Sensorimotor Interference in Cognitive Tasks for Children with Dyslexia.

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Abstract

There are many theories of dyslexia though mainly falling within three: phonological, cerebellar and magnocellular; of which auditory and visual fit within (Ramus, 2003). Historically it has been difficult to illuminate the underlying cause despite agreement on heterogenetic evidence. This study focused on the sensorimotor interferences that aid and abet recall for a group of children 8 & 12 years of age both with (WD) and without dyslexia (WO). It was hypothesised that there would be a significant difference between both groups in the (AI) due to auditory deficits for (WD) group. Analysis revealed weak correlation in the olfactory condition; moderate correlations between group scores in the auditory; visual and gustatory scores and a strong correlation in the tactile condition between groups; a significant difference between groups in a no interference (NI) and an auditory interference (AI) task. Further analysis in the chronological age group showed a significant difference between both groups in the (AI) task only (t(28) = -3.443 p < .001). CI 95% -3.504 to -.860 indicating as within other studies that children with dyslexia are significantly impaired in an auditory domain (Rosen et al., 2003; White et al., 2006). It was also hypothesised that the addition of movement for the experimental group in the (TI) would show a significant improvement in memory recall in comparison to the (NI) for that group. This as not the case however a significant difference was found between (AVM) and recall across between groups (t(19) = -2.395, p < .001). CI 95% -10.03473 to -.69597.

Keywords: dyslexia, auditory, interference, learning, sensorimotor
Introduction

According to western literature, dyslexia affects 5-17% of all children which cannot be explained by poor hearing; poor vision; lack of interest, motivation or education (Raschle, Chang & Gaab, 2011). It is defined as a combination of abilities and difficulties that can affect learning process in the area of reading, writing and arithmetic; identified by processing, sequencing, organization, memory, attention and visuo-spatial skills despite average to above average intellectual ability. The fields of cognitive neuroscience and special education share a common interest in understanding the constructs and aetiology of, and supports for specific learning disorders (SLDs). Historically it has been difficult to illuminate the underlying cause/s and had been defined as homo to heterogeneous. The theories are many and offer a multifaceted causal and diagnostic debate. It is scientifically agreed however, as with all developmental disorders, that several comorbid difficulties coexist (Goswami, 2003). On reflection of the main theories of interest this study attempts to add to previous studies in the area of modality interference on Dyslexia by facilitating a learning tool whereby the learning and teaching of children with Dyslexia could be met.

Explaining Dyslexia

Cognitive, biological and behavioural construct

50 years of research and still there are no universally designed tests for the identification of learning difficulties. There is empirical evidence that a family history of dyslexia explains structural abnormalities in the brain (Raschle, Chang & Gaab 2011). Electrophysiological differences have been found for those infants with familial risk for developmental dyslexia (Raschle et al., 2011; Eckert et al., 2003) found thinner cortices in both primary auditory and visual areas thought to underlie executive functions connected to
genetic variation; and reduced grey matter has been reported in the cerebellum of individuals with dyslexia. Richardson, Leppänen, Leiwo and Lyytinen (2003) demonstrated behavioural deficits in auditory processing for 6month old infants at risk of dyslexia. Galaburda and Kemper (1979) found, post mortem, that the normal asymmetry of the planum temporale tends to be absent in those with dyslexia favouring the left side previously discussed. Furthermore Galaburda & Kemper (1979) found abnormal symmetry in the posterior parietal cortex plus ‘brain warts’ (ectopias) clustered around the temporoparietal junction. These growths are believed to form at about the fifth month of foetal life and are associated with widespread disruption of the normal neural connections. Numerous other studies; in particular studies with twins; have shown that a genetic factor is accountable for the highly significant degree of familial similarities among individuals with dyslexia (Snowling, Gallagher & Frith 2003).

Learning to match auditory information of speech sounds with visual information of letters is understood as a first and integral step for competent literacy skills within alphabetic languages which is assumed deviant in processing auditory and visual cues for those with dyslexia (Blau, Reithler, van Atteveldt & Seitz, et al., 2010). Studies have shown that people with dyslexia have difficulties with tasks as a consequence of reading difficulty not as a cause of. Vellutino et al.’s (1973) study showed large difference in ability to read and to recall words in their own language but when a control group and an experimental group were asked to recall words in Hebrew, a language unknown to both groups there was no discrepancy in scores between them. Recent understanding simmers on the cognitive and/or biological construct that Dyslexia is neuropsychological but of a strong genetic disposition (Galaburda, Sherman & Rosen 1985; Raschle et al., 2011; Ramus, 2003; Snowling, 2000). The existence of dyslexia, and that it is both neurophysiological and epigenetic can therefore be soundly argued but what of its aetiology?
The marked degree of heterogeneity in persons with dyslexia has motivated the investigation of possible aetiological constructs mainly falling within three theories: phonological, cerebellar and magnocellular with auditory and visual fitting within those three main theories (Ramus, 2003). Functional imaging studies (FMRIIs) have made evident that language is not strictly localized to the left hemisphere as previously thought, it is clear that the more demanding the language task the more activated the left hemisphere appears to be as would be in the case of Dyslexia (Stein, 2001a). The wide variation of symptoms for the individual may well result from several discernible impairments and it may be many years before it is truly understood. In the interim the self-efficacy and literate and numerate achievements of the individual both within and outside the classroom need to be met.

