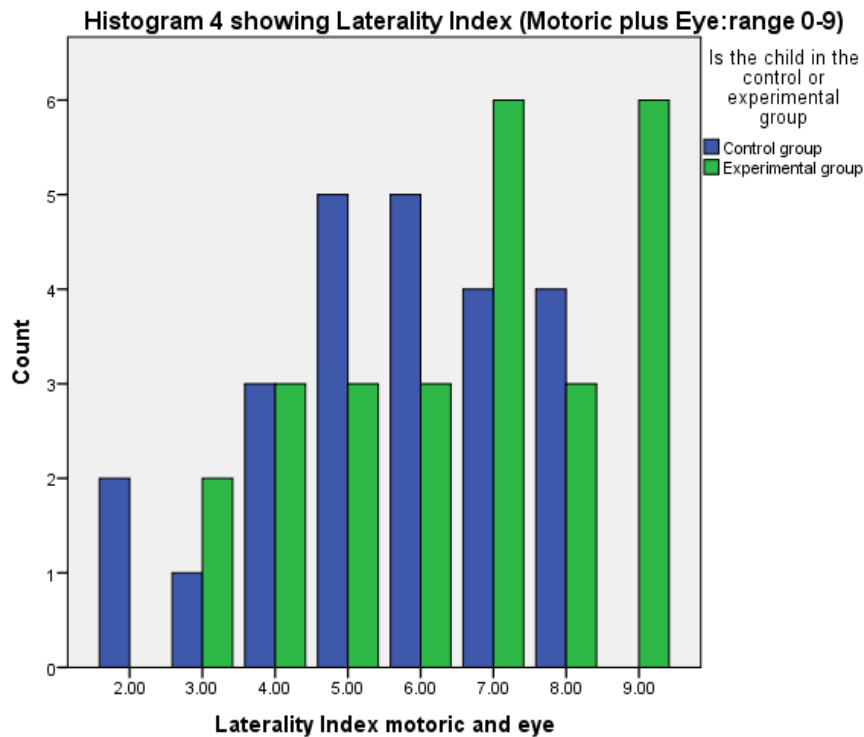
0 signifies totally unilateral to the left

6 signifies totally unilateral to the right

Table 4.2 Showing Percentage of Sample Population Assessed as Unilateral or Displaying CLP on Sensory Laterality Index

% unilateral to left		% displaying CLP On 1 measure or more		% unilateral to right	
Control	Experimental	Control	Experimental	Control	Experimental
8%	11.5%	79%	77%	13%	11.5%

In terms of sensory Laterality Index, Histogram 3 predominantly shows a shape resembling the normal curve of distribution within a population. Approximately, equal numbers were found to be unilateral to the left/right and the vast majority of the sample population (over 75% of both the Control and Experimental groups) were located in the CLP category.



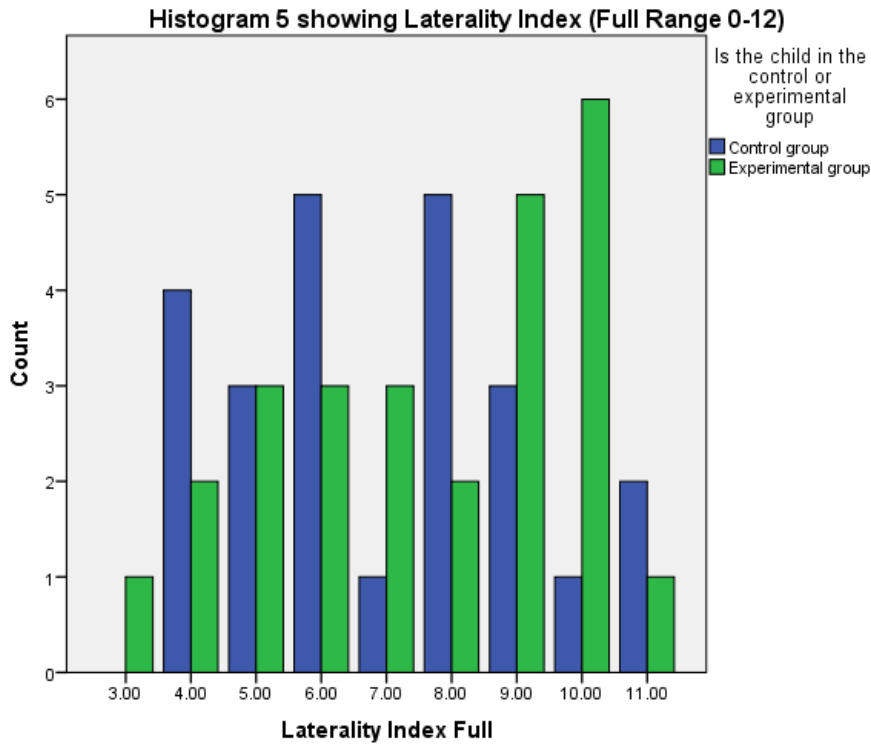
0 signifies totally unilateral to the left

9 signifies totally unilateral to the right

Table 4.3 Showing Percentage of Sample Population Assessed as Unilateral or Displaying CLP on Motoric Laterality Index plus Eye Preference

% unilateral to left		% displaying CLP On 1 measure or more		% unilateral to right	
Control	Experimental	Control	Experimental	Control	Experimental
0%	0%	100%	77%	0%	23%

In terms of motoric Laterality Index linked with eye preference, Histogram 4 shows a distinct shift towards the right, but not as markedly so as in Histogram 2. Interestingly, the Control group, although displaying this shift towards the right it is far less predominant, with 100% of the sample in the Control group falling within the CLP category, compared to 77% of the Experimental group.



0 signifies totally unilateral to the left

12 signifies totally unilateral to the right

Table 4.4 Showing Percentage of Sample Population Assessed as Unilateral or Displaying CLP on Full Laterality Index

% unilateral to left		% displaying CLP On 1 measure or more		% unilateral to right	
Control	Experimental	Control	Experimental	Control	Experimental
0%	0%	100%	100%	0%	0%

In terms of the Full Laterality Index, Histogram 5 shows that there remains a shift towards the right with 50 % of the Control group and 65% of the Experimental group being assessed at 7 and above, but not one individual falling within the totally unilateral to the right category.

21% of the Control group and 12% of the Experimental group were assessed at 6, the midpoint of the scale, suggesting potentially the greatest degree of CLP.

The remainder of the sample 29% of the Control group and 23% of the Experimental group were assessed as falling within the 3 to 5 category, a shift to the left.

Not a single individual from either group was found to be at points 2, 1 or 0, with 0 representing totally unilateral to the left.

Data pertaining to Research Question 2 and 3:

Research Question 2: Does the use of educational technology and multi-modal learning experiences provided by the software produced, assist children in the development of early letter/number formation and handwriting skills?

Research Question 3: Is a child displaying CLP disadvantaged in the learning environment, especially in terms of letter/number formation and handwriting skills?

4.6 Statistical Analysis

Using the pre and post information collated for both the Experimental and Control groups using two of sub-tests from the WIAT-11UK only, and measures of letters sequenced and numbers correctly formed, the researcher utilised SPSS 20 as described in 3.5.7 to analyse the results. Raw data can be found in Appendix L.

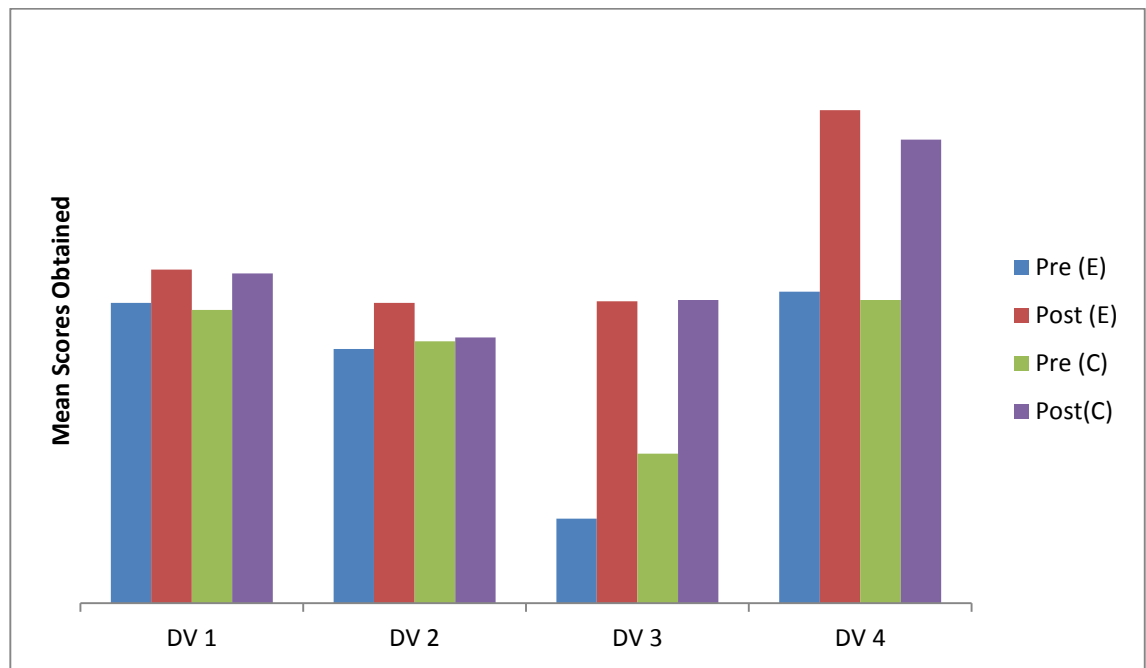
Table 4.5 Descriptive Statistics for the Experimental and Control Groups Pre and Post Intervention for Word Reading, Written Expression, Letters Sequenced and Numbers Correctly Formed

VARIABLES	EXPERIMENTAL GROUP		CONTROL GROUP	
	Pre mean (SD)	Post mean (SD)	Pre mean (SD)	Post mean (SD)
DV 1-Word Reading (Age equivalent)	4.78 (0.446)	5.31 (0.511)	4.67 (0.565)	5.25 (0.495)
DV 2-Written Expression (Age equivalent)	4.05 (0.195)	4.78 (1.242)	4.17 (0.495)	4.23 (0.582)
DV 3-Letters sequenced (n)	1.35 (1.809)	4.81 (6.788)	2.38 (5.148)	4.83 (2.959)
DV 4-Numbers correctly formed (n)	4.96 (2.905)	7.85 (2.55)	4.83 (6.657)	7.38 (2.565)

Note: SD = standard deviation

DV = dependent variable

Histogram 6 showing Pre/Post scores for Dependent Variables 1-4 for Experimental and Control Groups



On initial inspection the pre and post intervention means for both groups appear to be relatively similar. On all measures with the exception of Word Reading (DV 1-Age Equivalent), the difference between the means of the pre and post measures is greatest for the Experimental group, but only marginally so. The use of statistical techniques are employed to analyse the data further.

4.6.1 Univariate repeated measures ANOVAs

Table 4.6 Results of repeated measures ANOVAs of the study Dependent Variables: Word Reading, Written Expression, Letters Sequenced and Numbers Correctly Formed

DEPENDENT VARIABLES	EFFECT	F	p
DV 1-Word Reading	Time	69.688	.000*
	Group	.432	.514
	Time v Group	.112	.740
DV 2-Written Expression	Time	8.587	.005*
	Group	1.846	.181
	Time v Group	6.488	.014*
DV 3-Letters Sequenced	Time	18.248	.000*
	Group	.146	.704
	Time v Group	.524	.473
DV 4-Numbers Correctly Formed	Time	45.623	.000*
	Group	.201	.656
	Time v Group	.182	.671

* $p < .05$

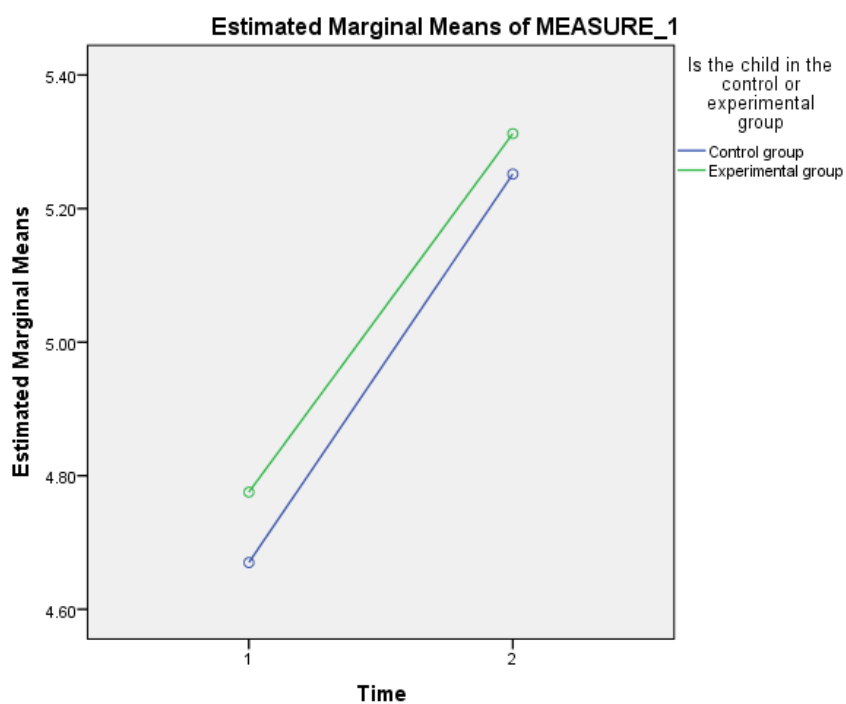


Figure 1- Dependent Variable 1 Word Reading

4.6.2 Pearson product moment correlation coefficient

Figure 1 shows the mean age equivalent scores obtained by the Experimental and Control groups on the Word Reading sub-test of the WIAT 11-UK (DV 1) across time. Time 1 represents the initial assessment, namely pre-intervention. Time 2 represents the second assessment period, post intervention.

The results from the univariate statistics show a significant Time main effect for Word Reading (DV 1). From pre to post intervention, scores for both groups increased in a

positive direction. The results do not highlight a significant interaction between time and intervention.

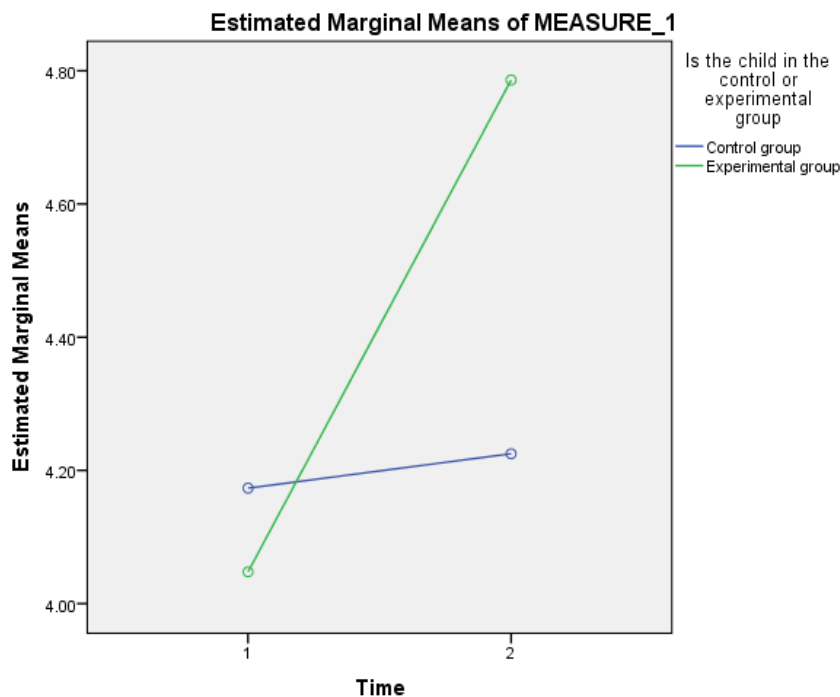


Figure 2-Dependent Variable 2 Written Expression

Figure 2 shows the mean age equivalent scores obtained by the Experimental and Control groups on the Written Expression sub-test of the WIAT 11-UK (DV 2) across time. Time 1 represents the initial assessment, namely pre-intervention. Time 2 represents the second assessment period, post intervention.

The results from the univariate statistics show a significant Time main effect for Written Expression (DV 2).

The results also show a significant interaction between Time and Intervention for DV 2; DV 2 $F(1, 48) = 6.488$ $p = .014$. This significant interaction is further highlighted graphically in Figure 2.

In order to further investigate this finding *post hoc* t tests were conducted to clarify how the significant interactions occurred.

Post hoc t test: Paired Samples t-test (dependent t-test)

The use of the paired samples t-test was employed as a *post hoc* test in order to provide clarification on how the significant interaction identified above occurred. The test was employed because the researcher was looking to examine the difference between the pre/post intervention scores of the same individuals, in order to examine the magnitude, either positive or negative, and to test these differences for statistical significance and most importantly which group, the control or the experimental differed significantly. Essentially a ‘within-subject’ design is being utilised for this part of the research.

Table 4.7 Results of the Paired Samples t-test applied to Pre and Post Intervention Measures obtained by the Experimental Group

	Mean	t value (degrees of freedom)	p value (level of significance)
DV 2- Written Expression (Age Equivalent)	-0.73692	-2.944 (df =25)	0.007 **

* represents $p < 0.05$ (2-tailed)

** represents $p < 0.01$ (2-tailed)

*** represents $p < 0.001$ (2-tailed)

Table 4.8 Results of the Paired Samples t-test applied to Pre and Post Intervention Measures obtained by the Control Group

	Mean	t value (degrees of freedom)	p value (level of significance)
DV 2- Written Expression (Age Equivalent)	-0.05167	-0.716 (df =23)	0.481

* represents $p < 0.05$ (2-tailed)

** represents $p < 0.01$ (2-tailed)

*** represents $p < 0.001$ (2-tailed)

In terms of Written Expression (DV 2), a statistically significant result was found regarding the Experimental group ($p=0.007$), showing that in the Experimental group Written Expression increased from the pre to the post intervention assessment. No significant changes across time were observed for the Control group.

