The relationship between attention and the development of early word reading skills in typically developing children and children at risk of reading difficulties

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Abstract

Several studies have reported attention to be a predictor of literacy outcomes and/or its precursors across different measures of attention (e.g., Sims & Lonigan, 2013; Wanless et al., 2011), however, the evidence is inconsistent (e.g., Steele, 2012; Shapiro et al., 2013). There is also evidence that attentional difficulties co-occur with reading and language difficulties in children (e.g.,Germano, Gagliano & Curatolo, 2010; Gooch, Hulme & Snowling, 2014) and there are suggestions that attention is causally linked to reading difficulties (e.g., Bosse et al., 2007; Facoetti et al., 2005; 2009). The present thesis sought to examine whether different sub-components of attention were unique concurrent and longitudinal predictors of variation in the emerging word reading in children, after controlling for established foundation skills for literacy. A second aim was to examine the attentional profiles of children from the sample identified as having a developmental delay in word reading and foundation literacy skills (i.e., at risk for reading difficulties) after the initial year of literacy instruction at school, through a case series.

Seventy-seven children in term 2 of Reception Year completed a set of tasks measuring foundation skills in literacy, visual and auditory attention (selective attention, sustained attention and attentional control). The sample was followed longitudinally over a period of 12 months, with their lexical and sublexical word reading skills assessed in Year 1 of school, together with their attentional skills.

Using stepwise regression analysis, it was found that selective attention accounted for a small but statistically significant variation in lexical word reading above and beyond well-established cognitive-linguistic predictors. Visual sustained attention, but not auditory, was a concurrent and longitudinal predictor of phonological awareness. In addition, attentional control was a concurrent predictor of phoneme awareness in Year 1. Finally, children at risk for reading difficulties exhibited a profile of multiple attentional difficulties with the most prominent being auditory sustained attention. It is suggested that sub-components of attention may play a differential role in the early acquisition of lexical and sub-lexical word reading accuracy. The theoretical and practical implications of these findings are discussed.

Declaration:

I, Emmanouela Chatzispyridou, hereby declare that, except where explicit attribution is made, the work presented in this thesis is entirely my own. Selected parts of the research have been presented in the following conferences:

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List of abbreviations

ACPT	Auditory Continuous Performance Task
ACPT Com.	Auditory Continuous Performance Task Commission Errors
ACPT Om.	Auditory Continuous Performance Task Omission Errors
ACPT Rt	Auditory Continuous Performance Task Reaction Time
BPVS	British Picture Vocabulary Scale
CELF	Clinical Evaluation of Language Fundamentals
DTWRP	Diagnostic Test of Word Reading Processes
DVSDpH	Dual Visual Search Distance per Hit
DVSFA	Dual Visual Search False Alarms
DVSTpH	Dual Visual Search Time Per Hit
E. W.	Exception word
EAL	English as an Additional Language
EWR	Early Word Reading
FSM	Free School Meals
HTKS	Head Toes Knees Shoulders
LSK	Letter Sound Knowledge
N. W.	Nonword
PA	Phoneme Awareness
R. W.	Regular Word
R.S.	Recalling Sentences
RAN	Rapid Automatized Naming
RV	Receptive Vocabulary
SWAN	Strengths and Weaknesses of ADHD symptoms
VCPT	Visual Continuous Performance Task
VCPT Com.	Visual Continuous Performance Task Commission Errors
VCPT Om.	Visual Continuous Performance Task Omission Errors
VCPT Rt	Visual Continuous Performance Task Reaction Time
VSDpH	Visual Search Distance per Hit
VSFA	Visual Search False Alarms
VSTpH	Visual Search Time Per Hit
YARC	York Assessment of Reading for Comprehension

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Chapter 1: Overview of the thesis

The current thesis aimed to investigate the role of attention in the development of early reading skills in typically developing children and children identified with a developmental delay in reading (referred to as 'at risk' for reading difficulties group). The starting point of this research was based around three main types of evidence. The first deals with accumulating evidence on the high co-occurrence and comorbidity of attention and reading difficulties (Germano, Gagliano & Curatolo, 2010). The second type of evidence comes from recent theoretical frameworks of reading (e.g., Bosse et al., 2007) which suggest visual attention as being causally linked to word reading difficulties (e.g., dyslexia). Finally, the third type of evidence comes from studies looking at attention as a predictor of variation in reading outcomes for typically developing children (e.g., Sims & Lonigan, 2013).