As comorbidity is entirely different for each individual learner with a (SLD), type dyslexia is intrinsically more complex to understand. Time has made numerous attempts to isolate single factors which could account for the symptoms of the entire disordered population (Denckla & Rudel, 1976) as have numerous studies tried to attribute to define a particular construct. At first the disorder was believed to be unitary, with a single underlying cause; intensively discussed under the medical term of ‘strephosymbolia’ congenital word blindness (Orton, 1925). Later it became known as a brain dysfunction (Strauss & Lehtinen, 1947) and later as a brain disability (Kirk, McCarthy & Kirk, 1967) and finally in 1968 the World Federation of Neurologists termed it a learning difficulty and entitled it ‘Dyslexia’ (Nicolson & Fawcett, 1994). Earlier terms are still banded around quite descriptively and inappropriately at times, instilling fear of brain disorders for those familiar with the neuromyths of learning difficulties (Goswami, 2003), such as left and right hemispherical dominance, and unfamiliar with the truths of Dyslexia.
Phonological theory

The phonological theory postulates that there lies a specific impairment in the representation, storage and/or retrieval of speech sounds for people with dyslexia. Support for this is evident in analysis of poor performance for people with dyslexia on phonological awareness tasks; such as phoneme and morpheme manipulation and recognition of speech sounds (Ramus, 2003); poor verbal short-term memory and slow automatic naming (Snowling, 2000). Children with dyslexia are significantly impaired with phonological difficulties preceding learning to read (Snowling, Gallagher & Frith 2003). Sensory and motor deficits have been referred to as contributing factors to the phonological difficulties within reading disorders (Moncrieff & Musiek 2002; Tallal, Merzenich, Miller, & Jenkins, 1998); as has lower-level auditory processing (Goswami, 2003). Guttorm et al. (2001) detected event related potential (ERP) differences in newborns from families with versus without familial risk for dyslexia to language sounds within hours or days of birth.

Tallal et al. (1998) and other theorists, place particular weight on these deficits to rapid auditory processing (RAP), or rather lack of. The divergence of symptoms has lead others to argue for a neurological disorder attributed from numerous factors (Russeler, Gerth & Munte, 2006). Other theories that balance out hypothetically as causal to dyslexia are cellebrellar dysfunction/automaticity (Nicolson et al., 1999) and magnocellular deficits (Stein, 2001). Challengers of the phonological theory do not dispute the existence of a phonological deficit and its contribution to reading difficulty but instead argue that the disorder is much more than that; incorporating general sensory, motor or learning processes (Ramus 2003). These theorists also dispute that the phonological deficit is just one aspect of many and that it is secondary to a more ‘basic auditory deficit’ (Ramus 2003). A major weakness in this theory of dyslexia is the inability to explain these other modalities. Phonological theorists essentially see the co-occurrence of modalities within reading
difficulties but dismiss them as causal (Snowling, 2000). The finding that dyslexic subjects under activate superior temporal brain regions when processing speech sounds is in line with previous paediatric neuroimaging studies that implicated perisylvian cortex including the left superior temporal gyrus (Pugh et al., 2000).

**Cerebellar/automaticity theory**

The biological claim is that the cerebellum is mildly dysfunctional in a dyslexic brain and certain cognitive difficulties arise such as speech inarticulation; difficulties with overlearned tasks, such as driving, typing, reading (Nicolson et al., 1999); poor performance within motor tasks (Fawcett, Nicolson & Dean, 1996) and poor dual tasks such as balance (Nicolson & Fawcett, 1994).

Brain imaging studies have shown these biological dyslexic aetiologies through anatomical, metabolic and activation variances (Ramus, Pidgeon & Frith, 2003) however the cerebellar theory however fails to account for the sensory disorders found with persons with dyslexia. It also remains uncertain what proportion of dyslexics are affected by motor problems. A number of studies have failed to find any (Ramus, 2003). Ramus’s (2002) study investigating motor control and its relationship with phonology provides partial support for the presence of motor problems within Dyslexia but he specifically states that there is no support that a cerebellar dysfunction is the ‘cause of their phonological and reading impairment’ therefore motor difficulties can be argued as a factor lying therein but not cause to dyslexia.