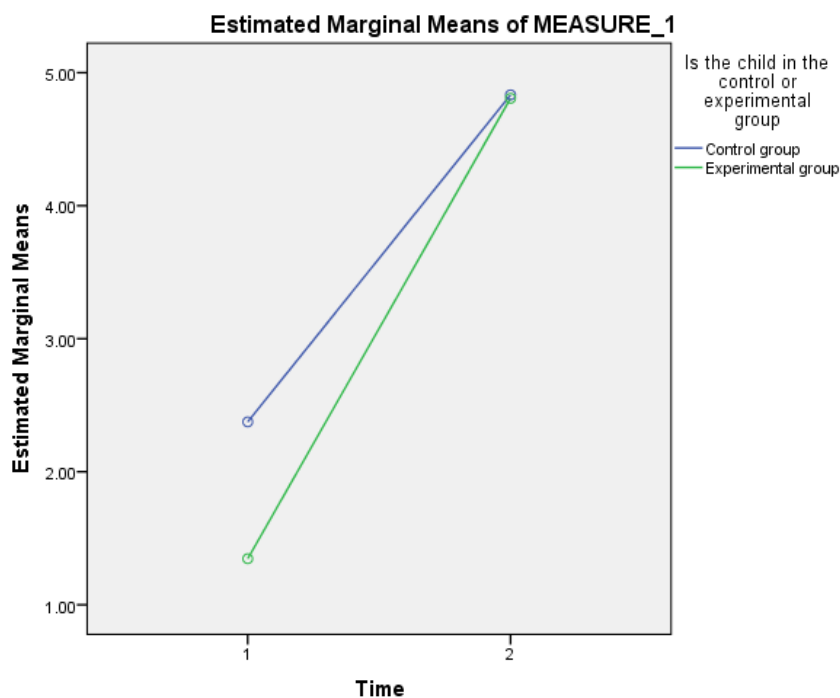


Figure 3-Dependent Variable 3 Letters Sequenced

Figure 3 shows the mean number of letters correctly sequenced alphabetically verbally, by the Experimental and Control groups across time. Time 1 represents the initial assessment, namely pre-intervention. Time 2 represents the second assessment period, post intervention.

The results from the univariate statistics show a significant Time main effect for Letters Sequenced (DV 3). From pre to post intervention, scores for both groups increased in a positive direction. The results do not highlight a significant interaction between time and intervention.

In order to discover if a statistically significant relationship exists between the dependent variables identified within the Experimental and Control groups respectively and the measures of laterality, use was made of the Pearson product moment correlation coefficient, as described in 3.5.7.

As described in 3.4.1 a 12 point laterality continuum was utilised to explore the establishment of laterality and record ‘degrees’ of laterality, with 0 representing totally unilateral to the left and 12 representing totally unilateral to the right. However, in order to provide numeric values of equal weighting, irrespective of whether an individual was

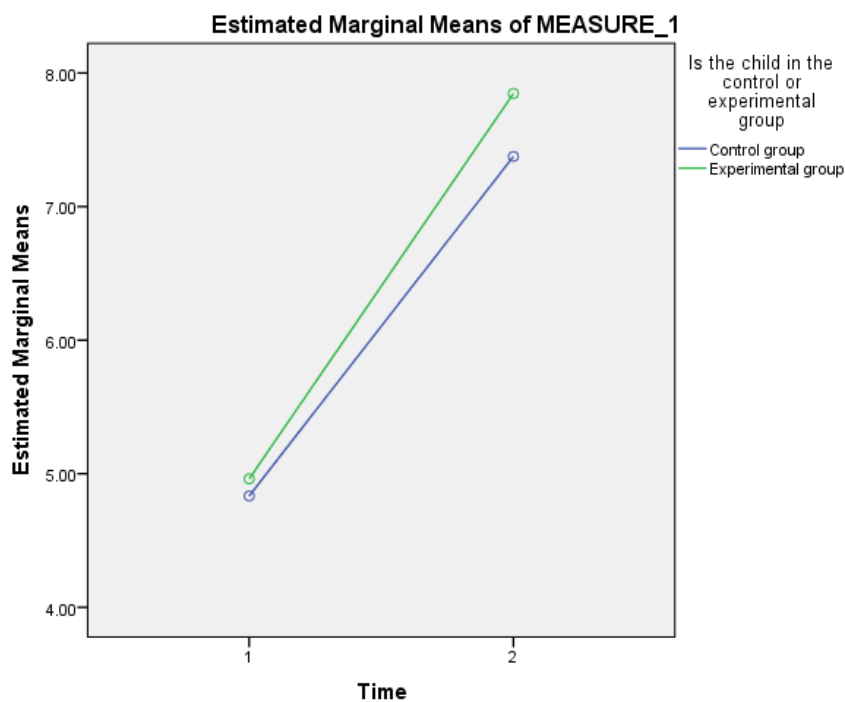


Figure 4-Dependent Variable 4 Numbers Correctly Formed

Figure 4 shows the mean number of numbers correctly formed by the Experimental and Control groups across time. Time 1 represents the initial assessment, namely pre-intervention. Time 2 represents the second assessment period, post intervention. The results from the univariate statistics show a significant Time main effect for Numbers Correctly Formed (DV 4). From pre to post intervention, scores for both groups increased in a positive direction. The results do not highlight a significant interaction between time and intervention.

biased towards the left or right adjustments to the values had to be made prior to the use of this statistical test. Therefore the motoric and sensory laterality continuum ranging from 0-6, with the mid-point of 3 representing the greater degree of CLP, was revised to range from -3 to 3, with 0 representing the greatest degree of CLP. All values were then adjusted to read as positive so that equal values of 3 were assigned to unilaterality, irrespective of to the right or left.

Similarly, on the motoric plus eye laterality continuum ranging from 0-9, this was adjusted to range from -4.5 to 4.5, and the full scale laterality continuum ranging from 0-12, was adjusted to range from -6 to 6. As above, all values were adjusted to read as positive to provide scales ranging from 0-4.5 and 0-6 respectively, with 0 representing the greatest degree of CLP.

Table 4.9 Correlation between Motoric laterality index and Pre and Post intervention measures

Variables	Experimental Group (n =26)		Control Group (n =24)	
	r	p	r	p
LI(m)/Pre Intervention Word Reading Age Equiv	-.007	0.974	-.151	0.482
LI(m)/ Post Intervention Word Reading Age Equiv	.074	0.720	-.036	0.866

LI(m)/Pre Intervention Written Expression Age Equiv	-.353	0.077	-.099	0.647
LI(m)/Post Intervention Written Expression Age Equiv	-.029	0.887	-.193	0.366
LI(m)/Pre Intervention letters sequenced	.170	0.407	.107	0.618
LI(m)/Post Intervention letters sequenced	.084	0.682	.023	0.915
LI(m)/Pre Intervention numbers correctly formed	.105	0.610	-.087	0.687
LI(m)/Post Intervention numbers correctly formed	-.143	0.486	-.245	0.249

*correlation is significant at the 0.05 level (2 tailed)

**correlation is significant at the 0.01 level (2 tailed)

No statistically significant correlations were found.

Table 4.10 Correlation between Sensory Laterality Index and Pre and Post Intervention Measures

Variables	Experimental Group (n =26)		Control Group (n =24)	
	r	p	r	p
LI(s)/Pre Intervention Word Reading Age Equiv	.294	0.145	.291	0.168
LI(s)/ Post Intervention Word Reading Age Equiv	.009	0.965	.427	0.037*
LI(s)/Pre Intervention Written	-.093	0.652	-.018	0.933

Expression Age Equiv				
LI(s)/Post Intervention Written Expression Age Equiv	.318	0.113	.227	0.285
LI(s)/Pre Intervention letters sequenced	-.256	0.206	-.309	0.142
LI(m)/Post Intervention letters sequenced	-.047	0.819	-.103	0.630
LI(s)/Pre Intervention numbers correctly formed	.080	0.699	.265	0.211
LI(s)/Post Intervention numbers correctly formed	.128	0.533	-.046	0.832

*correlation is significant at the 0.05 level (2 tailed)

**correlation is significant at the 0.01 level (2 tailed)

A positive moderate correlation was found between the Word Reading scores in the post intervention assessment for the Control group (p=0.037).

Table 4.11 Correlation between Laterality Index (motoric + eye) and Pre and Post Intervention Measures

Variables	Experimental Group (n =26)		Control Group (n =24)	
	r	p	r	p
LI(m+eye)/Pre Intervention Word Reading Age Equiv	-.253	0.213	-.264	0.212
LI(m+eye)/ Post Intervention Word Reading Age Equiv	-.095	0.644	-.413	0.045*

LI(m+eye)/Pre Intervention Written Expression Age Equiv	-.157	0.444	-.147	0.494
LI(m+eye)/Post Intervention Written Expression Age Equiv	-.293	0.146	-.286	0.175
LI(m+eye)/Pre Intervention letters sequenced	.203	0.321	.066	0.758
LI(m+eye)/Post Intervention letters sequenced	-.025	0.903	-.059	0.785
LI(m+eye)/Pre Intervention numbers correctly formed	-.048	0.817	-.185	0.387
LI(m+eye)/Post Intervention numbers correctly formed	-.152	0.458	.103	0.633

*correlation is significant at the 0.05 level (2 tailed)

**correlation is significant at the 0.01 level (2 tailed)

A negative moderate correlation was found between the Word Reading scores in the post intervention assessment for the Control group ($p=0.045$).

Table 4.12 Correlation between Laterality Index (full) and Pre and Post Intervention Measures

Variables	Experimental Group (n =26)		Control Group (n =24)	
	r	p	r	p
LI(f)/Pre Intervention Word Reading Age Equiv	-.165	0.421	-.148	0.489
LI(f)/ Post Intervention Word Reading Age Equiv	-.223	0.273	-.164	0.443

LI(f)/Pre Intervention Written Expression Age Equiv	-.200	0.328	-.094	0.662
LI(f)/Post Intervention Written Expression Age Equiv	-.158	0.442	-.138	0.520
LI(f)/Pre Intervention letters sequenced	.043	0.833	-.048	0.823
LI(f)/Post Intervention letters sequenced	-.093	0.650	-.069	0.747
LI(f)/Pre Intervention numbers correctly formed	-.081	0.693	.099	0.647
LI(f)/Post Intervention numbers correctly formed	-.273	0.177	.091	0.672

*correlation is significant at the 0.05 level (2 tailed)

**correlation is significant at the 0.01 level (2 tailed)

No statistically significant correlations were found.

Use of the Bonferroni correction procedure was not employed as a *post hoc* test despite making multiple comparisons using the Pearson product moment, and possibly finding significant results due to chance. Given the small sample size used within this research project (n= 50), the use of the Bonferroni correction procedure is less advised. A serious problem associated with the Bonferroni correction procedure is a substantial reduction in the statistical power of rejecting an incorrect Ho in each test (e.g. Holm, 1979; Perneger, 1998; Rice, 1989).

Data pertaining to Research Question 4: What level of understanding do those involved in early years education have of HLP/CLP.

4.6.3 School Staff Questionnaire

Questionnaires were issued to sixteen members of staff involved in early years education within the school, namely Reception, Year 1 and Year 2. A 100% response rate was achieved.

Sample n=16

Qualified Teacher Status (QTS) = 31% (5) and Teaching Assistant (TA) = 69% (11).

Consideration was given to using what Hayes (2000) describes as a ‘thematic analysis’ as a qualitative method of data analysis, to organise the responses on the staff questionnaire. Similarly, Braun and Clarke (2006) defined ‘thematic analysis’ as a ‘method for identifying, analysing and reporting patterns (themes) within data’ (p.79). However, on closer examination of the responses very few themes emerged due to the fact that the sample population of staff reported very limited knowledge on the area under investigation. As a result it was decided to report all responses as well as highlighting the dominant, but limited number of themes.

Table 4.13 Showing responses to Staff Questionnaire

Teacher responses 31% (5)	Teaching Assistant response 69% (11)
<i>1. What is your understanding of cross lateral preference (CLP)/mixed dominance?</i>	
None (x 3)	None (x 10)
Unsure of dominant hand (x 1)	Unsure of dominant hand (x 1)
Difficulty crossing body mid-line (x 2)	
<i>2. Are you aware of any pupils with CLP in your school?</i>	
No (x 5)	No (x 11)
<i>3. How would you know if a pupil had CLP?</i>	
Don't know (x 4)	Don't know (x 9)
Ask AENCo (x 1)	Ask AENCo (x 2)
<i>4. Do you feel that pupils with CLP are disadvantaged in school?</i>	
Don't know (x 4)	Don't know (x 11)
Yes- with writing, also fine and gross motor skills (x 1)	
<i>5. Do you feel that pupils with CLP experience greater difficulty with school work generally?</i>	
Don't know (x 4)	Don't know (x 11)
Yes- writing (x 1)	
<i>6. If a pupil is experiencing learning difficulties in school would you consider that the difficulties may be related to laterality issues or would you give no thought to this?</i>	
Don't know (x 4)	Don't know (x 8)
No (x 1)	No (x 1)
	Had no training (x 1)
	Not aware of laterality issues (x 1)
<i>7. If you were aware of a pupil in your class as having CLP what support if any would you provide for that pupil?</i>	
Don't know (x 3)	Don't know (x 11)
‘Write Dance’ exercises (x 1)	

Confer with AENCo (x 1)	
8. If you have any further thoughts/questions relating to CLP please note them below.	
None (x 2)	None (x 8)
Would like to know what CLP is (x 1)	
I am unaware of what CLP is (x 1)	
Would like training (x 1)	

A first reaction to the responses in Table 4.15 is that the sample population of staff involved in the survey had little or no understanding of cross lateral preference/mixed dominance and its' potential impact on the learning experiences of the young child.

For example:

Question 1; *What is your understanding of CLP/mixed dominance?*

81% of the sample population responded with 'none'.

Question 2; *Are you aware of any pupils in your school with CLP? If yes how are you aware?*

100% of the sample population responded with 'no'.

Question 3; *How would you know if a pupil had CLP?*

81% of the sample population responded with 'don't know' and the remaining 19% responded with 'ask the AENCo', suggesting that no one within the sample population would be able to identify a pupil displaying CLP.

Question 4; *Do you feel that pupils with CLP are disadvantaged in school in any way?*

94% of the sample population responded with 'don't know', and just 6% highlighted writing and fine and gross motor skills.

Question 5; *Do you feel that pupils with CLP experience greater difficulty with school work generally?*

94% of the sample population responded with 'don't know', and just 6% suggested that pupils might experience difficulties with writing.

Question 6; *If a pupil is experiencing learning difficulties in school would you consider that the difficulties may be related to laterality issues or would you give no thought to this?*

75% of the sample population responded with 'don't know', 13% responded with 'no', 6% with 'had no training' and a further 6% with 'not aware of laterality issues'.

Essentially all responses were negative.

Question 7; *If you were aware of a pupil in your class as having CLP what support if any would you provide for that pupil?*

88% of the sample population responded with 'don't know', 6% with making use of 'Write Dance' exercises and a further 6% would confer with the AENCo.

Question 8; *If you have any further thoughts/questions relating to CLP please note them below.*

63% of the sample population had no further thoughts that they wished to highlight, 25% reported that they did not know what CLP is, 6% wanted to know what CLP is and a further 6% requested training to gain a better understanding of CLP.

4.7 Key Findings

Four hypotheses were formulated in 3.7. These hypotheses are linked to the four research questions posed at the beginning of this chapter. A brief summary of the key findings will be highlighted under these four key areas.

Research question 1: What is the prevalence of CLP amongst young children?

Hypothesis 1: CLP will be observed in the sample population within the range indicated by previous studies.

Histogram 5 illustrates that when consideration is given to the Full laterality index, composed of the four measures relating to hand, foot, eye and ear, 0% of the sample population were found to be unilateral to the left or right, thus suggesting that 100% of the sample population display, to varying degrees CLP. On average, 16% of the total sample achieved a score of 6 on the continuum, the mid-point, potentially the greatest degree of CLP. 57% of the total sample achieved a score of 7 or above, representing a shift to the right compared to just 25% achieving a score of 5 or below representing a shift to the left. Thus suggesting that CLP is part of normal development for children of this age.

Histogram 2 displaying Motoric laterality index, as expected shows a clear shift to the right with 16% of the total population displaying unilaterality to the right and 76% scoring at 4 and above on the continuum. 0% of the total sample displayed unilaterality to the left and just 6% of the total sample scored at 2 or below.

Histogram 3 displaying Sensory laterality index shows approximate equal numbers at the pole ends of the continuum, representing unilaterality, left 10% and right 12%. The

remainder of the sample population are fairly evenly distributed along the continuum for this measure.

Research findings suggest that H1 should not be rejected.

Research question 2: Does the use of educational technology and multi-modal learning experiences provided by the software produced, assist children in the development of early letter/number formation and handwriting skills?

Hypothesis 2: Multi modal learning experiences, incorporating the use of educational technology in the form of a touch screen software program which utilises changes in colour and sound to help emphasise directionality, along with tactile experiences, will help all children with letter/number formation and handwriting skills, but more specifically those with CLP.

The results from the univariate ANOVA analysis shows a statistically significant result $p = .014$, for the Experimental group post intervention for DV 2, Written Expression (age equivalent) only. *Post hoc* tests lend further support. The independent samples t test for this variable yielded a statistically significant relationship between the means of the Experimental and Control groups $p = .046$. Furthermore, analysis using the paired samples t test applied to the pre and post intervention measures produced a statistically significant result in respect of the Experimental group only $p = .007$, suggesting a distinct difference between group performance has occurred. Therefore, given the statistically significant results obtained from three separate analyses, supporting the notion that the difference between the Experimental and Control groups for DV 2, written expression, is unlikely to have occurred by chance.

Research findings suggest that H2 should not be rejected as a statistically significant result was obtained in relation to DV 2 Written Expression (writing the letters of the alphabet-timed).

Research question 3: Is a child displaying CLP disadvantaged in the learning environment, especially in terms of letter/number formation and handwriting skills?