The literature review revealed there were only a limited number of longitudinal studies examining both auditory and visual attentional processing in relation to the acquisition of early word recognition skills in the same sample of young children. The evidence from existing research is largely inconsistent, possibly due to methodological differences across studies in terms of the attentional measures employed (reflecting differences in the conceptualization of attention), control tasks, and differences in the word recognition skills measured.

The unique contribution of this thesis to the literature lies with its longitudinal investigation of the contribution of different components of visual and auditory attention (conceptualized by Petersen and Posner, 2010) as independent predictors of variation in children's developing word recognition strategies (both lexical and sub-lexical) after controlling for established foundation skills in early word reading (phoneme awareness, letter knowledge and RAN). It also examines the possible influence of attention in literacy outcomes both directly and indirectly. Namely, not only does it study the predictive power of attention in accounting for variation in early word reading accuracy, but also in predicting variation in the foundations of early reading (i.e., phoneme awareness, letter-knowledge etc.). Finally, the hypotheses considered in this thesis were explored further using a case studies approach with a subgroup of children from the sample identified with early reading skills falling at the lower end of the normal distribution after one year of literacy instruction.

An overview of the main models of reading and its foundation skills is presented in Chapter 2, with a focus on word reading accuracy. Chapter 3 discusses the literature regarding the relationship between attention and reading skills, with a primary focus on developmental studies. Posner and Petersen's (1990) model of attention was employed as the framework through which different sub-components of attention were examined, in relation to early reading acquisition. Namely, 3 separate but interacting sub-components of attention were assessed: sustained, selective and attention control.

Chapter 4 presents the rationale, aims and research questions of the study as well as the results of a preliminary analysis separated in two parts (Developmental Changes and Predictors of Word reading). Children from one school in Greater London were tested in the Spring term of their Reception Year (Time 1) and followed longitudinally up to the Spring term of Year 1 (Time 2). Experimental paradigms appropriate for this age group were employed so as to measure visual selective attention, auditory and visual sustained attention, and attention control (inhibition control and shifting of attention). A behavioural teacher rating scale of inattention was also used. Baseline measures of foundation literacy skills were administered at both times. At Time 1, letter-sound knowledge, phoneme awareness, rapid naming and receptive vocabulary were assessed. At Time 2, the subtests from the Diagnostic Test of Word Reading Processes (regular, exception and nonword reading; DTWRP, Forum for Research into Language and Literacy, 2012) were used to assess word reading skills. A recalling sentences task (CELF4) was used as an additional language measure.

Chapters 5-7 present the concurrent and longitudinal results for sustained attention, selective attention and attentional control respectively, and their relationship with early reading development for children in the sample. In brief, visual selective attention was found to predict concurrently lexical word reading; visual sustained attention and attentional control accounted for unique variance in phoneme awareness. Chapter 8 presents the results of a series of case by case analysis examining the attentional profiles of children 'at risk' of reading difficulties. It was found that the at risk group had both quantitative and qualitative differences in their attentional skills compared to their typically developing peers. Chapter 9 discusses the findings from the research presented in this thesis and their implications for theory and practice. Limitations and suggestions for future research will also be considered.

Chapter 2: Word Reading development

2.1 Introduction

It is well documented and recognized that reading difficulties in children (e.g., dyslexia) can have a negative impact on their academic attainment (e.g., Bishop & Adams, 1990; Ehri, 1994; McGee, Prior, Williams, Smart & Sanson, 2002), and for some individuals with dyslexia, the experience of these early learning difficulties may also have an adverse social and psychological impact in adulthood (Maughan & Carroll, 2006; Mugnaini, Lassi, La Malfa & Albertini, 2009; St Clair, Pickles, Durkin & Conti-Ramsden, 2011; Nalavany, Crawan & Sauber, 2015). Furthermore, the field of reading research has come a long way in terms of effective interventions for reading difficulties, but individual differences in response to interventions mean further research is required to better understand the causal factors contributing to the variation in literacy development and outcomes.

In recent years the focus of research has moved 'beyond phonology' to consider multiple causal factors, including the role of broader oral language and non-linguistic cognitive skills (e.g., attention, speed of processing) in reading development and dyslexia (e.g., Pennington, 2006; Hulme & Snowling, 2009). In the longer term, it is hoped this research will inform education practice to improve the early identification of children struggling to learn to read and the efficacy of early intervention programmes.