**Magnocellular and sensorimotor theory**

Much research has investigated auditory and visual theories as congruent of dyslexia but more recently supporters of these theories agree that they are more part of a general magnocellular dysfunction (Ramus, 2003). The magnocellular theory of dyslexia, through a
singular biological cause, essentially is generalised to all modalities (visual, auditory, phonological, motor as well as tactile). As the cerebellum receives massive input from various magnocellular systems in the brain, it is also predicted to be affected by the general magnocellular defect (Stein et al., 2001). Magnocellular abnormalities have been discovered in the medial and lateral geniculate nucleus of dyslexics' brains and poor performance of individuals with dyslexia have been found in the tactile, visual and auditory domains (Ramus, 2003).

Ramus (2003) however has noted that there has been a number of failures to replicate findings of auditory disorders in dyslexia. He found that results were inconsistent with the ‘idea that the auditory deficit lies in “rapid” auditory processing’, and therefore with magnocellular function. Studies have argued that auditory deficits do not predict phonological deficits therefore discounts a magnocellular construct. Mody, Studdert-Kennedy and Brady (1997) and McArthur and Bishop (2005) are not alone in postulating that auditory deficits are not causal to dyslexia but additional to language impairments within some individuals with dyslexia. The magnocellular also fails to explain the absence of sensory and motor disorders in a significant proportion. The physical environment is often distracting and surely causal to many disturbances in performance (Rae & Perfect, 2014). Banbury and Berry’s work survey (2005) claimed that open plan office space noise was so distracting it adversely affected 99% of workers concentration thus advocating for sensorimotor distraction regardless of having a SLD, just as would be the case in a classroom environment. Perfect, Andrade & Eagan (2011) have evidenced beneficial effects of reducing environmental distraction via instruction of eye-closure in the field of eye-witness interviews has helped recall. Markson and Paterson (2009) found that performance on a visual-spatial imagination task was poorer when participants maintained face-to-face eye-contact with the experimenter as opposed to gaze aversion or eye closure. Averting the gaze disengages the environment
and facilitates remembering (Glenberg, Schroeder & Robertson, 1998) and eye closure helps memory by reducing cognitive load and enhancing visualisation (Vredeveldt, Hitch & Baddeley, 2011).

**Implications in Education: reading, attention and processing**

Ramus (2003) spoke of research in dyslexia facing an ‘intriguing paradox’; in that while sensory and motor deficits were seen to be increasingly akin to the difficulties found within dyslexia it is was also becoming increasingly clear that they play only a limited role in its aetiology. The *Dyslexia Debate* (Elliott & Grigorenko, 2014) reviews this issue in detail and shows that relevant studies have provided contrasting beliefs and recommends that our current knowledge would better fair in concentrating directly on academic skills and overcoming difficulties rather than seeking to improve underlying processes. Elliott and Grigorenko (2014) propose that rather than looking for causes and diagnoses professionals should be immediately responding and intervening for the child who struggles before waiting for that child to fail each time and ‘to adopt a more scientific approach that will ensure that all children who encounter literacy difficulties receive the help that they need’.

As already discussed, advances in neuroscience over the past 30 years yield important insights into mental functioning, but their implications for the field of special education have remained largely unexplored (Gough & Tunmer, 1986). As cited in (Goswami, 2003) neuroscientist Bruer (1997) promoted the belief that teachers and policy makers should dismiss findings based on neuroscience and focus instead on what psychologists and cognitive scientists had already discovered and put into practice pertaining to teaching and learning. These challenges later resulted in a belief among educators that they were incapable of understanding how the brain worked or how to apply the neuroscience findings. This gulf between current science and direct classroom applications doesn’t compliment strides for
intervention. Tommerdahl (2010) encourages teachers to turn their attention to assessment, treatment and intervention posing specific questions for neuroscientists to answer in order for educational researchers to design teaching strategies that help students acquire the skills necessary to be successful in the classroom. It is strongly believed in the education field that children benefit from intensive multi-sensory learning opportunities (Kennedy et al., 2012). Where neuropsychologists have examined patterns of strengths and weaknesses in sensory and perceptual systems, educational researchers have questioned how sensory channels affect human learning.

By understanding the plasticity and individual variability of the developing brain the educator can develop tools essential for designing integrated intervention programs. These interventions should be based on an assessment of the individual student's strengths and deficits in motor functions, intellectual and psychosocial abilities, memory, and learning processes (King, Wood & Fulkner 2008). Further, their implementation must be practical, given the environmental factors in which learning occurs. Little study of the interrelationship between sensory channels and thinking processes has been designed to determine how individuals might maximize intelligence, perceiving and learning (King, Wood & Fulkner 2008) so therefore this study aims to develop an interrelationship for all learners in a cohort of location and age to develop those questions required for intervention by focusing on the sensorimotor interferences in the day to day classroom environment.