Hypothesis 3: Individuals who display CLP experience greater difficulty with letter/number formation and handwriting skills than those who do not.

Use was made of the Pearson product moment coefficient in order to investigate whether a statistically significant relationship exists between the DVs and the measures

of laterality. A statistically significant result was obtained between the Sensory laterality index and the Sensory and Eye laterality index for the post intervention Control group only on Word Reading (DV1).

The values of 'r' were anticipated to be positive for all measures, suggesting that as one became increasingly unilateral the individual would score higher on the measures undertaken. This however was not found to be reflected in the results obtained.

Research findings suggest that H3 should be rejected.

Research question 4: What level of understanding do those involved in early years education have of HLP/CLP?

Hypothesis 4: Educators have little knowledge or understanding of HLP/CLP within early years settings.

Responses from the staff questionnaire highlight very limited knowledge of cross lateral preference/mixed dominance and its potential impact on the learning experiences of the young child. No-one within the sample questioned felt that they would be able to identify whether a pupil displayed CLP, and 88% responded by stating that they would not know how to address or support a child displaying CLP if identified.

Research findings suggest that H4 should not be rejected.

CHAPTER 5: DISCUSSION OF FINDINGS

5.1 Overview

This chapter provides an overview of the key findings of this study and discusses them in relation to psychological theory and existing research literature. The limitations of the study will also be explored.

This research project aimed to investigate the lateral preferences of 50 pupils aged 4-5 years in terms of the motoric measures of hand and foot, and the sensory measures of eye and ear, in an attempt to determine the prevalence of cross lateral preference amongst young children, with a view to exploring whether those pupils displaying CLP

are disadvantaged in the learning environment, particularly in relation to letter/number formation due to difficulties with directionality and left to right orientation.

The researcher designed, commissioned and evaluated a multi-modal computer programme for use with an interactive table/board/tablet. The multi-modal programme attempted to promote the development of motor, visual and auditory memory for directionality amongst young children, thus aiding letter/number formation and recognition.

Finally the researcher sought to assess the level of understanding of human lateral preference/cross lateral preference amongst those involved in the education of our young, namely qualified teachers and teaching assistants in Key Stage 1 of a local Primary school.

Within the research project use was made of both standardised and non-standardised measures with the sample population of pupils that generated numerical values for a number of different variables identified. The researcher employed the use of statistical analysis in order to explore the relationship between these variables.

It had been intended to make use of thematic analysis to examine the themes that emerged from the responses of the staff to the questionnaire. However, the responses collated from the sample population highlighted little awareness of cross lateral preference, its potential impact on the learning experiences of the child and how they might address difficulties possibly related to CLP. As no themes emerged apart from lack of awareness, it was not possible to utilise this technique.

The key findings in relation to the research questions will be explored and any significant findings will be highlighted.

5.2 Discussion of Key Findings based on Evidence Obtained and Links with Existing Literature

5.2.1 The Prevalence of CLP amongst Young Children

As highlighted in 1.4.3 there remains some debate regarding the prevalence of CLP within the population. For example, Porac, Coren and Duncan (1978) reported significant positive correlations among the indices hand, foot, eye and ear, as measured by a behaviourally validated preference inventory. Research data (Coren, Porac and Duncan 1979; Brito and Santos-Morales 1999) highlight a potential shift in the pattern

of lateral preference as a function of chronological age, supporting the notion of an overall shift to right sidedness and towards greater congruency across the indices with maturity. Within the population as a whole it was postulated in 1.4.3 that 29% of the population display CLP when the four indices of hand, foot, eye and ear are included. It was anticipated that this percentage would be higher amongst young children due to their lack of maturity and opportunity to develop greater congruency across the indices and given the notion that CLP is a developmental phenomenon and for the vast majority of individuals a normal stage in development.

For ease of reference and comparison, the findings using the laterality continua have been summarised in table format, (see Table 5.1).

Table 5.1:Prevalence (%) of CLP/Unilaterality as Measured on Laterality Continuum

	FULL (0-12)	MOTORIC (0-6)	SENSORY (0-6)	MOTORIC AND EYE (0-9)
TOTAL SAMPLE N=50				
*Greatest degree of CLP	16	16	24	16
**Right side shift	58	78	40	62
***Left side shift	26	6	36	22

****Unilaterality	0	16	22	12
EXPERIMENTAL GROUP N=26				
*Greatest degree of CLP	12	12	27	12
**Right side shift	65	90	38	69
***Left side shift	23	0.5	35	21
****Unilaterality	0	27	23	23
CONTROL GROUP N=24				
*Greatest degree of CLP	21	21	21	21
**Right side shift	50	71	38	54
***Left side shift	29	1	35	25
****Unilaterality	0	4	21	0

*Scoring on the mid-point of the continuum

**Scoring above the mid-point on the continuum, including unilateral scores to the right

***Scoring below the mid-point on the continuum, including unilateral scores to the left

****Scoring at the extreme ends of the continuum only.

NB As the scores for unilaterality have been absorbed within right/left side shift categories, as well as standing alone in the unilateral category, the figures will not necessarily total to 100.

Based on the measures used to assess lateral preference of all four indices as described in 3.4.1, 100% of the total sample population could be described as displaying CLP to a greater or lesser degree, as shown in Histogram 5.

The fact that 100% of the sample population was found to display at least some elements of CLP when all four indices were considered was totally unexpected. More specifically, using the laterality continuum, ‘degrees’ of CLP within the total sample population can be identified.

Greatest Display of CLP (at median of 6 on Full Laterality Continuum)

16% scored 6

36% scored 5-7

62% scored 4-8

80% scored 3-9

94% scored 3- 10

100% scored 3-11

No Display of CLP/Unilateral (score of 12 or 0)

NB: No scores of <3 or > 11 were recorded.

When the laterality continuum for motoric, sensory and motoric plus eye are considered individually, very high percentages of CLP are also recorded: 84, 78 and 88 respectively. These figures are far in excess of those highlighted in any previous research studies sourced and generally contradict the findings of others in the field (Coren, Porac and Duncan, 1979; Brown and Taylor, 1988), who reported significant positive correlations between the indices of hand, foot eye and ear, as measured by a lateral preference questionnaire. It is possible that the discrepancy in findings may be due to the use of differing methodologies.

Although techniques to assess lateral preference have varied between studies, the majority have utilised self-report questionnaires, presumably to aid expediency and avoid the need to assess large populations of individuals. The majority of these questionnaires have been concerned with handedness, and are considered to be highly reliable and valid , for example; Crovitz and Zener (1962), Annett (1970) and Oldfield (1971) as described by Van Strien (2002). For the purpose of this research study, given the size and age of the sample population, it was believed that the most accurate, reliable and consistent method of lateral preference data collection was through individual performance based assessment.

However, whether individual performance based assessment techniques are used or self-report questionnaires, there are obvious problems with both methods. If the former is utilised, which for smaller samples may be considered the most reliable indicator of

lateral preference, one must consider how many activities should be sampled and how frequent. In terms of self-reported responses there must be some concern regarding whether the written responses collated actually correlate with the overt behaviour of the sample population, and once again how many activities should be sampled and how frequent.

Furthermore, consideration should be given to whether a simple dichotomy, right/left is too insensitive a measure, and maybe degrees of laterality for each specific index (hand, foot, eye, ear) would be preferable, but potentially task related. The development of the 12 point laterality scale for the purpose of this study, made some attempt to address this issue. Twelve tasks requiring right/left responses from each of the four indices assessed were presented and lateral preference on three actions for each index were recorded, rather than a single measure for each index. The use of this measurement technique is likely to explain the discrepancy found between the prevalence of CLP highlighted in previous studies compared to this study, with the latter providing possibly a more sensitive measuring tool, as a result making it more difficult to attain unilateral status.

However, when the ‘majority rule’ for each index was employed in this research, so that for each index if the participant scored either 2 or 3, then that ‘side’ was considered as the preferred lateral preference for that index, slightly different results are obtained. These results for the full laterality continuum, although not synonymous with findings from previous studies, warrant reporting.

78% of the total sample population displayed CLP, suggesting that the remaining 22% are unilateral, when measures are considered in this way. These measures are relatively evenly distributed between the Experimental and Control groups and between boys and girls, this suggests that CLP is part of normal development for children of this age.

To provide some context, the percentages of dichotomous right side dominance for the four indices studied will be provided (for this study based on the majority rule).

Table 5.2: Percentage of Population showing Right Side Dominance

INDEX	THIS STUDY (Total Population)	EMPIRICAL STUDIES BASED ON WORLD POPULATION	STUDY BY MANDAL et al. (1991)

		(reported in Mandal et al., 1991)	
HAND	92	90	–
FOOT	68	80-90	87
EYE	58	60-70	88
EAR	34	Thinly reported	74

Considering the relationship between the indices themselves, as highlighted in 1.4.3, reports (Coren and Kaplan, 1973; Porac and Coren, 1975;1976;1978;1979) highlight more positive correlations between the motoric indices of hand and foot, than between hand-eye; hand-ear; foot-eye and foot-ear.

It is difficult to compare the results of this study with these findings, however in terms of hand and foot preference as measured by the motoric laterality continuum, just 16% displayed unilaterality, whereas in terms of eye and ear dominance, as measured by the sensory laterality continuum, 22% displayed unilaterality. Thus suggesting a marginally greater congruence for sensory measures than motoric.

These percentages are low and do not concur with the findings of previous studies. If these figures are considered to be a true reflection of the prevalence of unilaterality amongst young children, these figures support the notion that CLP is part of normal development for children of this age, namely 4-5 years. Furthermore, this suggests that a much higher percentage of young children display CLP than first anticipated.

5.2.2 Analysis of the Use of Educational Technology and Multi-Modal Learning Experiences to Help Develop Early Letter/Number Formation and Handwriting Skills

Standardised baseline data were collected from the total sample population pre and post intervention, using four sub-tests from the Wechsler Individual Achievement Test -11UK (as described initially in 3.5.4, and in more detail in Appendix D).

Raw data are displayed in Appendix L showing pre/post intervention scores on the WIAT-11UK sub-tests administered for both the Experimental and Control groups.

In addition, a record was made of the number of letters correctly sequenced alphabetically verbally, and the number of numbers correctly formed ranging from 1-10,

were observed and recorded. The number 10 was included despite being comprised of two digits, so that the researcher could check left to right orientation of digits; namely that 10 was written as 10 and not 01, with the latter being considered as incorrect.

The results from the univariate repeated measures ANOVAs highlight the following:

Dependent Variable 1: Word Reading (Age equivalent scores from WIAT-11UK)

From the pre to post intervention period, scores for both the Experimental and Control groups increased in a positive direction. However, the results did not yield a significant interaction between time and the intervention. DV1, the Word Reading sub-test, at the age of the sample population, would involve assessment of pre-reading skills, predominantly naming the letters of the alphabet when presented visually and out of sequence. Those within the sample population who scored better, and hence would have progressed further through the assessment, would have also had their phonological awareness skills assessed in terms of identifying and generating rhyming words, identifying beginning and ending of words through sound and matching sounds with letter blends. Statistical analysis of the results suggests that there was no significant difference between the progress of the Experimental group when compared to the Control group; therefore it is assumed that the intervention on this occasion did not support the development of the skills highlighted above significantly.

However, many of the sample population from both Experimental and Control group, provided the letter sound rather than the letter name in response to the stimulus, and as a result were given no credit in line with the scoring guidance. However, it is a possibility that this may have affected the results obtained.

Dependent Variable 2: Written Expression (Age equivalent scores from WIAT-11UK)

The use of the standardised Written Expression sub-test from the WIAT-11UK as highlighted in 3.3.1 involves:

- Write the alphabet (timed)
- Demonstrate written word fluency
- Combine and generate sentences
- Produce a rough-draft paragraph (8-11)

Given the age of this sample, individuals in practical terms were assessed writing the letters of the alphabet sequentially, whilst being timed. This measured sequential knowledge of the alphabet, letter formation and a degree of automaticity in terms of letter formation, given the time factor.

From the pre to post intervention period, scores for both the Experimental and Control groups increased in a positive direction, with significantly greater gains for the Experimental group. The results from the univariate statistics show a significant interaction between Time and Intervention for DV 2; $DV 2 F(1, 48) = 6.488 p = .014$.

A *post hoc* paired samples t-test was employed which produced a statistically significant result for the Experimental group only ($p = 0.007$), and no significant change across time was observed for the Control group. This does not infer that the Control group made no progress in respect of DV 2, (across time the mean age for this group increased from 4.17 months to 4.23 months). Therefore, statistical results suggest a distinct difference between group performance has occurred which was very unlikely to be due to chance.

Given the statistically significant result for Written Expression sub-test for the Experimental group only, it is inferred that the difference has occurred due to the Experimental group being exposed to the intervention. The score for this sub-test for the age group of the sample population is based upon the number of correctly formed letters written in 15 seconds. Each correctly formed letter (based on the guidance in the scoring manual) and correctly sequenced (sequencing is established in reference to the last letter correctly formed) written within the time frame is given credit. It was hypothesised in 2.8 that through the implementation of the newly developed software, some individuals will improve their ability to visualise letters/numbers and their motor memory for correct formation. These initial findings are encouraging and, in respect of letter formation at least, statistical results may be cautiously interpreted as lending support to this hypothesis resulting in increased automaticity; the ability to retrieve and produce letters automatically and sequential knowledge of the alphabet.

Berninger and her colleagues in the White Paper of July 2007, considered writing development to be composed of multiple components including low level and higher level skills. The lower level skills were thought to represent a good understanding of the written alphabet letters, to be able to generate letter representations from memory and to be able to access these letters from memory in order to utilise motor planning and motor

production to produce letters fluently. Exposure to the intervention **may** have helped to promote the development of these lower level skills enabling the individuals within the Experimental group to retrieve and produce letters more fluently, thus being able to produce more correctly formed letters within the given time frame when compared to the Control group.

Furthermore, promoting a possible reduction in the amount of ‘in air’ time as described in research by Rosenblum, Parush, Epstein and Weiss (2003), highlighted in Chapter 2, due to greater consistency and efficiency of writing movements, possibly due to a multi-modal learning approach to letter formation with multi-modal feedback. Promoting more efficient learning through minimising any difficulties relating to component skill immaturity/‘developmental dissociation’ (Berninger and Hart, 1992). The intervention attempts to ensure that the learning/skill development opportunities are presented in a format that permits the maximum number of ‘valid co-occurrences’ (Bertelson and De Gelder, 2004), at an age appropriate level.

In addition, feedback from the class teacher and indeed from the pupils themselves whilst visiting the classroom, suggest that the pupils found using the interactive table for this task an enjoyable activity, as a result potentially increasing engagement in learning. This would be in line with the research highlighted in Chapter 2 (p.45) by Beeland (2002) who reported, based on responses from class teachers, that the use of a whiteboard in learning tasks did improve pupil engagement during lessons, and this was attributed to the pupils being able to see the information on the screen, interact/touch the screen and hear the sounds.

Dependent Variable 3: Letters Sequenced Verbally Alphabetically

From the pre to post intervention period, scores for both the Experimental and Control groups increased in a positive direction, with marginally greater gains for the Experimental group. The mean gain for the Experimental group was 3.46 compared to 2.45 for the Control group. However, the results did not yield a significant interaction between time and the intervention. Therefore it is considered that the intervention on this occasion did not support the development of this skill significantly, despite the fact that it is linked to DV 2 which required recalling the alphabetic sequence. Consideration therefore must be given to the possibility that it is the automaticity of letter writing and correct letter formation that gave rise to the significant result above, rather than the sequencing element of the task.

Dependent Variable 4: Numbers Correctly Formed

From the pre to post intervention period, scores for both the Experimental and Control groups increased in a positive direction, with marginally greater gains for the Experimental group. The mean gain for the Experimental group was 2.89 compared to 2.55 for the Control group. However, the results did not yield a significant interaction between time and the intervention. Therefore, once again it is considered that the intervention on this occasion did not support the development of this skill significantly, despite the fact that the intervention provided very similar target practice for numbers as for letters, and for the latter, a significant result was found.

A possible explanation for this discrepancy is that when pupils were given their daily individual access to the interactive table, they were instructed by their class teacher to firstly practice all the letters of the alphabet before practising their numbers. However, in an effort to ensure that all pupils had daily access to the programme, time restrictions were applied. It was reported by the school staff and the sample population themselves, that many pupils failed to get to the numerical practice on a regular basis due to these time constraints and as a result possibly failing to make a significant improvement with their number formation.

Furthermore, after the pupils in the Experimental group were given initial instruction by the class teacher on the use of the programme on the interactive table, the researcher had requested wherever possible for pupils to be given appropriate adult intervention to facilitate and extend learning, so that the use of the programme could be monitored and extended. It was imperative that letter/number formation itself, not just the end result was scrutinised, so that any incorrect formations were quickly corrected, so that these correct formations and associated motor movements, differences in sound and colour changing properties on the interactive table became embedded. For example; an individual with his/her eyes shut theoretically should be able to state whether another individual correctly formed the letter 'o', by simply listening to the sound (tune) made by the formation on the interactive table, even if the end result looked the same.

Equally, once an individual has been exposed to correct letter/number formation on the interactive table using the computer programme, with associated colour changing properties and changes in pitch of sound as the child's finger moves around the table, it is hoped and anticipated that with sufficient practice and reinforcement that an individual will recognise through visual and auditory input what a specific letter/number

looks like (in terms of sequence of colour change) and sounds like (in terms of sequence of pitch of sounds) correct. Correct responses through the visual and auditory modes will endorse the formation of motor memory learning for specific letters/numbers. Once this motor memory for specific letters and numbers has become firmly embedded, it is anticipated that the individual can progress to making correct formations on paper and other materials, without the support of the sounds and colour changes on the computer programme.

5.2.3 Analysis of whether a Child Displaying CLP is Disadvantaged in the Learning Environment Especially in Terms of Letter/Number Formation and Handwriting Skills

In an attempt to explore whether a child displaying CLP is disadvantaged in the learning environment use was made of the Pearson product moment correlation coefficient (r) in order to investigate whether there was a quantifiable relationship between the Dependent Variables 1-4 and the scores obtained on the four different laterality continua. It was anticipated that the values for the correlation coefficient would be positive for all results based on the assumption that as an individual displays greater degrees of unilaterality either to the left or right (scores higher on the laterality scales) the individual would score higher on the measures recorded.