2.2 Becoming a skilled reader

2.2.1 The Simple View of Reading

According to the Simple View of Reading (Hoover & Gough, 1990; Stuart et al., 2008) learning to read involves two interdependent processes: decoding words and language comprehension. Language comprehension is a skill that, for most children, develops "naturally" before they learn to read, and is an essential foundation for reading comprehension(e.g., Nation et al., 2010). However, most children need to be taught how to decode print, hence the strong emphasis of phonics instruction in literacy teaching during the early years of school. Two processes that a child needs to acquire in order to become skilled with word recognition are sight word reading/lexical word reading and phonically based decoding/sublexical word reading (Stuart, Stainthorp & Snowling, 2008). It is possible that when children struggle to decode the words in a text, they are not able to pay attention to the meaning of the word and comprehend text. Language comprehension, compared to word reading accuracy, only correlates weakly with reading comprehension in young children (Vellutino et al., 2007), becoming more important in the later stages of reading development.

This chapter will first consider developmental models of word reading development, starting with Frith's stage model of decoding, before considering Ehri's highly influential phase model of sight word reading development (Frith, 1985; Ehri, 1991; 1994). Both models were influenced by the study of the reading errors young children make when first learning to read.

When studying word reading development and causal explanations for reading difficulties, it is important to consider established theories of word reading which have a strong evidence base from research. Theoretical models try to explain and predict human behavior, and are typically developed on the basis of research, and then subsequent research will test their assumptions and predictions. In particular, theories of word reading try to explain in a systematic way how people learn to read and become fluent readers by taking into account different concepts and evidence from observations and/or research. Phonological theories of word reading development have a strong evidence base from longitudinal research, studies of dyslexia, and reading intervention research. This literature will be briefly reviewed in this chapter, before considering the limitations and gaps in the existing evidence.

Computational models of skilled visual word recognition (e.g. Dual Route model, Coltheart et al., 2001; 'Triangle' model, Plaut et al., 1996) simulate the reading system and processes involved when adults read words, and the behavioural findings from studies with cases of adults and children with disorders of word reading (acquired and developmental) (e.g., Hinton &Shallice, 1991; Castles & Coltheart, 1993; Harm & Seidenberg, 1999; Ziegler et al., 2008). Research typically examines the ability of the output of such models to fit data from experimental studies of human reading behaviour to establish how well the theory can explain this behaviour. Nonetheless, it should be taken into consideration that even if a computational model shows that a theory is ‘complete and sufficient’ this does not mean that it is also correct (Coltheart et al., 2001). However, they provide a framework through which novel findings can be conceptualized, and theories tested. This chapter will consider two highly influential models of skilled word recognition which have been used to conceptualise the development of the subcomponents of word reading in children and developmental dyslexia - the DRC model (Coltheart et al., 2001) and the connectionist Triangle model (Plaut et al., 1996).

2.2.2 Developmental models of word reading

2.2.2.1 Frith’s Stage Model

Frith’s (1985) stage model of reading acquisition explains how children learn to read words. According to this model, there are three separate stages where children rely on different strategies when presented with a written word to read aloud: the logographic, alphabetic and orthographic stages.

The Logographic strategy means that the reader recognizes the word by using salient graphic cues (i.e., recognizing McDonald’s by their logo). At this stage the order of the letters in a word does not affect reading (i.e., the child might recognize the word “Pepsi” by its graphic representation but will read the word “Pespi” in the same way). This is the strategy that beginner readers use.

The next stage is the Alphabetic, in which the reader starts using their emerging knowledge of grapheme to phoneme correspondence rules and is able to blend the sounds in order to read the word. Finally, the Orthographic stage is when the reader is now able to recognize larger parts of a word and read them as a whole. Namely, they are able to read strings of letters without decoding each grapheme separately (i.e., when reading the word “decode” the reader recognizes the morphemes “de” and “code”).

Frith (1985) proposed that learning to read is not a gradual process but that there is a qualitative change in strategies at each stage. This implies that the child is not just improving on one skill (e.g., decoding) but that they move on to a new strategy at the next stage (i.e., from Alphabetic to Orthographic stage).