The focus of this study is not to seek cause of this vastly studied and widely debated phenomenon but to analyse the simple every day interferences that further impede on the epigenetic and neuro physiological difficulties faced by the school child within her/his own learning environment. Sometimes, these students are struggling to learn in an environment that is designed inadvertently to frustrate their efforts. A child with a SLD will often tune out or get bored in response to feeling alienated from tasks that are either out of reach, or
misunderstood, within a mainstream classroom (Willis, Irish times, 2012). Scans have revealed increased metabolic state in the prefrontal cortex (PFC) that block information processing when boredom or frustration sets in (Eisenhart & DeHaan, 2005). New learning cannot be retained if the PFC is blocking access to memory retrieval therefore by reducing the stress of the child with a SLD the child will be able to utilise their PFC more effectively and engage in their learning. Willis (2012) as cited in Irish Times explains how a fixed mindset develops for the struggling learner whereby communication from the PFC emotional control is lost to a reactive brain and goes on to explain how these students and their ‘uninformed teachers come to believe that nothing better can be expected’ where the fixed mindset lends the ‘brain's primitive survival networks restrict effort toward goals that, by experience, are not expected to be reached”.

Rosie Bissett (2015) of Dyslexia Association of Ireland speaks of the current Irish education assessment system of rote learning and examination being very unhelpful for the child with dyslexia explaining that the dyslexic brain ‘is wired differently’ and how as a nation a lot is being lost by teaching and assessing in this ‘narrow’ way and suggests that a universally designed system would be better placed in our education system, for everyone (“Irish Times”, April 2015, para. 2.). Pauline Cogan (2016), an Educational Psychologist and researcher dyslexia reacts to the many complaints by Irish parent/guardians to the States Examinations Commission that not only children who’s needs are ‘bad enough’ are getting adequate exam supports as officials are acting as ‘gatekeepers’ to who and who does not get support and that the general allocation model is a one-for-all despite vast diversity in difficulties and abilities. David Sousa (2007) reflects this well when he points out:

‘As we gain a greater understanding of the workings of the human brain, we may discover that some students currently designated as "learning disabled" may be merely "schooling disabled" (Sousa, 2007, p 2.)
The purpose of this study was to address this situation by using research from the aforementioned theories of dyslexia in a learning experiment to assess memory recall and movement across sensory interferences for learners with and without dyslexia. It was hypothesised that there would be a significant difference between both groups in the (AI) due to auditory deficits in the control group echoing both phonological and magnocellular theories. It also was hypothesised that the addition of movement for the experimental group in the (TI) would show a significant improvement in memory recall because of this learning aid (putty ball). It was expected that there would be difference across all individual participants and between both groups; but that there would be significant differences between groups.

Method

Participants

The study was approved by the Dublin Business School Ethics Committee. Schools invited to participate in the study were selected as a purpose to be inclusive of typical school children within the local region including multidenominational and religious specific schools; co-educational and one sex schools; fee paying and public schools; special education, mainstream and Montessori schools. The participants were children permitted by parental/guardian consent from local primary schools selected across the Dun Laoghaire-Rathdown area. Criteria of exclusion for both groups was impaired sight or hearing; intellectual disability according to DSM-IV criteria and English as a second language. All participants had to be between 8 and 12 years of age. Criterion for the group (WO) included confirmation of micra-T scores above the 60% percentile as national standard competent reading level for this age cohort or an equivalent standard test criteria operated by the respective schools. This intended for the ruling out of any deficits that may otherwise impede
the performance of a control group and have them match rather than differentiate in reading ability with the control group. The (WD) group, were required to have evidence of a specific learning difficulty (SLD), type dyslexia by an Educational Psychologist as in DSM-IV criteria, ruling in literacy difficulty. All data collection points reported in this study were collected within the child’s natural school environment throughout February 2016.

Seven schools out of 36 responded with a total of 31 children presented for study: 13 females and 18 males; 1 female of two Romanian parents, 1 male of one Irish parent and one Dutch; 1 female of two Asian parents; 1 male of one African and one Irish parent; 1 boy of Asian and South American parents. All others participants presented as children of Caucasian parents who spoke English as their first language.

**Design**

An independent t-test analysis between groups and a paired samples t-test analysis within groups were performed to interpret how individual (SI) and movement relate to retrieval and memory recall all participants between the ages of 8 and 12 inclusive of reading & chronological ages and a further analysis between participants between 10-12 ages ruling in chronological age only.

**Procedure**

A statutory declaration permitted the study to operate with children upon ethical approval for the study obtained from the DBS ethics committee. Informed consent to participate was given by parent/guardian, child and school principal. Children were tested individually in a quiet room within their school during typical school hours. Testing was divided into six tasks lasting approximately 12 mins for every child. This series of 6 conditions consisted of memory word recall tasks and measurement of movement via accelerometer vector magnitude (AVM) through 6 conditions: (1) (NI), (2) (AI), (3) visual
interference (VI), (4) tactile interference (TI), (5) olfactory interference (OI) & (6) gustatory interference (GI).