Furthermore, it was anticipated that the value of (r), post intervention, would be higher for both groups, when compared to pre intervention measures, with the values of (r) for the experimental group being slightly lower than those of the control group, assuming the intervention negated at least some of the effects of CLP.

However, the results displayed in Tables 4.9- 4.12 do not in general support these assumptions.

The distribution of positive and negative values for (r) in the tables 4.9-4.12 on initial inspection appear to be quite random, and it was difficult to identify a specific pattern to these findings. Furthermore just two results reached statistical significance, and these were in respect of the Control group only.

In relation to DV 1, Word Reading, a statistically significant positive moderate correlation was found on the post intervention assessment for the Control group only ($p=0.037$), in respect of the sensory laterality continuum, suggesting that as the score attained on the Word Reading sub-test increased, the individual's score on the sensory

laterality continuum also increased (move towards increased unilaterality for sensory indices). A positive correlation was also found between these two variables in respect of the Experimental group, but not at a statistically significant level ($p=0.965$).

Further, in relation to DV 1, Word Reading, a statistically significant negative moderate correlation was found on the post intervention assessment for the Control group only ($p=0.045$), in respect of the motoric + eye laterality continuum, suggesting that as the score on the Word Reading sub-test increased, the individual's score on the motoric + eye laterality continuum decreased (move towards increased CLP for motoric + eye indices). A negative correlation was also found between these two variables in respect of the Experimental group, but not at a statistically significant level ($p=0.644$). In respect of this negative correlation it is not possible however to ascertain from the results whether the lower score on the continuum reflects discord between the motoric indices and the sensory index the eye, or between the motoric indices themselves. As a result it is not possible to make any specific inferences. Further research would be required in order to explore this further.

Given the randomisation of positive and negative values for (r) and relative lack of statistically significant results, the results attained using the Pearson Product moment correlation coefficient yields no evidence to support the hypothesis that a relationship exists between attainment, in respect of the measures taken, and CLP.

These findings are in keeping with previous research findings by De Agostini and Dellatolas (2001) who found no evidence to support the notion of inconsistent lateral preference of the hand, eye or foot having any deleterious effect on children's cognitive performance. However, studies by Whittington and Richards (1987, cited in Beaton 2004; Crow et al., 1998; De Agostini and Dellatolas, 2001) do lend support to a relationship between lack of consistent handedness and processing difficulties, and increasing cognitive abilities with increasing dextrality respectively. However, the lack of consistent handedness and decreasing dextrality is not synonymous necessarily with CLP.

More specifically in relation to letter/number formation, children with handwriting difficulties were found by Volman, Schendel and Jongmans (2006, p.459) to perform 'less proficiently on measures of visual perception, fine motor coordination, visual-motor integration and cognitive planning in comparison with children without handwriting problems'. This study reported that two differing mechanisms, namely fine

motor skills and visual-motor integration as predictors of the quality of handwriting equated with letter formation, with the latter being the better predictor amongst those identified as having handwriting problems.

Visual Motor Integration (VMI), the ability of the eyes and hands to work together in smooth and efficient patterns, as highlighted in Chapter 2 is frequently considered to be the most important pre-requisite skill for developing handwriting skills. Indeed, Volman, Schendel and Jongmans (2006) considered that for children with handwriting difficulties attention should be given to improving visual motor integration processes. There is a distinct possibility that by providing multi-modal learning experiences through the vehicle of educational technology (interactive table /tablet), more specifically the interaction between the touch screen and visual colour changing properties of the software, that VMI is enhanced, and further supported by other modalities, thus helping to lay down the important foundations for developing handwriting skills. However, further research to elucidate the development of visual motor integration processes in relation to the use of this particular software would need to be conducted before such claims could be made, therefore these claims at this time remain speculative.

5.2.4 Analysis of the Level of Understanding amongst Educators Regarding CLP

Responses from the staff questionnaire highlight very limited knowledge of cross lateral preference/mixed dominance in the sample school. Due to the lack of emerging themes, thematic analysis could not be applied to the responses as originally intended. The lack of emergent themes does however lend support to the hypothesis that educators have little knowledge or understanding of human lateral preference, CLP and mixed dominance.

With hindsight, it is possible that the questions posed were too specific and restrictive in relation to cross lateral preference/mixed dominance. More helpful and relevant data may have been collected if the questions had been more general, at least initially, to explore background knowledge in relation to motor difficulties, before ‘drilling down’ and exploring laterality issues. However, the pilot run of the same questionnaire in a different local primary school yielded an interesting cross section of data; as a result it was felt that no adjustments to the questionnaire were necessary.

One possible explanation for this difference is that the school where the questionnaire was piloted is one serviced by the researcher. The researcher has shared her thoughts and knowledge regarding this area, and has consulted with staff regarding issues related to laterality in respect of individuals referred to the service, as a result potentially increasing staff awareness of laterality issues and its impact on learning. Therefore, it is likely that this helped to increase awareness amongst staff in the school, and this was reflected in their responses to the pilot questionnaire.

5.3 Limitations of the Research

5.3.1 Generalisation of the Findings

This current study provides some initial evidence to support the use of the newly devised computer software to positively enhance the development of young children's letter formation skills. This assumption is based on the statistically significant results obtained in respect of the Experimental group on the post intervention scores on the Written Expression sub-test.

However, in terms of generalisation of findings, although quantitative research aims to make generalisations to the whole population, or at least to the larger population of which the sample population represents a subset, this depends on 'fairness'. Samples should be large enough to provide sufficient statistical power to make the results of such tests unambiguous, providing an unbiased estimate of the population mean. In respect of this study, the use of inferential statistics to predict population parameters based on such a small sample ($n=50$) may be considered as a valid criticism, despite the fact that every attempt was made to ensure that the research design was robust enough to produce results that are reliable, valid and contribute to new knowledge. Furthermore, a 95% confidence interval was used, meaning that if this research was repeated several times, the true population value would be in the confidence interval 95% of the time.

5.3.2 Critique of Methods Used

Whilst overall this study lends support to the notion that the application of the newly designed software appears to have had a positive impact on the development of letter formation skills, there are limitations to this study, which should be acknowledged when drawing conclusions and when considering the development and use of the software in the future.

This study was a small scale research project involving just fifty pupils from one local primary school and spanned a relatively short time period. Given that the total sample for this research project was drawn from one local primary school, the question remains is this sample typical of the population as a whole or perhaps typical of just a subset of the population? Further, consideration was not given to the previous experiences of the participants in terms of preschool education, namely attendance at playgroup or nursery. Further, although the research incorporated the use of Experimental and Control groups, participants preferably should be assigned at random. As highlighted previously, this was not possible within this study as two existing reception classes within the school were to act as the sample population. However, in general these classes were roughly matched for gender, age and ability and had been assigned randomly at the beginning of the year.

As two distinct reception classes were utilised to act as an Experimental and Control group, this also meant that the groups had two separate class teachers and different support staff. Therefore despite following the same curriculum and using the same schemes of work and resources, with the exception of the intervention, undoubtedly teacher/support staff attributes including personality, teaching style, level of experience and motivation would have impacted upon the children's learning experiences within the study, consequently possibly affecting the results obtained.

In terms of reliability of lateral preference assessment techniques, direct behavioural testing procedures were utilised. As highlighted in 3.4, the screening tool utilised to assess the lateral preferences of the sample population was constructed and applied by drawing upon some of the measures utilised by Coren and Porac (1978). The criteria used for selection for this study included developmentally appropriate tasks with easily observable responses. All behavioural testing was conducted by the researcher herself in an attempt to ensure consistency, and a script was used in an attempt to ensure uniformity of instructions. All items that were part of the laterality assessment were presented to each participant centrally, so as to not favour one side of the body over the other. Despite much consideration being given to the use of reliable techniques to assess lateral preference and these techniques being carried out consistently and as reliably as possible, undoubtedly there is still room for error or inconsistencies.

Within the sets of data collected, use of standardised tests was made wherever possible to permit more reliable comparisons between groups, and between pre and post

measures. However, suitable age appropriate standardised tests were not available for some variables under investigation, therefore in terms of sequencing the alphabet verbally and correct number formation, the number of correct responses were tallied. Due to the fact that in respect of number formation, unlike letter formation, an appropriate standardised test was not available, there was no specific guidance or models available pertaining to what was permissible in terms of the output by the individual; discretion had to be employed in an attempt to ensure consistency and fairness. The lack of specific guidance to which to adhere may however be considered to be a weakness.

Some considerations of improvements to the construction and use of the staff questionnaire have already been discussed. Additional viewpoints may have been expressed if the questionnaire had been less specific or if responses had been collated from staff through a personal interview. More themes may have emerged during an interview session if prompt questions were asked, however the notion of equal opportunities to express views in response to questioning would then be a consideration.

5.4 Further Discussions and Links with Existing Literature

Research in general lends support to the notion that the child's cognitive development is largely dependent on interaction with the environment and the resulting feedback received, and each new step is built on the foundation of past experiences and previous learning. The play based curriculum of the Foundation Stage has enabled young children to experience an enriched environment, predominantly on their own terms and at their own developmental level, with adult support and scaffolding as deemed appropriate to further extend learning, all aspects of learning, including developing the appropriate pre-requisite skills for handwriting.

5.4.1 The use of ICT

Despite the introduction of ICT resources into schools over the past few decades, especially the use of the Interactive White Board (IWB), undoubtedly significantly impacting on the way many teachers teach, although the pupils themselves still seem to have relatively few opportunities within the learning environment for interactive experiences for learning, especially within the pre-school years. Furthermore, some teachers feel that sometimes the learning objectives can become 'lost', whilst using ICT resources. For example, Armstrong et al (2005) investigating the interactions between

students, teachers and technology that occur within the classroom found that at times the fun and gaming element of lessons overtook the learning objectives.

In addition, Kennewell, Tanner, Jones and Beauchamp (2008) concluded from their research that ‘the transformation of pedagogy towards more pupil autonomy and personalization of the learning experience, which the early adopters of ICT envisaged, has not yet been widespread in the UK’ (p. 71). Similarly, Kennewell et al (2008) highlight that, whilst technical interactivity is a valuable feature of ICT resources which can help to motivate learners, they also felt that learning objectives were sometimes not realised due to the student’s drive to obtain the correct responses by whatever means.

The research above highlights the need for clearly defined learning objectives when using ICT with pupils and the importance of close monitoring of pupil activity and progress. Given the age range of the sample population and the intended use of the newly designed software, the current research did not envisage the programme being used for lengthy periods by youngsters individually, but more in keeping with the underpinnings of the Foundation Stage, namely, facilitating the learning of the child within an enriched environment (including the availability of technical interactive learning experiences) along with opportunities for support and direct instruction from adults when appropriate to scaffold and extend learning.

Therefore, referring back to the Welsh Government publication of May 2008 entitled ‘Language, Literacy and Communication Skills’ which supports the notion that children should have plenty of opportunities to mark make and write, coupled with the developmental stages in writing which includes left to right orientation, strangely enough developmentally after attempts to write letters, it is suggested that all young children would benefit from interacting with the environment in activities that encourage the development of these skills. Within this highly technological age, where many young children have easy access to tablets and computers from a very young age, it is believed that educational technology has a role to play in providing some of these experiences.

Furthermore, as exposure to the environment results in stimulation to several different modalities simultaneously, the skill development opportunities must be presented in a format that minimises the effect of component skill immaturity. Therefore, it is postulated that using the newly developed software on a robust, child friendly interactive surface within the Foundation Stage, or even before, would provide young

children with opportunities to practice their early mark making skills, whilst simultaneously and unknowingly developing a sense of left to right orientation with the reinforcement of visual, auditory and tactile stimuli, thus helping to develop those vitally important pre-requisite handwriting skills and handwriting skills themselves.

Through taking this multi-modal learning approach to letter/number formation, via the vehicle of educational technology, incorporating what are considered to be right hemisphere functions (visual, abstract, shapes and patterns), perhaps this helps to redress the imbalance highlighted by Bogen (1975, 1977) that too much emphasis placed on what he terms 'left-hemisphere learning'.

5.4.2 Children with Specific difficulties/disorders

Despite this research yielding no evidence to support the hypothesis that a relationship exists between attainment, in respect of the measures taken, and CLP, there is statistical evidence to support the hypothesis that through the implementation of the newly developed software, some individuals might improve their ability to visualise letters and their motor memory for correct formation. Furthermore, an increase in automaticity; the ability to retrieve and produce letters automatically, may occur. This is evidenced by the fact that during the pre to post intervention period, scores for both the Experimental and Control groups increased in a positive direction, but with significantly greater gains for the Experimental group. The results from the univariate statistics show a significant interaction between Time and Intervention for DV 2; $DV 2 F(1, 48) = 6.488 p = .014$. Sub-groups of children with specific difficulties or who have diagnosed disorders may benefit in particular from access to this software. Although this did not form a specific part of this research, it is considered beneficial to briefly explore this further in order to consider possibilities for future research.

5.4.2.1 Dyslexia

Brief reference was made to dyslexia in 2.5.2, pertaining to Orton's belief that children who displayed dyslexia were also more often left handed or displayed crossed hand-eye dominance, which resulted in some children displaying these characteristics being labelled dyslexic. Dyslexia is generally considered to be a learning difficulty which is characterised by difficulties in phonological awareness, verbal memory and processing speed, however in relation to mirror reversals in writing these may persist longer amongst the sub group highlighted by Orton above. The term 'dyslexia' remains

commonly used but poorly defined; however it is considered to be beyond the scope of this research to explore definitions and suggested root causes. However suffice to say that definitions of dyslexia predominantly make reference to ongoing difficulties with reading and spelling, due to the difficulties highlighted above, but dyslexia is also often characterised by difficulties with writing, including reversals/inversions of letters, and words are frequently written and read backwards.

Indeed, Martlew (1992) in her study comparing 10 year old dyslexic pupils with children of the same chronological age and with younger children of the same spelling age found that the dyslexic pupils had automatised movement patterns that were built on accumulated inaccuracies in both letter formation and spelling. Letter formation inaccuracies coupled with potential difficulties relating to directionality, and more specifically left to right orientation are frequently seen as contributory factors in dyslexia. Difficulties that use of the multi-modal software aims to address.

Children with such difficulties are regularly referred to EPs by school staff and parents in the hope that they can deliver psychological services through a variety of interventions and contexts that will help to promote positive change for the child. Therefore, it is reiterated that it is imperative that EPs have an awareness of the processes involved in the development of writing skills and issues relating to laterality, also sufficient knowledge to advise those concerned how to help address these difficulties, including awareness of appropriate interventions.

5.4.2.2 Developmental Co-ordination disorder (DCD)/clumsy children

Children with motor skills difficulties may present as clumsy, and only a few may have a formal diagnosis of DCD/dyspraxia. It has been suggested (Gibbs, Appleton & Appleton, 2007) that difficulties with motor skills can be considered as being on a continuum, with a larger proportion of children having milder problems than those with greatest difficulty, the latter may also have a formal diagnosis of DCD. There is sparse evidence within research studies relating to the possible association between poorly established laterality/CLP and motor coordination difficulties. However, whatever the cause of the motor coordination difficulties, research highlighted in 2.5.2 suggests that children who are poorly coordinated or who have failed to reach important motor skills milestones are likely to find themselves disadvantaged in the learning environment both socially and academically.

As highlighted in 2.4, motor skills are obviously used in the production of written letters and words, and Chang & Yu (2009) report that poor handwriting has become one of the important diagnostic criteria for DCD. That does not mean to say that all individuals who have poor handwriting have problems with motor control. Indeed, more than half of the participants in the study conducted by Chang and Yu had no evident motor problems as assessed on the Movement ABC (Henderson and Sugden, 1992) and DCDQ. However, there is evidence to suggest that for many children who experience the difficulties with handwriting these children also have lower fine motor ability (Hamstra-Bletz & Blote, 1993; Chang & Yu, 2009). Therefore it would be pertinent to reiterate a point previously made, namely due consideration has to be given to the successful attainment of the pre-requisite skills for letter/number recognition/formation and handwriting to ensure that the most appropriate intervention is provided, which may not be a handwriting intervention programme at all, despite the observed difficulties with handwriting.

Motor skills are used in the production of written letters/numbers which require motor learning. Motor learning, both gross and fine, in relation to letter/number formation can be supported with stimuli from other modalities to aid motor memory for specific letters/numbers. Therefore any intervention to aid handwriting development should take these considerations into account.

5.4.2.3 Sensory Impairment

Although not specifically part of this small scale research project it has been highlighted previously that the hearing and visually impaired population may benefit from access to this software.

To reiterate, as highlighted by Bertelson and De Gelder (2004) in 1.6, within our everyday environment usually stimulation to several modalities occurs simultaneously. When individuals are exposed to specific multi-modal learning experiences, there is the potential for the learner to more easily develop certain skills, even when one mode is less efficient for any reason or fails completely, with perception being facilitated by the other modes.

Therefore for those with a hearing impairment it is hoped that the number of valid co-occurrences will be increased by the visual effects produced by the changing colours

associated with change of direction on the surface of the interactive device along with the tactile effects produced from the fingers touching the surface.

Similarly, for those with a visual impairment it is hoped that the valid number of co-occurrences will be increased by the auditory effects produced by the changing sounds associated with change of direction, so effectively the learner will be able to ‘hear’ letter formation along with the tactile effects produced from the fingers touching the surface.

However, research studies using this specific intervention with different sub-groups of the population would need to be conducted before any conclusions can be drawn.

5.4.2.4 Autism

As highlighted previously, anecdotal evidence suggests that children with autism may perceive colour differently to typically developing children, especially when one considers the behavioural displays in relation to obsessions and particular colours. Franklin, Sowden, Burley, Notman and Alder (2008) conducted research to investigate whether colour perception is atypical in children with autism and found that the findings of two experiments supported the notion of less accurate colour perception amongst this population when compared to matched controls without autism. One possible explanation put forward by the researchers for this is that ‘the difference arises from differences in the anatomical and functional organisation of the brain in autism’ (Franklin et al., 2008). Therefore it is likely for some children on the autistic spectrum at least the colour changing properties of the software would be too subtle to be of benefit in terms of aiding letter/number.