For each condition the participant was standing upright with both feet hip distance apart, arms hanging side by side and unmoving and looking straight ahead. A mobile phone was strapped to the upper right arm of the participant and a headset placed on the participants head attached via lead to dictaphone placed on a table beside them. The phone recorded the participant’s x,y and z axial movement via mobile App Sensor Kinetic Pro. The axial movement for each participant was then converted, post study from a csv. file, recorded by Sensor Kinetic Pro, into an excel file where an avm was calculated for each participant. The mobile was turned on in tandem with audio file being activated and kept recording until completion of all 6 conditions.

The wordlists were presented aurally via headset, whereby the headset recording instructed the participant what to do step by step. For each condition the instruction were as follows: to listen to a wordlist that will be orated twice; to then wait for 20 seconds to try and memorise as many words as possible before asked to recall these. After the 20 secs pause the participant
was then cued to recall out loud as many words as possible. The time period was 20sec for each wordlist. Each word was recorded in a data set by the experimenter. The conditions varied as follows:

**Condition 1:** There was no additional interference so the condition was just as mentioned above. The recording lasted 1 minute and 14 seconds. The wordlist consisted of a mix of 5 phonetic and 5 non phonetic words which were as follows:

<table>
<thead>
<tr>
<th>socks</th>
<th>hot</th>
<th>house</th>
<th>bun</th>
<th>hats</th>
</tr>
</thead>
<tbody>
<tr>
<td>colour</td>
<td>purple</td>
<td>cross</td>
<td>fly</td>
<td>flap</td>
</tr>
</tbody>
</table>

**Condition 2:** This proceeded similar to condition 1 but with the addition of white noise recorded over the whole recording on the headset. The recording lasted 1 minute and 27 seconds. The wordlist consisted of another mix of 5 phonetic and 5 non phonetic words which were as follows:

<table>
<thead>
<tr>
<th>shoe</th>
<th>whose</th>
<th>how</th>
<th>open</th>
<th>door</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>square</td>
<td>clap</td>
<td>sunlight</td>
<td>top</td>
</tr>
</tbody>
</table>

**Condition 3:** This proceeded also similar to condition 1 but with the addition of the participant having to massage a putty ball, held in the left hand, throughout the task. The recording lasted 1 minute and 21 seconds. The wordlist consisted of another mix of 5 phonetic and 5 non phonetic words which were as follows:

| moon | train | fan | knife | heart |
Condition 4: This proceeded also similar to condition 1 but with the addition of the participant closing her/his eyes throughout the task. The participants were advised to open their eyes for a split second if they felt wobbly or dizzy as they might feel off balance. The recording lasted 1 minute and 21 seconds. The wordlist consisted of another mix of 5 phonetic and 5 non phonetic words which were as follows:

<table>
<thead>
<tr>
<th>sword</th>
<th>sand</th>
<th>green</th>
<th>marble</th>
<th>tan</th>
</tr>
</thead>
<tbody>
<tr>
<td>caps</td>
<td>water</td>
<td>yeast</td>
<td>yoghurt</td>
<td>plait</td>
</tr>
</tbody>
</table>

Condition 5: This proceeded also similar to condition 1 but with the addition of the participant subjected to a strongly scented cotton pad with lavender oil, held in the left hand, throughout the task. The recording lasted 1 minute and 27 seconds. The wordlist follows:

<table>
<thead>
<tr>
<th>movie</th>
<th>ship</th>
<th>fanatic</th>
<th>dread</th>
<th>Wednesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>bus stop</td>
<td>Autumn</td>
<td>nut</td>
<td>eye</td>
<td>keep</td>
</tr>
</tbody>
</table>

Condition 6: This proceeded also similar to condition 1 but with the addition of the participant chewing strongly flavoured strawberry bubble gum. The recording lasted 1 minute and 28 seconds. The wordlist consisted of another mix of 5 phonetic and 5 non phonetic words which were as follows:

<table>
<thead>
<tr>
<th>when</th>
<th>if</th>
<th>possible</th>
<th>outside</th>
<th>blocks</th>
<th>other</th>
</tr>
</thead>
</table>
Data Analysis

A series of independent samples t-tests was conducted as a between subject factor and paired t-tests as a within-subject factor to reveal any significance between both groups. Of particular interest was 1.) difference between groups in recall with no interference; 2.) difference within group across each modality interference and 3.) difference in movement behaviour throughout listing, retention and retrieval of memory task for both groups. It was hypothesized that the avm for all children would be greater in the (TI) tasks in comparison to other tasks. It was also hypothesized that the (WD) group would show significantly greater memory recall in comparison to other (SI) tasks as it was expected that use of the putty ball would aid in the process of retrieval and rehearsal of new information.