However, past research studies (Plaisted, Swettenam & Rees, 1999; Mottron & Belleville, 1993; Mottron, Belleville & Menard, 1999) have shown that individuals with high functioning autism when compared to control participants, revealed superior performance in pitch processing of auditory stimuli. Therefore it is possible that this sub-group of the population would be more suitably placed to ‘hear’ the letter formation, when using the software. Caution should be adopted however, as presently, the audible sounds associated with movements on the interactive surface are quite ‘tinny’, and may not appeal to some on the autistic spectrum and indeed to some not on the spectrum too.

5.4.2.5 Attention Deficit Hyperactivity Disorder (ADHD)

Rosenblum, Parush, Epstein & Weiss (2003) report that poor handwriting is common among children with Attention Deficit Hyperactivity Disorder and this is supported by research by Tucha, Laufkotter, Mecklinger, Klein & Lange (2001).

Imhof (2004) hypothesised that youngsters with ADHD 'typically have problems to control and fine-tune motor behaviour, which may impede the execution of pertaining tasks, such as handwriting' (p.194). Imhof's study examined the effect of colour stimulation on graphomotor control in children diagnosed with ADHD and found that typical features of handwriting improved amongst the target population with the use of coloured paper. It was concluded that children with ADHD respond to the colour stimulation with improvements in terms of motor processes and attention control. This is in line with the findings of other research studies, namely Iovino, Fletcher, Breitmeyer & Foorman (1998), and Lee & Zentall (2002). Imhof has postulated that 'colour stimulation has an unspecified effect on cortical activation and attention regulation' (p.196). Imhof added that for undiagnosed children with problems in the area of attention regulation and motor timing, colour stimulation may also be beneficial.

Therefore it is possible that the colour changing properties of the software would have a beneficial effect on this sub-group of the population, although use would need to be monitored to ensure that it did not encourage visual hyper-excitability and have an opposite effect. Therefore, once again further research studies using this specific intervention with this sub-group of the population would need to be conducted before any conclusions can be drawn.

Furthermore, there are a number of studies that provide supportive evidence of the comorbidity of DCD and ADHD (Vickers, Rodrigues & Brown, 2002; Norrelgen, Lacerda & Forssberg, 1999; Periera, Eliasson & Forssberg, 2000; Tervo, Azuma, Fogas, Falls & Fiechtner, 2002) and Alloway (2011), with suggestions that the overlap between the two could be as high as 50%.

Within Alloway's study (2011), although presenting symptoms of each sub-group were very different, children with ADHD could not be distinguished from those with DCD in terms of their working memory profile which is characterised by visuo-spatial memory deficits. It is considered by Alloway that disruption to the underlying cognitive mechanisms in each of the sub-groups could result in a similar working memory profile. Furthermore, Alloway highlighted strong evidence in her study to link working memory

skills with learning outcomes. Given these findings, consideration should be given to the possibility that colour stimulation would also be beneficial for those with DCD.

5.4.2.6 Post Traumatic Stress Disorder (PTSD)

Choudhary and O'Carroll (2007) have found an increased prevalence of left handedness and mixed hand preference amongst male combat veterans and children diagnosed with PTSD. Choudhary and O'Carroll highlight in their study that in people diagnosed with PTSD, there is evidence to suggest relative hypoactivation in the left hemisphere of the brain when compared to hyperactivation in the right hemisphere.

Further, Saltzman, Weems, Reiss and Carrion (2006) found increased mixed laterality in traumatised children with PTSD and a correlation between laterality scores and symptom severity, with increasing symptomatology associated with a left hand bias. Laterality measures were confined to handedness within this study and associations with footedness found in the study by Spivak, Segal, Mester & Weizman, 1998, were not found. It is also reported that neither study found any associations between PTSD and eye and ear preference.

Choudhary and O'Carroll (2007) study highlights a relationship between strong left hand preference and increased prevalence of PTSD. This contrasts to the study by Saltzman et al. (2006), whose findings suggest reduced lateralisation in handedness was associated with PTSD.

These findings have an indirect link only to this study but are considered noteworthy in the context of this research. Future researchers in this field might utilise this information to instigate research relating to CLP, learning outcomes and in specific cases associations with PTSD in traumatised children.

CHAPTER 6: CONCLUSIONS

6.1 Overview

This chapter discusses the final conclusions that may be drawn from the findings of this study. Consideration is given to the significance and implications for professional practice, not only in education, but also in terms of the professional practice of educational psychologists.

6.2 Final Conclusions

This study aimed to investigate the prevalence of cross lateral preference amongst primary aged pupils within a local primary school, and whether those individuals identified as displaying cross lateral preference were disadvantaged in the learning environment.

More specifically, this study aimed to explore whether pupils who displayed cross lateral preference experienced greater difficulty in acquiring skills in relation to letter/number recognition and formation.

Furthermore, this study specifically investigated the impact of the use of researcher designed software for a child friendly interactive table to assist all pupils in the development of their motor, visual and auditory memory skills for letters and numbers, including directionality and left to right orientation.

Finally, this study aimed to explore the knowledge and understanding of cross lateral preference amongst teachers/teaching assistants responsible for educating our young.

The findings of this study have suggested that:

- 100% of the total sample population of 4-5year olds were found to display at least some elements of cross lateral preference when both motoric and sensory indices were considered, these figures support the notion that CLP is part of normal development for children of this age,
- there is no evidence to support the hypothesis that a relationship exists between attainment (in respect of the measures taken) and cross lateral preference.
- the intervention with the Experimental group involving the application of the researcher designed software for use with an interactive table, brought about significant improvements in letter formation.
- it is possible that individuals in the Experimental group improved their ability to visualise letters and their motor memory for correct letter formation, resulting in increased automaticity; the ability to retrieve and produce letters automatically.
- the intervention with the Experimental group had no impact on number formation.
- school staff in the sample school have a very limited knowledge of cross lateral preference/mixed dominance. However it is not possible to generalise this finding to other educational establishments with any degree of confidence.

Reflections on these findings leads to some suggested implications for young children, parents and educational professionals listed below. Furthermore, the research has extended existing knowledge in relation to human lateral preference and its impact on learning, and contributes original and new knowledge to the field of educational psychology.

6.3 Practical Implications of Key Findings

6.3.1 In Terms of Children and their Parents

- parents should encourage their children to reach their early motor milestones by ensuring that they are exposed to appropriate opportunities to develop these skills.
- parents should provide their children from a very young age with plenty of opportunities to explore and interact within an enriched environment, appropriate to the child's developmental level.
- parents should encourage their children to involve themselves in developmentally appropriate physical activities to help foster the development of motor skills and lateral preferences.
- children should be encouraged to mark make from an early age.
- parents should promote the development of correct letter formation when teaching their child to write their name, as incorrect formations can become embedded and difficult to undo.

6.3.2 In Terms of Educators of Young Children

- educators to be aware of all the points highlighted in 6.3.1.
- educators to be aware of the importance that young children should be developmentally rather than chronologically ready for writing, by checking that the necessary pre-requisite skills are developed.
- educators should be made increasingly aware of the benefits of multi-modal learning experiences for children.
- educators should ensure that when developmentally ready, children should have access to opportunities to adequately develop their lower level writing skills, including the ability to retrieve and produce letters automatically before being expected to develop higher level writing skills.
- educators to access information/training which highlights the prevalence of cross lateral preference amongst young children, also promoting the fact that CLP is part of normal development for young children, and the trend towards a rightward shift with increased maturity. Information and training should explore the potential difficulties with handwriting around confusion over directionality and

left to right orientation that can occur in any child irrespective of lateral preference.

- educators to be aware of the benefits of the use of educational technology in motivating the learner and the importance of providing interactive experiences for the child.
- educators to be able to experiment with the use of the new software in an attempt to ascertain whether it promotes the development of visual, auditory and motor memory in young children for correct letter formation and helps children avoid confusion over directionality and left to right orientation.

6.3.3 In Terms of the Practice of Educational Psychologists

- EPs to be aware of all the points highlighted in 6.3.1 and 6.3.2.
- EPs to further develop their knowledge of the processes involved in the development of handwriting skills, in order to be able to pinpoint areas of difficulty and to be able to impart sufficient knowledge to advise/address these difficulties.
- EPs will need to integrate an understanding of the developmental and psychological processes underpinning handwriting skills when involved in intervention planning and monitoring, and give due consideration to the practical supports/ technology available within their schools.
- EPs need to give consideration to how educational technology might be used to address some specific difficulties, including those related to laterality, directionality and handwriting.
- EPs need to integrate their knowledge regarding technological advances with practical implications for teaching and learning and disseminate this to the parents and educators of our young.

6.4 Future Research in this Field and Related Fields

The findings from this study predominantly lend support to the relatively few previous research studies in this area. However, there are also some findings that are not in keeping with previous studies. Undoubtedly there is a need for more research into the area of human lateral preference and related fields.

A number of potential research areas have been highlighted already within this study, but for convenience will be summarised below. Furthermore, reflections on and

developments within this study itself has brought new considerations to the forefront, which will also be discussed below.

6.4.1 Summary of potential research areas highlighted previously

The following future research studies are advocated:

- differing methodologies to collect reliable and valid data regarding human lateral preference, particularly in relation to self-report questionnaire versus performance based assessment techniques.
- whether a simple dichotomy right/left is a too insensitive measure when assessing human lateral preference. Consideration to whether a more sensitive measure would yield different results needs to be explored.
- use of a developmental model in terms of assessing CLP in order to gain further insight regarding the effects of maturation and increased unilaterality.
- whether lack of time/opportunity to practise number formation on the interactive programme brought about the lack of statistically significant evidence to support the use of the programme for number formation.
- the awareness of educators of issues relating to human lateral preference and more specifically cross lateral preference as a developmental phenomenon.
- whether specific sub-groups of the population including children diagnosed with dyslexia, developmental coordination disorder, hearing impairment, visual impairment, autism or attention deficit hyperactivity disorder would benefit from accessing the intervention.

6.4.2 Further considerations

- It would be helpful to repeat the laterality assessment with the sample population over regular time intervals in an attempt to monitor whether there is a right-ward shift and greater congruence with increased maturity as suggested by related studies.
- It would be prudent to repeat the study, preferably with a larger sample drawn from a number of different schools, in order to discover if the results from this study can be replicated. Furthermore, it would be helpful to test the software by manipulating the variables e.g. experiment with different age groups, allow pupils more time to use the software, especially in relation to number formation

and by applying more strict control over the variables in an attempt to achieve more specific findings.

- Improvements to the software will be considered especially in terms of softer, more pleasant auditory stimuli and more distinct colour changes to provide greater clarity to the visual stimuli, in an attempt to provide a more unique ‘multi-modal signature’ for each letter and number.
- It may be beneficial to introduce young children, including pre-school children to the software so that from some of their earliest mark making experiences they can start to ‘listen’ to directionality and gradually progress to becoming familiar with the unique ‘multi-modal signatures’ of letters and perhaps numbers, in an attempt to ensure correct formation.
- There is some evidence available to suggest that a relationship does exist between brain development and environmental factors in the learning process, with the brain remaining malleable in at least some areas right through to adulthood. Specific interventions have been shown to bring about neurological changes; therefore it is entirely possible that the use of this intervention will bring about such changes.
- Colour changes have been successfully incorporated into the use of some every day appliances including irons and kettles; sometimes coupled with auditory signals. Therefore there is no reason why this technology cannot be successfully modified to provide learning opportunities for children.
- A most useful extension to this study would be to utilise the digitizer-based evaluation tool as part of the pre and post intervention measures in an attempt to evaluate any changes in the amount of ‘in air’ time.

6.5 Final Reflections

There is evidence to support the notion that the use of educational technology can be used appropriately to enhance learning and provide learning opportunities otherwise not available to children and young people. However, all too frequently educational software is developed by commercial companies and designed to meet a niche in the market, usually for financial gain without regard to research. This research study came about as a result of a practising educational psychologist recognising the need for educational software to help address specific issues frequently encountered in her practise, namely that of confused laterality and directionality. An attempt has been made

to be proactive, hence commissioning the development of educational software and piloting its use amongst a sample population. The early indication of its use from the standpoint of letter formation does require further research, but initial findings are considered to be promising.

Therefore, in this ever increasing technological age, with increasing numbers of mobile interactive devices, the time is ripe to utilise this technology to enhance the development of a more traditional skill that is still essential within today's society.

To conclude a very useful quote Feder & Majnemer (2007, p.316)

‘Handwriting competency is not only important for academic success at school age, but it is a critical skill throughout adulthood.....It is especially important that health practitioners and educators appreciate the far reaching academic and psychosocial consequences of poor writing. This immediate form of communication continues to be an essential skill both inside and outside the classroom, despite the widespread use of technological devices’.

REFERENCES

- Alloway, T. P. (2011). A Comparison of working memory profiles in children with ADHD and DCD. *Child Neuropsychology*, 17(5), 483-494.
- Annett, M. (1970). A classification of handpreference by association analysis. *British Journal of Psychology*, 61, 303-321.
- Annett, M. & Alexander, M. P. (1996). Atypical Cerebral Dominance: Predictions and Tests of the Right Shift Theory. *Neuropsychologia*, 34, 1215-1227.
- Armstrong, V., Barnes, S., Sutherland, R., Curran, S., Mills, S., & Thompson, I. (2005). Collaborative research methodology for investigating teaching and learning: the use of interactive whiteboard technology. *Educational Review*, 59 (4).
- Bakan, P., Dibb, G., & Reed, P. (1973). Handedness and birth stress. *Neuropsychologia*. 11(3), 363-366.
- Barker, C., Pistrang, N., & Elliot, R. (2002). *Research Methods in Clinical Psychology* (Vol. 2). Sussex: John Wiley & Sons, Ltd.
- Beaton, A. A. (1985). *Left Side Right Side*. London: B. T. Batsford Ltd.

- Beaton, A. A. (2004). The Nature and Determinants of Handedness. In Hugdahl, K. & Davidson, R. J. (Eds.), *The Asymmetrical Brain*. London: MIT Press.
- Beeland, W. (2002). Student Engagement, Visual Learning and Technology: Can Interactive Whiteboards Help? *Action Research Exchange*, retrieved March 27, 2012 from http://chiron.valdosta.edu/are/Artmanscript/vol1/no1beeland_am.pdf.
- Beery, E. K. (1997). *The Beery-Buktenica Developmental Test of Visual-Motor Integration: Administration, Scoring and Teaching Manual, 4th Edition*. Parsippany, NJ: Modern Curriculum Press.
- Berninger, V. W., & Hart, T. M. (1992). A Developmental Neuropsychological Perspective For Reading and Writing Acquisition. *Educational Psychologist*, 27(4), 415-434.
- Berninger, V. W., & Shaywitz, B. A. (2006). Inroduction to the Special Issue. *Developmental Neuropsychology*, 30(1), 527-530.
- Berninger, V.W., & Swanson, H. L. (1994).Modifying Hayes and Flower’s model of skilled writing to explain beginning and developing writers. In Carlson, J.S. (Series Ed.) & Butterfield, E.C. (Vol. Ed.), *Advances in cognition and educational practice: Vol 2 Children’s writing: Towards a process theory of the development of skilled writing*. 57-81. Greenwich, CT: JAI
- Bertelson, P., & De Gelder, B. (Eds.). (2004). *The Psychology of Multimodal Perception*. Oxford: Oxford University Press.
- Bishop, D. V. M. (1990). *Handedness and Developmental Disorder*. Oxford: Blackwell Scientific Publications Ltd.
- Bogen, J.E. (1975). Some educational aspects of hemispheric specialization. *UCLA Educator*, 17, 24-32.
- Bogen, J. E. (1977). Some educational implications of hemispheric specialization. In Wittrock, M. C. (Ed.). *The Human Brain*. Englewood Cliffs:Prentice-Hall.
- Bond, C., Cole, M., Fletcher, J., Noble, J., & O’Connell, M. (2011). Developing and sustaining provision for children with motor skills difficulties in schools: the role of educational psychologists. *Educational Psychology In Practice*, 27(4), 337-351.
- Bonnel, A., Mottron, L., Peretz, I., Trudel, M., Gallun, E., & Bonnel, A. (2003). Enhanced Pitch Sensitivity on Individuals with Autism: A Signal Detection Analysis. *Journal of Cognitive Neuroscience*, 15(2), 226-235.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Research in Psychology*, 3(2), 77-101.
- Briggs, M. P., Nebes, R. D. (1975). Patterns of hand preference in a student population. *Cortex*, 12, 230-238.

- Brito, G. N. O. & Santos-Morales, T.R. (1999). Lateral Preference in 8- to 15- Year Old Brazilian Children Assessed With the Edinburgh Inventory: Different Measures of Handedness and Comparison With Younger Children and Adults. *Developmental Neuropsychology*, *16*(3), 433-454.
- Bronfenbrenner, U. (1979). *The Ecology of Human Development*. United States of America: Harvard University Press.
- Brown, E. R., & Taylor, P. J. (1988). Handedness, footedness and eyedness. *Perceptual and Motor Skills*, *66*, 183-186.
- Cameron, R. J. (2006). Educational Psychology: The Distinctive Contribution. *Educational Psychology in Practice*, *22*(4), 289-304.
- Campbell, D. T., & Stanley, J. C. (1963). Experimental and Quasi-Experimental Designs for Research on Teaching. In Gage, N. L. (Ed.), *Handbook on Research on Teaching*. Chicago: Rand McNally and Co..
- Chambers, M., & Sugden, D. (2006). *Early Years Movement Skills. Description, Diagnosis and Intervention*. London: Whurr Publishers.
- Chang, S., & Yu, N. (2010). Characterization of motor control in handwriting difficulties in children with or without developmental coordination disorder. *Developmental Medicine & Child Neurology*, *52*, 244-250.
- Choudary, C., & O'Carroll, R. E. (2007). Left Hand Preference is Related to Posttraumatic Stress Disorder. *Journal of Traumatic Stress*, *20*(3), 365-369.
- Claxton, G. (1999). *Wise Up. The Challenge of Lifelong Learning*. London: Bloomsbury.
- Corballis, M. C., & Beale, I. L. (1976). *The Psychology of Left and Right*. Oxford. Blackwell Publishing.
- Coren, S., & Kaplan, C. P. (1973). Patterns of ocular dominance. *American Journal of Optometry and archives of the American Academy of Optometry*, *50* (4), 283-292.
- Coren, S., & Porac, C. (1977). Fifty centuries of right handedness: The historical record. *Science*, *198*, (4317), 631-636.
- Coren, S., & Porac, C. (1978). The Validity and Reliability of self-report items for the measurement of lateral preference. *British Journal of Psychology* (69), 207-211.
- Coren, S., & Porac, C. (1981). *Lateral preferences and human behaviour*. New York: Springer-Verlag.
- Coren, S., Porac, C., & Duncan, P. (1979). A behaviourally validated self report inventory to assess four types of lateral preference. *Journal of Clinical Neuropsychology*, *1*, 55-64.

- Coren, S., Porac, C., & Duncan, P. (1981). Lateral Preference Behaviours in Preschool Children and Young Adults. *Child Development*, 52, 443-450.
- Cornhill, H., & Case-Smith, J. (1996). Factors that relate to good and poor Handwriting. *American Journal of Occupational Therapy*, 50, 732-739.
- Crovitz, H.F. & Zener, K. (1962). A group-test for assessing hand- and eye-dominance. *American Journal of Psychology*, 75, 271-276.
- Crow, T.J., Crow, L. R., Done, D.J., & Leask, S. (1998). Relative hand skill predicts academic ability: Global deficits at the point of hemispheric indecision. *Neuropsychologia*, 36, 1275-1282.
- Cytowic, R.E. (2002). *Synesthesia: A Union of the Senses*. 2nd Ed. Massachusetts Institute of Technology.
- Davidoff, J. (1991). *Cognition through colour*. Cambridge, MA: MIT Press.
- Davidoff, J. (1997). Higher-level cortical processing of colour. *Acta Psychologica*, 97, 1-6.
- De Agostini, M., & Dellatolas, G. (2001). Laterality in Normal Children Ages 3 to 8 and Their Role in Cognitive Performances. *Developmental Neuropsychology*, 20(1), 429-444.
- Department for Children, Education, Lifelong Learning and Skills. (2008). *Language, Literacy and Communication Skills*. Cardiff: DCELLS.
- Department for Children, Education, Lifelong Learning and Skills. (2010). *Guidance in the teaching in writing skills*. Cardiff: DCELLS.
- Desai, A. S., & Rege, P.V. (2005). Correlation between developmental test of visual motor integration [VMI] and handwriting in cerebral palsy children. *The Indian Journal of Occupational Therapy*, 37(2), 27-32.
- Dinsdale, N. L., Reddon, A.R., Hurd, P.L. (2011). Sex differences in the relationship between aggressiveness and the strength of handedness in humans. *Laterality*, 16 (4), 385-400.
- Donaldson, M. (1978). *Children's Minds*. London: Fontana.
- Dunsmuir, S., & Clifford, V. (2003). Children's Writing and the Use of Information and Communications Technology. *Educational Psychology in Practice*, 19(3), 171-187.
- Elkind, D. (1986). Formal Education and Early Childhood Education: An Essential Difference', *Phi Delta Kappa*, 67 (9), 631-636.
- European Agency for Developments in Special Needs Education. (2001). *Information and Communication Technology in Special Needs Education: recent developments in 17 European countries*. Denmark. Middelfart.

- Fair, D.A., Brown, T.T., Petersen, S.E., & Schlaggar, B.L. (2006). A Comparison of Analysis of Variance and Correlation Methods for Investigating Cognitive Development With Functional Magnetic Resonance Imaging. *Neuropsychology*, *30* (1), 531-546.
- Farrell, P., Woods, K., Lewis, S., Rooney, S., Squires, G., & O'Connor, M. (2006). *A review of the functions and contributions of educational psychologists in England and Wales in light of 'Every child matters': Change for children*. London: DFES.
- Feder, K. P., & Majnemer, A. (2007). Handwriting development, competency, and intervention. *Developmental Medicine & Child Neurology*, *49*, 312-317.
- Feder, J.J., & Weber, C.K. (1986). Remedies for reversals. *Academic Therapy*, *22*, 87-90.
- Felzman, H. (2009). Ethical issues in school-based research. *Research Ethics Review*, *5*(3), 104-109.
- Fife-Shaw, C. (2012). Introduction to Quantitative Research. In Breakwell, G. M., Smith, J. A., & Wright, D. B. (Eds.). *Research Methods in Psychology*. London: Sage.
- Franklin, A., Sowden, P., Burley, R., Notman, L., & Alder, E. (2008). Color Perception in Children with Autism. *Journal of Autism Developmental Disorder*, *38* 1837-1847.
- Furner, B. (1985). *Handwriting instruction for a high-tech society: Will handwriting be necessary?* Report No. CS208970.
- Galanis, J. (2008). *The Effect of Handwriting Without Tears Program on Student Cursive Writing Achievement at Central Institute for the Deaf*. Washington: University School of Medicine.
- Gegenfurtner, K. R., & Rieger, J. (2000). Sensory and cognitive contributions of colour to the recognition of natural scenes. *Current Biology*, *10*, 805-806.
- Geschwind, N., & Galaburda, N. (1987). *Cerebral Lateralization: Biological Mechanisms, Associations and Pathology*. Cambridge, MA:MIT Press.
- Geschwind, N., & Behan, P. (1982). Left-handedness: Association with immune disease, migraine, and developmental learning disorder. *Proceedings of the National Academy of Sciences, USA*, *79*, 5097-5100.
- Gibbs, J., Appleton, J., & Appleton, R., (2007). Dyspraxia or developmental coordination disorder? Unravelling the enigma. *Archive of Diseases in Childhood*, *92*, 534-539.
- Graham, S. (1986). A review of handwriting scales and factors that contribute to variability in handwriting scores. *Journal of School Psychology*, *24*, 63-72.
- Graham, S., Berninger, V. W., & Weintraub, N. (1998). The Relationship Between Handwriting Style and Speed and Legibility. *Journal of Educational Research*, *91*(5),7.

- Graham, S., Harris, K.R., & Fink, B. (2000). Extra handwriting instruction: prevent writing difficulties right from the start. *Teaching Exceptional Children*, 33, 88-92.
- Graham, S., & Weintraub, N. (1996). A review of handwriting research: Progress and prospects from 1980 to 1994. *Educational Psychology Review*, 8, 7-87.
- Gray, J. W., Dean, R. S., & Seretny, M.L. (1986). Lateral Preference as a Predictor of Cognitive Rigidity. *Journal of Clinical Psychology*, 42(6), 956-961.
- Greenough, W. T., Black, J. E. & Wallace, C. S. (1987). Experience and brain development. *Child Development*, 5, 539-559.
- Hagtvet, B. E. (1993). From oral to written language: a developmental and interventional perspective. *European Journal of Psychology of Education*, 8 (3), 205-220 in Dunsmuir, S., & Clifford, V. (2003). Children's Writing and the Use of Information and Communications Technology. *Educational Psychology in Practice*, 19(3), 171-187.
- Halsey, J.H., Blaunstein, U. W., Wilson, E. W. & Wills, E. H. (1979). Regional cerebral blood flow comparison of right and left hand movement. *Neurology*, 29, 21-29.
- Hamstra-Bletz, L., & Blote, A. W. (1993). A Longitude Study on Dysgraphic Handwriting in Primary School. *Journal of Learning Disabilities*, 26(10), 689-699.
- Hayes, N. (2000). *Doing Psychological Research*. Buckingham: Open University Press.
- Heaton, P., Hermelin, B., & Pring, L. (1998). Autism and pitch processing: A precursor for savant musical ability? *Music Perception*, 15, 291-305.
- Hellige, J.B. (1993; 2001). *Hemispheric Asymmetry: What's Right and What's Left*. Cambridge: Harvard University Press.
- Hellige, J. B. (2006). Evolution of Brain Lateralization in Humans. *Cognitive, Brain, Behavior*, 10, 211-234.
- Henderson, S. E., & Sugden, D. A. (1992). *The Movement ABC Battery for Children*: Psychological Corporation.
- Hole, G. (2012). Experimental Design. In Breakwell, G. M., Smith, J. A., & Wright, D. B. (Eds.). *Research Methods in Psychology*. London; Sage.
- Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6, 65-70.
- Iaccino, J. F. (1993). *LEFT-BRAIN RIGHT-BRAIN DIFFERENCES Inquiries, Evidence, and New Approaches*. London: Lawrence Erlbaum Associates, Inc.
- Imhof, M. (2004). Effects of color stimulation on handwriting performance on children with ADHD without and with additional learning disabilities. *European Child & Adolescent Psychiatry*, 13, 191-198.

- Iovino, I., Fletcher, J. M., Breitmeyer, B. G. & Foorman, B.R. (1998). Coloured overlays for visual perceptual deficits in children with reading disability and attention deficit/hyperactivity disorder: are they differentially effective? *Journal of Clinical Experimental Neuropsychology*, 20, 791-806.
- Kaminsky, S., & Powers, R. (1981). Remediation of handwriting difficulties. A practical approach. *Academic Therapy*, 17, 19-25.
- Katz, L.G. (1998). 'Introduction: What is basic for Young Children', in S. Smidt (ed.), *The Early Years: A Reader*, London: Routledge.
- Kaufman, A.S., Zalma, R., & Kaufman, N. L. (1978). The relationship of hand dominance to the motor-co-ordination, mental ability and right-left awareness of young normal children. *Child Development*, 49, 885-888.
- Kennewell, S., Tanner, H., Jones, S., & Beauchamp, G. (2008). Analysing the use of interactive technology to implement interactive teaching. *Journal of Computer Assisted Learning*, 24(1)1, 61-73.
- Kershner, J. R. (2001). Reading and Laterality Revisited. *The Journal of Special Education*, 9(3), 271-279.
- Lavidor, M., Hayes, M. & Bailey, P.J. (2003). Handedness, measures of hemispheric asymmetry and lateralised lexical decision. *Laterality*.8(4), 347-361.
- Lee, D. L. & Zentall, S. S. (2002). The effects of visual stimulation on the mathematics performance of children with Attention Deficit/Hyperactivity Disorder. *Behaviour Disorders*, 27, 272-288.
- Levy, J. (1977). The mammalian brain and the adaptive advantage of cerebral asymmetry. *Annals of the New York Academy of Sciences*, 299, 264-272.
- Levy, J., & Nagylaki, T. (1972). A model for the genetics of handedness. *Genetics*, 72, 117-128.
- Liepmann, H., & Mass, O., (1907). Fall Von Linksseitiger, Agraphie und Apraxie bei rechtsseitiger Lahmung. *Journal of Psychology and Neurology*, 10, 214-227 in Beaton, A. A. (2004). The Nature and Determinants of Handedness. In Hugdahl, K. & Davidson, R. J. (Eds.), *The Asymmetrical Brain*. London: MIT Press.
- Lloyd-Jones, T., & Nakabayashi, K. (2009). Independent effects of colour on object identification and memory. *The Quarterly Journal of Experimental Psychology*, 62(2), 310-322.
- Luria, A.R. (1973). *The working brain: An introduction to neuropsychology*. London: Allen Lane, The Penguin Press.
- Macleod, I., & Lally, M. (1981). 'The effectiveness of computer controlled feedback in handwriting instruction', in Roberts, G., & Samuels, M. (1993). Handwriting

- Remediation: A Comparison of Computer-Based and Traditional Approaches. *Journal of Educational Research*, 87(2), 118-125.
- Maeland, A. F. (1992). Handwriting and perceptual-motor skills in clumsy, dysgraphic and 'normal' children. *Perceptual and Motor Skills*, 75, 1207-1217.
- Mandal, M., Pandey, G., Singh, S., & Asthana, H. (1991). Degrees of Asymmetry in Lateral Preferences: Eye, Foot, Ear. *The Journal of Psychology*, 126(2), 155-162.
- Marr, D., & Cermak, S. (2003). Consistency of Handwriting in Early Elementary Students. *The American Journal of Occupational Therapy*. 57 (2), 161-167.
- Martlewm, M. (1992). Handwriting and Spelling: Dyslexic Children's Abilities Compared with Children of the same Chronological Age and Younger Children of the Same Spelling Level. *British Journal of Educational Psychology*, 62(3), 375-390.
- McCarthy, D. (1972). *Manual for the McCarthy Scales of Children's Abilities*. New York: Psychological Corporation.
- McGurk, H., McDonald, J. Hearing lips and seeing voices. *Nature*. 264(5588), 746-748.
- McManus, I. C. (1976). Scrotal asymmetry in man and ancient sculpture. *Nature*, 259, 426.
- McManus, C., Nicholls, M., & Vallortigara, G. (2009). Is LRRTM1 the gene for handedness? *Laterality*, 14 (1),1-2.
- Meadows, S. (1993). *The Child as Thinker*. London: Routledge.
- Modlinger, I. (1983). *Disorders of written language: Diagnosis and remedial teaching*. Tel Aviv: Sifriyat Hapoalim.
- Mottron, L., & Belleville, S. (1993). A study of perceptual analysis in a high-level autism subject with exceptional graphic abilities. *Brain and Cognition*, 23, 279-309.
- Mottron, l., Belleville, S., & Menard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: Perceptual hierarchization or working memory deficit? *Journal of Child Psychology and Psychiatry*, 40, 743-755.
- Mottron, L., Peretz, L., & Menard, E. (2000). Local and global processing of music in high-functioning persons with autism: Beyond central coherence? *Journal of Child Psychology and Psychiatry*, 41, 1057-1065.
- Norrelgen, F., Lacerda, F. & Forssberg, H. (1999). Speech discrimination and phonological working memory in children with ADHD. *Developmental Medicine and Child Neurology*, 41, 335-339.
- Nutbrown, C. (2012). *Review of Early Education and Childcare Qualifications: Interim Report*. www.education.gov.uk/publications

- O'Connor, T.G., Bredenkamp, D., & Rutter, M. (1999). Attachment disturbances and disorders in children exposed to early severe deprivation. *Infant Mental Health Journal*, 20 (10), 10-29.
- OECD, (2010). PISA 2009 Results: Executive Summary.
- Olsen, J. (1999). *Handwriting Without Tears*
- Obrzut, G. C., & Hynd, G. (Eds.). (1986). *Child neuropsychology*. (Vol 1-2). New York: Academic.
- Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97-113.
- Orton, S. (1937). Reading, writing and speech problems in children. New York. Norton in *The American Journal of Psychiatry*, 94 (3), 749-753.
- Papousek, I., & Schulte, G. (1999). Quantitative Assessment of Five Behavioural Laterality Measures: Distributions of Scores and Intercorrelations Among Right-handers. *Laterality*, 4 (4), 345-362.
- Parliamentary Office of Science and Technology. (2000). *Early Years Learning, POST 140*. London: POST.
- Pereira, H.S., Eliasson, A.C., & Forssberg, H. (2000). Neural control of precision grip lifts in children with ADHD and anxiety in boys: Results from a family study. *Journal of the American Academy of Child and Adolescent Psychiatry*, 35, 988-996.
- Perneger, T.V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal*, 316, 1236-1238.
- Piaget, J. (1953). *The Origin of Intelligence in the Child*. London: Routledge and Kegan Paul.
- Plaisted, K., Swettenham, J., & Rees, L. (1999). Children with autism show local precedence in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry*, 40, 733-742.
- Porac, C., & Coren, S. (1975). Is eye dominance a part of generalized laterality? *Perceptual and Motor Skills*, 40, 363-769.
- Porac, C., & Coren, S. (1976). The Dominant Eye. *Psychological Bulletin*, 83 (5), 880-897.
- Porac, C., & Coren, S. (1979). Monocular asymmetries in recognition after an eye movement: sighting dominance and dextrality. *Perception and psychophysics*, 25, 55-59.
- Pound, L. (2005). *How Children Learn*. London: Step Forward Publishing.

- Price, C. J., & Humphreys, G. W. (1989). The effects of surface detail on object categorisation and naming. *Quarterly Journal of Experimental Psychology*, 41A, 797-828.
- Raymond, M., & Pontier, D. (2004). Is there geographical variation in human handedness? *Laterality*, 9(1), 35-51.
- Reis, E. M. (1990). Multisensory approaches for teaching handwriting to learning-disabled children. *Journal of Instructional Psychology*, 17(4), 190-194.
- Rice, W. R. (1989). Analyzing tables of statistical tests. *Evolution*, 43, 223-225.
- Reuter-Lorenz, P.A. & Miller, A.C. (1998). *Current Directions in Psychological Science*, 7(1), 15-20.
- Roberts, G., & Samuels, M. (1993). Handwriting Remediation: A Comparison of Computer-Based and Traditional Approaches. *Journal of Educational Research*, 87(2), 118-125.
- Rogers, L. J. (1980). Lateralization in the avian brain. *Bird Behaviour*, 2, 1-12.
- Rosenblum, S., & Livnah-Zirinski, M. (2008). Handwriting process and the product characteristics of children diagnosed with developmental coordination disorder. *Human Movement Science*, 27, 200-214.
- Rosenblum, S., Parush, S., Epstein, L., & Weiss, P. (2003). *Process versus product evaluation of poor handwriting among children with developmental dysgraphia and ADHD*. Paper presented at the Proceedings of the 11th Conference of the International Graphonomics Society.
- Rosenblum, S., Parush, S., & Weiss, P. (2003). Computerized Temporal Handwriting Characteristics of Proficient and Non-Proficient Hand-Writers. *The American Journal of Occupational Therapy*, 57(2), 129-138.
- Rosenblum, S., Weiss, P., & Parush, S. (2003). Product and Process Evaluation of Handwriting Difficulties. *Educational Psychology Review*, 15(1), 41-81.
- Rubin, N., & Henderson, S. E. (1982). Two sides of the same coin: Variation in teaching methods and failure to learn to write. *Special Education: Forward Trends*, 9, 17-24.
- Saltzman, K.M., Weems, C.F., Reiss, A.L., & Carrion, V.G. (2006). Mixed Lateral Preference in Posttraumatic Stress Disorder. *The Journal of Nervous and Mental Disease*, 194, 142-144.
- Sanghavi, R., & Kelkar, R. (2005). Visual-motor integration and learning disabled children. *The Indian Journal of Occupational Therapy*, 37(2), 33-38.
- Sassoon, R. (2002). *Unlocking Writing A Guide for Teachers*. London: David Fulton Publishers Ltd.