Results

1.1. Performance difference in memory across trials

Analysis revealed that there was a statistically significant difference in memory performance between groups ($t(28) = -2.237$, $p < .001$) in trial 1(NI). The 95% confidence limits show that the population mean difference of the variables lies somewhere between -2.682 and -.118 therefore the null can be rejected. In addition, there was a statistically significant difference in memory performance ($t(28) = -3.150$, $p < .001$) in trial 2 with auditory interference. The 95% confidence limits show that the population mean difference of the variables lies somewhere between -3.301 and -.699 therefore the null can also be rejected. Finally there was a significant difference between groups ($t(28) = -2.145$, $p < .001$) in trial 3 with tactile interference. The 95% confidence limits show that the population mean
difference of the variables lies somewhere between -2.998 and -.069 therefore the null can be rejected. However there was no statistically significant difference in memory performance for trials 4 (VI), (t(28) = -.809, p < .05) CI (95%) -2.119 - .919; trial 5 (OI) (t(28) = .342, p > .05) CI (95%) -.999 – 1.319 and in trial 6 (GI) (t(28) = -.759, p < .05) CI (95%) -1.479 – .679 therefore the null is present for trials 4 to 6. Further analysis was conducted in order to examine if there were statistically significant differences across chronological age by removing data from the 8-10 year olds.

**Table 1**

*Descriptive statistics for memory trials between (WD) and (WO) groups.*

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{x}$</td>
<td>-.1400</td>
<td>-2.00</td>
<td>-.1533</td>
<td>-.600</td>
<td>.200</td>
<td>-.400</td>
</tr>
<tr>
<td>SD</td>
<td>.626</td>
<td>.635</td>
<td>.715</td>
<td>.742</td>
<td>.586</td>
<td>.527</td>
</tr>
</tbody>
</table>

*Table 1* above displays the descriptive summaries for the data collected from each memory condition for those participants both with and without Dyslexia. *Table 2* below shows a weak correlation in the olfactory condition detecting poor correlation but true differences detected in moderate correlations between the group scores in the auditory; visual and gustatory scores and a strong correlation in the tactile condition between groups.

**Table 2 - Between groups**
Paired Samples Correlations

<table>
<thead>
<tr>
<th>Pair</th>
<th>N</th>
<th>Correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 None &amp; Auditory</td>
<td>30</td>
<td>.480</td>
<td>.007</td>
</tr>
<tr>
<td>Pair 2 None &amp; Tactile</td>
<td>30</td>
<td>.545</td>
<td>.002</td>
</tr>
<tr>
<td>Pair 3 None &amp; Visual</td>
<td>30</td>
<td>.325</td>
<td>.079</td>
</tr>
<tr>
<td>Pair 4 None &amp; Olfactory</td>
<td>30</td>
<td>.283</td>
<td>.130</td>
</tr>
<tr>
<td>Pair 5 None &amp; Gustatory</td>
<td>30</td>
<td>.335</td>
<td>.070</td>
</tr>
</tbody>
</table>

Descriptive statistics for conditions 1-6

A series of paired samples t-tests was also conducted in order to examine if there were statistically significant differences in memory performance following interference within each group.

Table 3 below displays the descriptive summaries for the data collected from each memory condition. It is apparent from Table 1 that the highest mean score for the (WD) group was obtained for condition 1(NI) ($\bar{x} = 4.93$, $SD = 1.792$) whilst the lowest mean score was obtained for condition 2 (AI) ($\bar{x} = 2.33$, $SD = 1.175$).

Table 3

Descriptive statistics for memory trials for children (WD).
Table 4 below displays the descriptive summaries for the data collected from each memory condition for those participants without Dyslexia. It is apparent from Table 4 that the highest mean score as in Table 3 was obtained for condition 1(NI) (\(\bar{x} = 6.33\), SD = 1.792) whilst the lowest mean score was obtained for the (OI) condition (\(\bar{x} = 3.60\), SD = 1.724). Furthermore, although recall of list one improved from the first trial to the second trial, mean scores indicates that the performance declined following interference. Further analysis was conducted in order to examine if there were statistically significant differences.

Table 4

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\bar{x})</td>
<td>6.33</td>
<td>4.33</td>
<td>4.40</td>
<td>4.47</td>
<td>3.60</td>
</tr>
<tr>
<td>SD</td>
<td>1.633</td>
<td>2.160</td>
<td>2.293</td>
<td>2.200</td>
<td>1.724</td>
</tr>
</tbody>
</table>

1.2. Performance differences in (AVM) across trials

An independent samples t-tests was conducted to examine if there were statistical significant difference in (AVM) between groups. Analysis revealed that there was no significant difference in (AVM) between groups (t(19) = -2.237, p > .001) in trial 1 (NI). The 95% confidence limits show that the population mean difference of the variables lies somewhere between -17523.718 and 42933.222 therefore the null is present. However when an independent t test analysis was conducted to look for any significant difference between
(AVM) and word recall between both groups a difference was discovered (t(19) = -2.395, p < .001). The 95% confidence limits show that the population mean difference of the variables lies somewhere between -10.03473 and -0.69597 therefore the null can be rejected.

(WO) (AVM) recording 0-240secs of participants y1, y2, y3 & y4.