- Sassoon, R. (2003). *Handwriting* (Second ed.). London: Paul Chapman Publishing.
- Scardamailia, M., Bereiter, C., & Goleman, H. (1982). The role of production factors in writing ability. In Nystrand, M. (Ed.). *What Writers Know: The Language Process and Structure of Written Discourse*. New York: Academic Press. 173-210.
- Schwartz, M. (1988). Handedness, prenatal stress, and pregnancy complications. *Neuropsychologia*, 15, 341-344.
- Shaywitz, B. A., Lyon, G. R., & Shaywitz, S.E. (2006). The role of functional magnetic resonance imaging in understanding reading and dyslexia. *Developmental Neuropsychology*, 30 (1), 613-632.
- Silverman, L. (2003). *Upside-Down Brilliance: The Visual Spatial Learner*. Denver: DeLeon Publishing.
- Smidt, S. (2007). *A guide to early years practice (3rd edition)*. London: Routledge, Taylor and Francis Group.
- Smits-Engelsman, B. C. M., Van-Galen, G. P., & Michelis, C. G. J. (1995). Prevalence of poor handwriting and the validity of estimation of motor proficiency and handwriting performance by teachers. *Tijdschrift voor Onderwijsresearch*, 20, 1-15.
- Smilansky, S. (1990). Sociodramatic Play: Its Relevance to Behaviour and Achievement in School, in Klugman, E. and Smilansky, S. (eds) *Children's Play and Learning: Perspectives and Policy Implications*. New York: Teachers College Press.
- Sonuga-Barke, E. J. S. (2003). On the Intersection Between ADHD and DCD: The DAMP Hypothesis. *Child and Adolescent Mental Health*, 8(3), 114-116.
- Sovik, N., Arntzen, O. (1991). A developmental study of the relation between the movement patterns in letter combinations (words) and writing. In Wann, J., Wing, A.M., & Sovik, N. (Eds.). *Development of graphic skills: Research perspective and educational implications*. New York: Academic Press.
- Spence, C., & Driver, J. (2004). *Crossmodal space and crossmodal attention*. Oxford: Oxford University Press.
- Spence, I., Wong, P., Rusan, M., & Rastegar, N. (2006). How Colour Enhances Visual Memory for Natural Scenes. *Psychological Science*. 17(1), 1-6.
- Spivak, B., Segal, M., Mester, R., & Weizman, A. (1998). Lateral preference in post-traumatic stress disorder. *Psychological Medicine*, 28, 229-232.
- Springer, S. P., & Deutsch, G. (1998). *Left BRAIN Right BRAIN* (Fifth ed.). New York: W. H. Freeman and Company.
- Stix, G. (2011). How to Build a Better Learner. *Scientific American*, 305(2), 50-57.

- Suzuki, K., & takahashi, R. (1997). Effectiveness of colour in picture recognition memory. *Japanese Psychological Research*, 39,25-32.
- Tammet, D. (2012). *Thinking in Numbers. How Maths Illuminates Our Lives*. London: Hodder & Stroughton Ltd..
- Tan, L. E. (1985). Laterality and Motor Skills in Four-Year-Olds. *Child Development*, 56, 119-124.
- Tanaka, J. W., Weiskopf, D., & Williams, P. (2001). The role of colour in high-level vision. *Trends in Cognitive Sciences*, 5, 211-215.
- Tao, S. & Walsh, C.A. (2006). Molecular approaches to brain asymmetry and handedness. *Nature Reviews Neuroscience*, 7(8), 655-662.
- Tervo, R. C. Azuma, S., Fogas, B., Falls, S., & Fiechtner, H. (2002). Children with ADHD and motor dysfunction compared with children with ADHD only. *Developmental Medicine and Child Neurology*, 44,383-390.
- Tindal, G., & Hasbrouck, J. (1991). Analyzing student writing to develop instructional strategies. *Learning Disabilities Research and Practice*, 6 (4), 237-245.
- Tucha, O., Laufkotter, R., Mecklinger, L., Klein, H., & Lange, K. (2001). handwriting of adult patients with attention deficit hyperactivity disorder. In Meulenbrock, R.G.J. & Steenbergen, B. (Eds.). *Proceedings of the Tenth biennial conference of the International Graphonomics Society*. 58-62. The Netherlands, University of Nijmegen: IGS Pub.
- Van Agtmael, T., Forrest, S. M. & Williamson, R. (2001). Genes for left-handers: How to search for the needle in the haystack? *Laterality*, 6(2), 149-164.
- Van Galen, G. P. (1991). Handwriting: Issues for a psychomotor theory. *Human Movement Science*, 10, 165-191.
- Van Strien, J. W. (2002). *The Dutch Handedness Questionnaire*. Erasmus University Rotterdam.
- Vernon, D., & Lloyd-Jones, T. J. (2003). The role of colour in implicit and explicit memory performance. *The Quarterly Journal of Experimental Psychology*, 56A(5), 779-802.
- Vickers, J. N., Rodrigues, S. T., & Brown, L. N. (2002). Gaze pursuit and arm control of adolescent males diagnosed with attention deficit hyperactivity disorder (ADHD) and normal controls: Evidence of a dissociation in processing visual information of short and long duration. *Journal of Sports Sciences*, 20, 201-216.
- Volman, M. J. M., van Schendel, B. M., & Jongmans, M. J. (2006). Handwriting Difficulties in Primary School Children: A Search for Underlying Mechanisms. *The American Journal of Occupational Therapy*, 60(4).

- Walker, S.F. (1980). Lateralisation of functions in the vertebrate brain: A review. *British Journal of Psychology*, *71*, 329-367.
- Walker, P., & Hinkley, L. (2003). Visual memory for shape-colour conjunctions utilizes structural descriptions of letter shape. *Visual Cognition*, *10*(8), 987-1000.
- Ward, J. P., & Cantalupo, C. (1997). Origins and Functions of Laterality: Interactions of Motoric Systems. *Laterality A Special Issue*, *2*(3/4), 25.
- Warren, J. M. (1980). Handedness and laterality in humans and other animals. *Physiological Psychology*, *8*, 351-359.
- Wechsler, D. (2001). *Wechsler Individual Achievement Test-Second Edition (WIAT-II)*: Psychological Corporation.
- Wernicke, C. (1874). *Der aphasische symptomkomplex*. Breslau, Germany: Cohn Weigert.
- Whittington, J. E., & Richards, P. N. (1987). The stability of children's laterality preferences and their relationship to measures of performance. *British Journal of Educational Psychology*, *57*, 45-55
- Wichmann, F. A., Sharpe, L.T., & Gegenfurtner, K.R. (2002). The contributions of colour to recognition memory for natural scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 509-520.
- Willats, J. (1985). Drawing systems revisited: the role of denotation systems in children's figure drawings. In Freeman, N. H., & Cox, M. V., (Eds.). *Visual Order: The nature and Development of Pictorial Representation*. Cambridge. Cambridge University Press.
- Wippich, W., & Mecklenbrauker, S. (1998). Effects of colour on perceptual and conceptual tests of implicit memory. *Psychological Research*, *61*, 285-294.
- Wood, E., & Attfield, J. (2005a). *Early Childhood Curriculum* (Second ed.). London: Paul Chapman Publishing.
- Wood, E., & Attfield, J. (2005b). *Play, Learning and the Early Childhood Curriculum* (Second ed.). London: Paul Chapman Publishing.
- Zaidel, E., Iacoboni, M. (Eds.) (2003). *The parallel brain: The cognitive neuroscience of the corpus callosum*. Cambridge: MIT Press.
- Zentall, S. S., Zentall, T. R. (1983). Optimal stimulation: a model of disordered activity and performance in normal and deviant children. *Psychology Bulletin*, *94*, 446-471.

LIST OF APPENDICES

<u>Appendix A:</u> Gate-keeper letter to Head Teacher.....	146
<u>Appendix B:</u> WIAT-11 (UK) description of sub-tests administered.....	149
<u>Appendix C:</u> Initial letter to parents.....	150
<u>Appendix D:</u> Pupil consent form.....	152
<u>Appendix E:</u> Debriefing script for pupils following initial screen.....	155
<u>Appendix F:</u> Debriefing script for pupils following administration of WIAT-11(UK) sub-tests.....	156
<u>Appendix G:</u> Information regarding specialist equipment required.....	157
<u>Appendix H:</u> Information sheet for school staff.....	159
<u>Appendix I:</u> Staff consent form.....	160
<u>Appendix J:</u> Teacher and support staff questionnaire.....	161

<u>Appendix K: Debriefing letter to parents</u>	165
--	-----

Appendix L: Raw Data

- **Table A.1 Showing Lateral Preferences of the Experimental Group**.....167
- **Table A.2 Showing Lateral Preferences of the Control Group**.....168
- **Table A.3 Showing Pre-Intervention Scores on WIAT-11uk Sub-tests for Experimental Group**.....169
- **Table A.4 Showing Post-Intervention Scores on WIAT-11uk Sub-tests for Experimental Group**.....170
- **Table A.5 Showing Pre-Intervention Scores on WIAT-11uk Sub-tests for Control Group**.....171
- **Table A.6 Showing Post-Intervention Scores on WIAT-11uk Sub-tests for Control Group**.....172

<u>Appendix M: Interactive table software</u>	USB
--	-----

Appendix A: Gate-keeper letter to Head teacher

Dear Head Teacher,

I am a fully qualified, Chartered Educational Psychologist and Doctorate student in the School of Psychology at Cardiff University. As part of my degree I am required to carry out a piece of research and I am writing to enquire whether you would be interested in /willing to allow me to carry out this research with pupils in your school.

The title of my research is '*Does the use of educational technology and multi-modal learning experiences assist children in the development of early letter formation and handwriting skills, especially those with cross-lateral preference?*' The basic aims of my research are to explore the relationship between laterality and letter/number recognition/formation, and whether more specifically the use of a programme, devised by the researcher, used in conjunction with the SMART table already located in your school can impact upon this.

I plan to screen the pupils of two Key Stage 1 classes to check their laterality by asking them to perform a small number of everyday tasks and noting their lateral preference. Class A would then be designated as the Experimental class and Class B as the control class. Both classes would then have their literacy and numeracy skills assessed by me both pre and post exposure of Class A to the newly devised programme. This individual assessment would take approximately 15-20 minutes per pupil.

Pupils of Class A would then be given in addition to their usual access to the SMART table, ten minutes daily access to a newly devised programme on an individual basis, for a period of eight weeks. Initially, this will require some input from an LSA to get the child set up with the programme.

The role of the school in this research would involve sending out one letter to parents to seek consent for their child to be involved in the project. The letter would be supplied by the researcher. The consent slips would be returned to school which would involve some organisation on the schools part.

The initial screening of the pupils of two Key Stage 1 classes and the subsequent assessments of their literacy and numeracy skills would require the use of a room for that period and some disruption would occur as the researcher collects and returns pupils to class.

Further, the researcher proposes to investigate staff awareness of issues relating to cross-lateral preference via a questionnaire. Participation in this is voluntary and will not require staff to name themselves. This will involve staff spending approximately 15 minutes of their time and then placing the completed questionnaire in a post box in the staff room, provided by the researcher.

I hope that this letter provides you with an idea of what involvement in this study would entail. I shall contact you once Ethics approval is obtained to discuss the research further and to answer any additional questions you may have.

Many thanks in advance for your consideration of this project. Please let me know if you require further information. My contact details are provided below.

Yours sincerely,

Christina Evans (Educational Psychologist)

Contact Details:

Researcher:

Christina Evans,
School of Psychology,
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT

Tel: 029 2087 4568

Email: EvansCL5@cardiff.ac.uk

Supervisor:

Dr. Simon Griffey,
School of Psychology,
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT

Tel: 029 2087 4568

Email: griffeysj@cardiff.ac.uk

If you would like to make any complaint about the study, please contact:

Psychology Ethics Committee Secretary

Cardiff University,
Tower Building,
Park Place,
Cardiff

CF10 3AT

Tel: 029 2087 0360

Email: psychethics@cardiff.ac.uk

Appendix B: WIAT-11 (UK) description of sub-tests administered

The WIAT-11UK is a comprehensive, individually administered test for assessing the achievement of children who are aged between 4 and 16 years and 11 months. The WIAT-11 UK was standardised on 892 individuals in the UK in 2004. It features comprehensive normative information including age-based standard scores, percentiles, stanines, normal curve equivalents and age equivalents for each of the sub-tests.

Assessment features of the sub-tests to be administered

Word Reading

Assess pre-reading (phonological awareness) and decoding skills.

- Name the letters of the alphabet when presented visually
- Identify and generate rhyming words
- Identify the beginning and ending sounds of words
- Match sounds with letters and letter blends
- Read aloud from a graded word list

Written Expression

Measure the child's writing skills at all levels of language.

- Write the alphabet (timed)
- Demonstrate written word fluency
- Combine and generate sentences
- Produce a rough-draft paragraph (8-11)

The Researcher has provided the full assessment potential of each sub-test, obviously the Researcher will be guided by the age appropriate start and finish points.

Appendix C: Initial letter to parents

LETTER TO PARENTS OF KEY STAGE 1 PUPILS IN THE EXPERIMENTAL AND CONTROL CLASSES

Dear Parent,

I am a qualified, Chartered Educational Psychologist and Doctorate student at Cardiff University about to undertake a research project at xxxxxxxx Primary School to investigate the use of educational technology in early letter/number formation amongst Key Stage1 pupils.

My research has two goals; I am trying to find out whether the use of educational technology can help all children acquire early letter/number formation skills. I am also interested in whether laterality (e.g. right/left handed) influences their abilities to recognise and form letters. I will be able to see if children with mixed laterality (e.g. prefer to use their right hand but left foot) will find the new educational technology especially helpful. Therefore, I am requesting permission for your child to participate in my research project at school.

WHAT WILL THIS INVOLVE?

- In order to identify lateral preferences I intend to ask pupils to perform a small number of everyday tasks and to make a note of their responses.
- On a separate occasion there will be an assessment of your child's basic literacy and numeracy skills by the researcher at school. This assessment will take approximately 20 minutes.
- Class A will have daily access to a newly devised programme for use with an interactive SMART table already in use in your child's school, for approximately 10 minutes a day for a period of eight weeks, to support the development of letter/number recognition and formation. Initially Class B will not access this new programme.
- At the end of the eight week period your child's ability to record and read letters/numbers will be re-assessed by the researcher at school.
- Following the eight week period Class B will be given priority to have daily access to the newly devised programme on an interactive SMART table for approximately 10 minutes per day for a period of eight weeks.



- The SMART table provides a colourful interactive multi-touch learning centre where pupils can play and learn. Using colour, touch and sound pupils will be taught to record and read letters and numbers.

If you are happy for your child to participate please complete and return the consent form attached. Contact details for me, my supervisor and the Ethics Committee are attached.

Thank you.

Christina Evans.

Appendix D: Pupil consent form

School of Psychology, Cardiff University

Consent Form - Confidential data

I understand that participation of my child in this project will involve my child having his/her lateral preferences assessed through participation in a number of everactivities (e.g. unscrewing a bottle top, talking on a telephone) and having his/her basic literacy and numeracy skills assessed at school by the researcher. The two classes involved will then be randomly assigned as Class A and Class B.

Class A will then have daily access to a newly devised programme for use with an interactive SMART table for a period of 8 weeks to support the development of letter/number recognition and formation. Class B will not initially. At the end of the 8 week period, children in both classes will have their basic literacy and numeracy skills re-assessed by the researcher. Class B will then be given daily access to the newly devised programme for use with an interactive SMART table for a period of 8 weeks to support the development of letter/number recognition and formation.

I understand that participation in this study is entirely voluntary and that I can withdraw my child from the study at any time without giving a reason.

I understand that I am free to ask any questions at any time. I am free to withdraw my child or discuss my concerns with the researcher Christina Evans or her supervisor Dr Simon Griffey.

I understand that the information collated will be held confidentially, such that only the researcher can trace this information back to my child. I understand that the data will be anonymised at the end of the study, and that after this point no-one will be able to trace the information back to my child. The information will be retained for up to one year when it will be destroyed. I understand that I can ask for information about my child to be destroyed at any time up until the data has been anonymised and I can have access to the information up until the data has been anonymised.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, _____(NAME OF PARENT), consent to my child
_____ participating in the study to be

conducted by Christina Evans, School of Psychology, Cardiff University with the supervision of *Dr Simon Griffey*.

Signed:

Date:

Contact Details:

Researcher:

Christina Evans,
School of Psychology,

Supervisor:

Dr. Simon Griffey,
School of Psychology,

Cardiff University,

Tower Building,

Park Place,

Cardiff

CF10 3AT

Tel: 029 2087 4568

Email: EvansCL5@cardiff.ac.uk

Cardiff University,

Tower Building,

Park Place,

Cardiff

CF10 3AT

Tel: 029 2087 4568

Email: griffeysj@cardiff.ac.uk

If you would like to make any complaint about the study, please contact:

Psychology Ethics Committee Secretary

Cardiff University,

Tower Building,

Park Place,

Cardiff

CF10 3AT

Tel: 029 2087 0360

Email: psychethics@cardiff.ac.uk

Appendix E: Debriefing script for pupils following initial screen

Debriefing of pupils following initial screen to determine lateral preferences

Thank you for helping me with my work.

I will now tell you a bit more about my work and give you the opportunity to ask any questions.

I am trying to find out which hand, foot, eye and ear children like to use when carrying out everyday activities.

I hope to find things that might help some children do some activities better, but I will not know until I finish all my work.