![Graph](image1)

Figure 3. An (AVM) measurement of 4 participants from the (WO) group who demonstrated individual physical movement in response to different conditions in the experiment (0-75sec (NI) task; 80-155 (AI) task; 160-235 (TI) task).

(WD) (AVM) recording 0-240secs of participants x1, x2, x3 & x4.

![Graph](image2)
Figure 4. An (AVM) measurement of 4 participants from the (WD) group who demonstrated individual physical movement in response to different conditions in the experiment (0-75 sec (NI) task; 80-155 (AI) task; 160-235 (TI) task).

1.3. Performance difference on an individual basis across trials.

Though analysis revealed a significant difference between groups in (AVM) some (WD) participants moved a lot less than many (WO). Similar results were found in Ramus’s study (2003) revealing marked individual difference for the dyslexic learner and suggests perhaps that movement both aids in, and also distracts, learning (Nicolson, et al., 1999). Despite significant findings between groups there were individual differences both between and within groups for (NI), (TI), (AI), (VI), (OI) & (GI) again marking the variant ways of learning on an individual level.

1.4. Phonetic and non-phonetic performance.

There was similar results for both groups in what words were recalled such as ‘movie’ (13) and ‘daughter’ (13) followed closely also by ‘purple’ (12) ‘socks’ (11) and ‘hot’ (11) for the (WD) group and for the (WO) group ‘socks’(14) and ‘hot’ (14) followed closely by ‘daughter’ (13) ‘moon’(12), ‘movie’(12) and ‘hot’(12). These words may have echoed for these participants explicit memories or desires and have little to do with phonemes or alphabetic cues. Though the study was not interested in investigating what items each participant attended to individually it is of interest to point out what may provoke retention.
The study did demonstrate however that where the (WO) group remembered almost as many phonetic words as non-phonetic

Ideally the control and experimental groups should have performed at the same level for at least one of the conditions of the experiment. It was expected like in many other studies that this would be the case for the (NI) task however it was this very task that differences were found. This is an unexpected result. A further analysis was run between groups for the participants aged between 10 and 12 yrs old only. A significant difference was found in the (AI) which is a more expected result whereby the (WD) group recalled significantly less words than in a (NI) condition $t(19) = 2.236, p < .027$.

1.5. Descriptive statistics for chronological memory trials between control and experimental groups.

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Trial 5</th>
<th>Trial 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{x}$</td>
<td>-.909</td>
<td>-2.182</td>
<td>-1.182</td>
<td>-.727</td>
<td>.364</td>
<td>.091</td>
</tr>
<tr>
<td>SD</td>
<td>.755</td>
<td>.634</td>
<td>.859</td>
<td>.993</td>
<td>.741</td>
<td>.608</td>
</tr>
</tbody>
</table>

Discussion

Snowling (2000) proposed that studies on dyslexia tend to look at the analysis between reading age cohort or chronological age but never of both. Here by doing both a marked difference was found between assessing (WD) and (WO) between reading and chronological age which leaves large implications for designing studies in this field and supporting a strong auditory deficit for this SLD. Other studies found that only with chronological age was an auditory difference found between both groups (Goswami et al.,
2002; Muneaux et al., 2004). Significant differences however were found between both
groups in the (AI) and (NI) conditions. Analysis of individual data in this sample reveals that
9 out of 15 dyslexics have a deficit within this (AI). This could explain the ‘selective hearing’
myth of the classroom whereby selective ‘attention’ deficits on early neural processing rather
‘selective hearing’ could have consequences child’s ability to respond to instruction (Stevens
et al., 2013). Our acoustic environment is said to be different everywhere always with some
ambient noise present and especially for children (Cohen, Glass & Singer, 1973). For
children in school, slowing down instructional speech and enunciating words provides better
clarity for understanding. Learning supports could factor in blocking out noise perhaps by the
use an FM device, as this would isolate the teacher’s voice and reduce background noise
(Hornickel, Zecker, Bradlow & Kraus, 2012). In supporting literacy development for
learners with dyslexia the focus here could be on removing the obstacles of learning by
reducing the interferences as opposed to trying to ‘fix the problem’; taking the child out of
the pram so that it can learn how to walk confidently rather than expecting the child to walk
when strapped in to the pram.

A number of other observations can be made. The findings within this study repeat
similar findings of other studies (Rosen, 2003; White et al., 2006) by showing that only
certain persons with dyslexia are affected by sensory and motor interferences which may
indicate impairments in those conditions. It also shows sensory motor interferences with
those children without a diagnosis of any SLD. When subjected to (VI), (OI) and (GI) both
groups showed little difference in recall in comparison to their recall rates of the (NI) and
(AI). Interestingly scores for both groups in recall by blocking out the visual gaze did not
show enhanced performance by reducing cognitive load (Vredeveldt, Hitch & Baddeley,
this was due to capacity or lethargy as the tasks progressively exhausted both but where some
participants waned in performance in both groups others remained consistent also in both groups, indicating individual difference across modality. Central capacity limits are useful in predicting which thought processes individuals can execute, and in understanding individual differences in cognitive maturity and intellectual aptitude (Cowan, 2010). Previous studies have looked at these phonological processing executions where superior temporal brain regions in processing speech sounds have been found to be under activated for persons with dyslexia.