Do you have any questions you would like to ask about my work?

Thank you for helping me with my work. Would you like to choose a sticker as a reward for helping me?

Appendix F: Debriefing script for pupils following administration of WIAT-11(UK) sub-tests

Debriefing of pupils following assessment using the WIAT-11UK

Thank you for helping me with my work.

I will now tell you a bit more about my work and give you an opportunity to ask any questions.

I am trying to find out about things that help children learn best in school.

I hope to find things that might help some children learn better, but I will not know until I finish all my work.

Do you have any questions you would like to ask about my work?

Thank you for helping me with my work. Would you like to choose a sticker as a reward for helping me?

Appendix G: Information regarding specialist equipment required

The SMART table

SMART Table interactive learning centre



This equipment is already in use in the pilot school.

Young students are drawn to the surface of the SMART Table™ interactive learning centre, where work and play come together. The SMART Table is the first multi-touch, multi-user interactive learning centre that allows groups of early education students to

work simultaneously on one surface. The SMART Table's interface is so intuitive that even young students can start using it without instruction.

Because the SMART Table complements the SMART Board interactive whiteboard and other SMART products, a variety of different teaching styles can be accommodated. You can also create interactive lessons and move smoothly between whole-class and small-group learning.

Help students collaborate and learn

Today's tech-savvy students naturally gravitate to the SMART Table, and its horizontal, 360 degree surface makes it easy and fun for them to collaborate on activities. While working on the interactive learning centre, students have the opportunity to build cognitive, social and fine motor skills. Even relatively shy children feel comfortable participating, and show leadership skills when completing group work. With its unique and engaging features, the SMART Table is accessible by all students, including those with special needs.

Use it with the SMART Board interactive whiteboard...

To optimize both whole-class and small-group learning, the SMART Table is an excellent complement to the SMART Board interactive whiteboard. For instance, when teaching a lesson, you could first introduce a concept on the interactive whiteboard with all students, then reinforce it through group work on the SMART Table.

Mobile

Because the SMART Table is mounted on casters, it moves easily from class to class and fits through standard doorways. The power cord detaches from the interactive learning centre to facilitate moving.

Sound

The SMART Table features simplified volume control through the teacher interface.

Appendix H: Information sheet for school staff

I am a qualified Chartered Educational Psychologist and Doctorate student at Cardiff University about to undertake a research project at your Primary School to investigate the use of educational technology in early letter formation amongst pupils who have exhibited mixed laterality/cross lateral preference.

As part of my research I will be conducting a number of activities in your school. I will be involved with two Key Stage 1 classes only, which will be randomly assigned as Class A and Class B. Class A will initially be designated as the Experimental class and Class B the Control class. After collecting baseline information, the Experimental class will be involved in using a newly devised programme on the SMART table on a daily basis for eight weeks in an attempt to further develop their letter/number formation. The Control class will have the opportunity to utilise this newly devised programme on the SMART table for the same period of time following Class A. At the end of the research project I will collate and analyse my findings and return to your school to share this information with you.

I would be most grateful if you could spare the time to complete the attached questionnaire and return it to me in the envelope provided via the posting box left in the staffroom. I thank you in anticipation and take this opportunity to apologise for any inconvenience I may cause in the future whilst working in your school.

So that you are fully aware of my correspondence to parents in relation to this project I append the letter I have sent to parents.

Thank you,

Christina Evans.

Appendix I: Staff consent form

School of Psychology, Cardiff University

Consent Form - Confidential data

I understand that my participation in this project will involve the completion of a single questionnaire about my awareness and understanding of mixed laterality/cross lateral preference which will require approximately 15 minutes of my time.

I understand that participation in this study is anonymous and entirely voluntary and that I can withdraw from the study at any time without giving a reason.

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with the researcher Christina Evans or her supervisor Dr Simon Griffey.

I understand that the information provided by me will be anonymous and will be held securely. I understand that it will not be possible to trace this information back to me individually. The information will be retained for up to one year when it will be destroyed.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, _____(NAME) consent to participate in the study conducted by Christina Evans, School of Psychology, Cardiff University with the supervision of Dr Simon Griffey.

Signed:

Date:

Contact details for me, my supervisor and the Ethics Committee are located at the end of the questionnaire.

Appendix J: Teacher and support staff questionnaire

I would be most grateful if you would spend approximately 15 minutes of your time to complete this questionnaire. Please complete questions based on your existing knowledge. You can omit any question that you do not feel happy about answering. If more space is required please use an additional sheet and staple your sheets together. On completion please place in the posting box located in the staff room. Thank you in anticipation.

Please indicate your position in school by circling the appropriate description:

TEACHER

SUPPORT ASSISTANT

1. What is your understanding of crossed lateral preference (CLP)/mixed dominance?

2. Are you aware of any pupils in you school with CLP? If yes, how are you aware?

3. How would you know if a pupil had CLP/test for CLP?

4. Do you feel that pupils with CLP are disadvantaged in school in any way? If yes in what way?

5. Do you feel that pupils with CLP experience greater difficulty with school work generally? If yes in what way?

6. If a pupil was experiencing learning difficulties in school would you consider that the difficulties may be related to laterality issues or would you not give thought to this possibility?

7. If you were aware of a pupil in your class as having CLP what support if any would you provide for that pupil?

8. If you have any further thoughts/questions relating to CLP please note them below.

Thank you for taking the time to complete this questionnaire.

I am a qualified, Chartered Educational Psychologist and Doctorate student at Cardiff University about to undertake research in your school. Research findings to date are inconclusive about the effect of age and other factors on laterality. The purpose of this project is to explore the letter and number recognition/formation abilities of children and correlate this with lateral preference. The project involves giving some pupils access to a newly devised programme on the SMART table in your school, for eight weeks, to investigate how this will impact on their letter and number skills.

As part of my research I am very keen to explore the knowledge and views of teachers and support staff in relation to cross lateral preference amongst pupils. Therefore, your responses are most important as they will provide this vital insight. Please feel free to contact me should you wish to have further information.

Thank you,

Christina Evans.

Contact Details:

Researcher:

Supervisor:

Christina Evans,
School of Psychology,
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT
Tel: 029 2087 4568
Email: EvansCL5@cardiff.ac.uk

Dr. Simon Griffey,
School of Psychology,
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT
Tel: 029 2087 4568
Email: griffeysj@cardiff.ac.uk

If you would like to make any complaint about the study, please contact:

Psychology Ethics Committee Secretary
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT
Tel: 029 2087 0360
Email: psychethics@cardiff.ac.uk

Appendix K: Debriefing letter to parents

Dear Parent,

Thank you for allowing your child to take part in my research project at school. I would now like to provide you with more information about the study. The title of my study is

‘Does the use of educational technology and multi-modal learning experiences assist children in the development of early letter formation and handwriting skills, especially those with cross-lateral preference?’

The research is finding out about the letter and number recognition/formation abilities of children and relating it to their lateral preference e.g. right handed and left footed.

The research project involved giving two Key Stage 1 classes access to a newly devised programme for use with the SMART table for eight weeks to investigate how this will impact on their letter/number skills.

I hope to find out about things that might help children with their letter/number skills. I will not know this until I have had an opportunity to look at all the information. When I have done this I will send you a letter, which will contain a summary of details of my findings. The school will also be sent a summary of findings, but in no way will they receive any sort of feedback regarding individual pupils.

Once I have looked at my results I will anonymise all data. After this point no-one will be able to trace any information back to your child. The information will be retained for up to one year when it will be destroyed. You can ask for the information about your child to be destroyed at any time up until the data has been anonymised in accordance with the Data Protection Act.

If you have changed your mind about your child taking part in this study, then please let me know and I will destroy all information relating to your child. If you think of anything that you would like to ask please contact me directly or through the school.

Many thanks for your co-operation with this study.

Christina Evans.

(Educational Psychologist).

Contact Details:

Researcher:

Christina Evans,
School of Psychology,
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT
Tel: 029 2087 4568

Email: EvansCL5@cardiff.ac.uk

Supervisor:

Dr. Simon Griffey,
School of Psychology,
Cardiff University,
Tower Building,
Park Place,
Cardiff
CF10 3AT
Tel: 029 2087 4568

Email: griffeysj@cardiff.ac.uk

If you would like to make any complaint about the study, please contact:

Psychology Ethics Committee Secretary

Cardiff University,

Tower Building,

Park Place,

Cardiff

CF10 3AT

Tel: 029 2087 0360

Email: psychethics@cardiff.ac.uk

Appendix L: Raw Data

Table A.1 Showing Lateral Preferences of the Experimental Group

		HAND			FOOT			EYE			EAR			*
Code	m/f	1	2	3	1	2	3	1	2	3	1	2	3	LI
A1	m	R	R	R	L	L	R	L	L	L	L	L	L	4
A2	f	R	L	R	R	L	L	L	L	L	R	L	L	4
A3	m	R	R	R	R	L	R	L	L	L	L	L	L	5
A4	m	R	R	R	R	R	R	R	R	R	L	R	R	11
A5	f	R	L	R	R	L	R	R	R	R	R	R	R	10
A6	m	R	R	R	R	R	L	R	R	R	L	R	L	9
A7	m	R	R	R	R	R	R	R	R	R	L	L	L	9
A8	m	R	R	R	R	R	R	L	L	L	L	L	L	6
A9	f	R	R	R	R	L	R	L	L	L	R	L	L	6
A10	f	R	R	R	R	R	R	R	R	R	L	L	L	9
A11	m	R	L	R	R	L	R	R	R	R	L	L	L	7
A12	f	R	L	R	R	L	R	R	R	R	R	R	R	10
A13	f	R	R	R	R	L	L	R	R	R	L	L	L	7
A14	f	R	R	R	R	R	L	L	L	L	R	L	L	6
A15	f	R	L	R	L	L	R	R	R	R	R	L	L	7
A16	f	R	R	R	R	R	R	R	R	R	R	L	L	10
A17	f	R	R	R	R	R	R	R	R	R	L	L	L	9
A18	m	L	R	R	R	L	R	L	L	L	R	L	L	5
A19	m	R	L	R	R	R	R	R	R	R	R	R	L	10
A20	f	R	R	L	R	R	L	L	L	L	L	R	L	5
A21	f	R	R	L	R	L	R	R	R	R	R	R	R	10
A22	f	R	R	R	R	R	R	R	R	R	L	L	L	9

A23	f	R	R	R	L	R	R	R	R	R	R	R	L	10
A24	m	R	R	R	L	L	L	R	R	R	R	R	L	8
A25	m	L	R	L	L	L	R	L	L	R	L	L	L	3
A26	m	R	L	R	R	R	R	R	L	R	R	L	L	8

* Laterality Index

Table A.2 Showing Lateral Preferences of the Control Group

Code	m/f	HAND			FOOT			EYE			EAR			* LI
		1	2	3	1	2	3	1	2	3	1	2	3	
B1	f	R	L	R	R	L	L	R	R	R	R	R	R	9
B2	f	R	L	R	R	L	R	R	R	R	L	L	R	8
B3	m	R	L	R	R	L	R	R	R	R	R	R	L	9
B4	f	L	L	R	R	L	R	R	R	R	L	L	L	6
B5	f	R	L	R	R	R	R	R	R	R	R	L	L	9
B6	m	R	L	R	R	R	R	L	L	L	L	L	L	5
B7	f	R	R	R	R	L	R	R	R	R	R	L	R	10
B8	f	R	R	R	L	L	R	L	L	L	R	L	L	5
B9	m	R	L	R	L	L	R	R	R	R	L	L	L	6
B10	m	R	L	R	R	L	R	R	L	L	R	L	L	6
B11	f	R	R	R	R	L	L	L	L	L	R	R	L	6
B12	m	R	R	R	R	L	L	L	L	L	L	L	L	4
B13	m	R	R	R	L	L	R	R	R	R	R	L	L	8
B14	f	R	R	R	R	R	R	L	L	L	R	L	L	7
B15	f	R	L	R	R	L	L	R	R	R	R	R	L	8
B16	m	R	L	R	R	L	R	R	R	R	R	L	L	8
B17	m	R	L	R	R	R	R	R	R	R	R	R	R	11
B18	m	R	R	R	R	L	R	L	L	L	R	L	L	6
B19	m	R	L	R	R	L	R	L	R	L	L	L	L	5
B20	f	R	L	L	L	L	L	L	L	R	R	R	L	4
B21	m	R	L	L	L	L	L	L	L	R	R	R	L	4
B22	f	R	R	R	R	L	R	L	L	L	R	R	R	8
B23	m	R	L	R	L	R	L	L	L	L	R	L	L	4

B24	m	R	L	R	R	R	R	R	R	R	R	R	R	R	11
------------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	----

* Laterality Index

Table A.3 Showing Pre-Intervention Scores on WIAT-11uk Sub-tests for Experimental Group

Code	CA	Word Reading (Age Equiv)	* SS	Written Expression (Age Equiv)	Decile
A1	5:02	5:00	98	4:00	60
A2	5:01	5:00	101	4:04	80
A3	5:00	5:08	110	4:00	60
A4	5:00	5:04	107	4:00	60
A5	4:11	4:08	97	4:04	100
A6	4:11	5:04	111	4:00	90
A7	4:11	5:08	118	4:00	90
A8	4:10	5:04	113	4:00	90
A9	4:10	5:00	109	4:04	100
A10	4:11	5:00	108	4:04	100
A11	4:10	5:08	135	4:00	90
A12	4:09	5:00	103	4:00	90
A13	4:08	4:08	100	4:00	90
A14	4:08	5:08	118	4:04	100
A15	4:08	5:08	117	5:00	100
A16	4:08	5:08	118	4:00	90
A17	4:08	4:08	98	4:00	90
A18	4:07	5:00	121	4:00	90

A19	4:07	4:00	96	4:00	90
A20	4:06	5:04	129	4:00	90
A21	4:06	5:00	117	4:00	90
A22	4:06	4:08	110	4:00	90
A23	4:06	5:04	126	4:00	90
A24	4:05	4:08	111	4:00	90
A25	4:05	5:08	133	4:04	100
A26	4:05	4:00	88	4:00	90

* Standard score

Table A.4 Showing Post-Intervention Scores on WIAT-11uk Sub-tests for Experimental Group

Code	CA	Word Reading (Age Equiv)	* SS	Written Expression (Age Equiv)	Decile
A1	5:08	5:00	89	5:04	60
A2	5:07	6:00	121	5:08	100
A3	5:05	6:00	121	6:00	100
A4	5:05	5:08	112	4:00	60
A5	5:06	5:08	116	5:00	90
A6	5:04	5:08	111	4:00	60
A7	5:05	6:04	137	8:08	100
A8	5:04	5:08	113	5:00	90
A9	5:04	6:00	127	7:08	100
A10	5:04	6:00	121	6:00	100
A11	5:04	5:08	116	4:04	80
A12	5:03	5:08	116	9:00	100
A13	5:02	5:08	109	4:04	80
A14	5:01	6:00	118	6:00	100
A15	5:02	6:00	118	4:04	80
A16	5:01	6:00	121	4:04	80
A17	5:01	5:04	104	4:00	60
A18	5:01	5:08	111	4:00	60
A19	5:01	5:00	99	4:00	60

A20	5:00	5:08	116	6:08	100
A21	5:00	5:08	113	4:04	80
A22	4:11	5:00	108	4:04	100
A23	5:00	5:08	112	4:00	60
A24	4:11	5:04	115	4:00	90
A25	4:11	5:08	121	4:00	90
A26	4:11	4:04	96	4:00	90

***Standard Score**

Table A.5 Showing Pre-Intervention Scores on WIAT-11uk Sub-tests for Control Group

Code	CA	Word Reading (Age Equiv)	* SS	Written Expression	Decile
B1	5:02	5:00	102	4:00	60
B2	5:02	4:08	93	4:00	60
B3	5:02	5:04	106	4:04	80
B4	5:02	5:04	108	4:00	60
B5	5:01	4:08	93	4:04	80
B6	5:01	6:04	129	4:00	60
B7	5:00	4:08	95	4:04	80
B8	4:11	5:08	124	6:00	100
B9	4:11	4:04	96	4:00	90
B10	4:10	4:08	102	4:00	90
B11	4:10	5:04	110	4:00	90
B12	4:10	5:08	118	4:00	90
B13	4:09	5:04	112	4:00	90
B14	4:09	4:08	100	4:00	90
B15	4:08	5:08	119	5:00	100
B16	4:08	4:00	87	4:00	90
B17	4:08	4:08	101	4:00	90
B18	4:07	5:04	124	4:00	90
B19	4:07	4:04	109	4:00	90
B20	4:06	5:00	120	4:04	100

B21	4:04	5:00	120	5:00	100
B22	4:04	4:04	104	4:00	90
B23	4:04	5:00	116	4:00	90
B24	4:04	5:00	121	4:00	90

***Standard Score**

Table A.6 Showing Post-Intervention Scores on WIAT-11uk Sub-tests for Control Group

Code	CA	Word Reading (Age Equiv)	* SS	Written Expression	Decile
B1	5:07	5:08	111	4:04	80
B2	5:08	5:00	87	4:00	60
B3	5:08	5:08	99	4:00	60
B4	5:07	5:04	108	4:04	80
B5	5:06	5:00	100	4:00	60
B6	5:05	7:00	147	5:00	90
B7	5:05	5:08	115	4:04	80
B8	5:04	6:04	131	6:00	100
B9	5:04	5:08	111	4:00	60
B10	5:04	5:04	106	4:00	60
B11	5:04	5:08	115	4:04	80
B12	5:03	6:00	119	4:04	80
B13	5:02	5:08	112	4:04	80
B14	5:01	5:00	99	4:04	80
B15	5:01	6:00	121	6:00	100
B16	5:01	5:08	111	4:00	60
B17	5:01	5:08	111	4:00	60
B18	5:01	5:08	111	4:04	80
B19	5:01	5:08	111	4:00	60
B20	4:11	5:08	123	4:04	100
B21	4:10	5:00	108	9:00	100

B22	4:09	5:04	111	4:00	90
B23	4:09	5:00	109	4:00	90
B24	4:09	5:00	107	4:00	90

***Standard Score**