Tests of working memory demonstrate practical limits that vary, depending demand and typically 3–5 chunks in children or young adults (Cowan, 2001). What was demonstrated in this study was a typical example of that with a few exceptions of greater/lesser performance ability. For most participants extreme effort is demonstrated in scores of above 5 words recalled and for one in particular a score of 29/30 in the first three conditions was quite remarkable. This one participant however declined dramatically in recall from the third condition scoring a zero in her fourth wordlist (VI), a two in her fifth (OI) and a four in the wordlist (GI). Curiously she was the only participant in the whole study to score both a ten/ten and a zero/ten. Perhaps this was due to capacity expenditure by over prescribing on the first three conditions and exhausted her capacity for storage and retrieval or maybe the particular (VI), (OI) and (GI) were of particular difficulty for her. Such an analysis can only here be an observation and any empirical understanding is beyond the scope of this study.

Other interesting observations on individual basis was that six of the (WD) participants performed higher with (SIs) than in the (NI) condition and seven from the (WO) did as well or better than the (NI) task showing again considerable differentiation in learning ability regardless of learning difficulty. This analysis highlights the multimodality of learning for the individual child which is of great importance in the classroom, as it is in everyday life.
Finally the (WD) remembered 25% more non phonetic indicating a marked difference in phonetic segmentation as Snowling’s (2000) hypothesis of probability in phonological memory deficits proposed. Ramus (2000) study would propose that the participants in the experimental group possible recalled this non phonetic word as is supposedly more readily retrieved from memory for people with dyslexia.

**Limitations and Future Directions**

Selecting a larger sample size would inevitably increase the validity of the differences found between the (WD) and (WO) groups. This would also highlight typical behaviours and individual difference for both groups. Greater (AVM) accuracy could be achieved by having both groups participate barefoot with the (AVM) detecting natural postural sway. Attaching the (AVM) measuring device to the torso would diminish random movements for the participant such as sudden scratching of the nose or using hand to block coughing as was observed in this study. A repeated measure design 6 weeks later with the same participants would factor in analysis of typical behaviour and rule out circumstantial evidence. Also a qualitative measure in the design could increase understanding of how both the (WD) and (WO) participants responded to all interferences. It would also be of interest for further studies if decay of memory would increase or decrease for the (WD) group with longer rehearsal times as there was a trend for some individuals within this group to shout out words from previous wordlists remembered indicating a longer delay in retrieval of information or perhaps coding information. This did not happen interestingly enough for any (WO) participant. The 20 seconds storage and retrieval times may be too short a window for the children with dyslexia.
Conclusion

It can be assumed from the paired sample t-tests and independent sample t-tests conducted in this experiment that actual interference occurred for both groups with the addition of interferences across the senses; sound, touch, sight, smell and taste but in particular by the interference of sound and touch for the children with dyslexia. This is an interesting result in that many children with dyslexia are advised to use stress balls or even blue tack or putty rubber as an aid to learning in the classroom (NEA, 2015). These results could mean that this task may in fact on the contrary be too distracting for children with dyslexia or it may indicate that having to stand relatively still on task completion is not a natural method of learning for the experimental group or indeed the control group either. This also could have ignored the comorbidity of additional SLDs, such as dyspraxia. With further research empirical discrimination between actual interference of (TI) on word recall between still and moving conditions may make more evidence of learning patterns for children in general as neurologist Nelson Cowan (2008) encouraged.

That a phonological deficit is just one aspect of many and that it is secondary to a more ‘basic auditory deficit’ (Ramus 2003) is possible in the interpretation of the data found for these 31 participants however poor performance within motor tasks (Fawcett, Nicolson & Dean 1999) and poor dual tasks such as balance (Nicolson & Fawcett, 1994) was not detected in this data therefore cannot support a magnocellular theory for all (Stein et al., 2001). There is an undeniable association between (AI) and word retrieval and rehearsal for the (WD) group across chronological age comparison.

For a person with dyslexia there is often a significant gap between potential and actual academic achievement often thus mislabelled as being “lazy” or “slow” and teachers expecting if the pupil tried harder the problem would be “fixed”. The frustrating part is as the learner tries harder they often give up or find ways to compensate to get by (Hughes, Ball,
Bissett & McCormack, 2015). It is the role of the educator, be it teacher or parent, to find ways to enhance individual ability in learning.

“Dyslexia is a different brain organization that needs different teaching methods. It is never the fault of the child, but rather the responsibility of us who teach to find methods that work for that child.” - Wolf, 2015.
References