One of the criticisms of this model is that it is incorrect to assume that reading develops in separate stages and that there is one strategy used during each of these stages (Stuart & Coltheart, 1988). Even skilled readers might use sublexical strategies to read unfamiliar words they encounter in print, whereas in Frith's model it is assumed that at the last stage of reading development the reader uses only lexical strategies(i.e., sight word reading). Similarly, some readers at the alphabetic stage, may start to show signs of attempts to use an orthographic strategy in early reading and spelling. Ehri's phase model(1991, 1994) of sight word reading is often favoured in the more recent literature as a theoretical framework to conceptualize the early developmental changes in children's early word reading strategies, describing a series of phases which are less rigid than Frith's stages.

2.2.2.2 Ehri's Phases Model

Ehri (1991, 1994) identified four strategies that people use when reading words; those are: decoding, analogizing, predicting and by memory. Decoding, analogizing and predicting are used for unfamiliar words and the fourth strategy is used for familiar-sight words. It should be noted that by "sight words", Ehri means all the words, regular and irregular, that are familiar to the reader. Through her model, Ehri explains how children learn to read sight words; or in other words, how they learn to read words automatically without having to attend to each letter/phoneme of the word. She suggested that readers learn sight words by gradually forming connections in memory between the graphemes and the phonemes in words, and highlighted the importance of letter-sound knowledge as a mnemonic system that secures the written form of a word and its pronunciation in the memory.

Four phases in the development of sight word reading were distinguished by Ehri (1991): the pre-alphabetic, the partial alphabetic, the full alphabetic and the consolidated alphabetic phase. In the pre-alphabetic phase, the reader has no knowledge of the alphabetic principle, but forms connections between the visual form and the pronunciation of words. For example, they might recognize their name but they are not aware of the different sounds that each letter represents.

In the partial alphabetic phase readers start to form some connections between letters and sounds. It is suggested that the reader is able to recognize some words using their partial letter sound knowledge. For example, they may be able to identify the initial and final sounds of words, suggesting their phonological awareness segmentation skills have started to develop. However, since they have incomplete orthographic knowledge in this phase, they are not able to decode all the letter-sounds.

In the full alphabetic phase, the reader is able to fully decode a word and also read unfamiliar words by analogy (i.e., by applying their previous knowledge of sight words onto the new word). They form connections between all the graphemes and phonemes and they are able to blend the sounds of a word and produce its pronunciation. However, they are still not fully accurate and tend to regularize irregular words.

During these phases children are developing their sight vocabulary by retaining the sight word in their memory and are establishing decoding processes. The development of these two skills depends on phonological awareness and knowledge of grapheme-phoneme correspondence rules (Stuart, Stainthorp & Snowling, 2008).

Finally, in the consolidated alphabetic phase the reader can consolidate letter patterns into larger units. In this way they are able to read the word quicker and also it is easier to retain it in their memory. For example, instead of having to remember four connections between letters and sounds in the word ‘nest’ (/n/, /e/, /s/, /t/), if the reader has reached the consolidated phase, they may be able to read this word by forming only two connections /n/ and /est/. During this phase their sight vocabulary continues to develop and the more they are exposed to print, the larger their sight vocabulary becomes.

It is suggested, based on the National Curriculum reading levels expectations (The national curriculum in England: Framework Document, DfE, 2014) that children in Reception Year are typically in the partial alphabetic phase, children in Year 1 in the full alphabetic, and in Year 2 in the consolidated phase. Nonetheless, these phases are not completely separate but overlap with each other. In contrast to stage theories, having "completed" one phase is not a prerequisite to move onto the next one. As children's reading develops they use strategies from different phases in order to read words. Children can now read sight words with accuracy and fluency.

Table 2.1: Summary of the main phases/stages of Ehri's (1991) and Frith's (1985) theories of reading

Development of reading	Frith's stages	Ehri's phases
Pre-reading	Logographic	Pre-alphabetic
Early reading	Logographic	Partial alphabetic
Decoding	Alphabetic	Full alphabetic
Fluent reading	Orthographic	Consolidated alphabetic

2.2.2.3 Share's Self-Teaching hypothesis

Share's (1995) self-teaching hypothesis is a theory about the role of decoding in sight word acquisition. It postulates that each time that a reader successfully decodes an unfamiliar word, he/she can acquire the orthographic information specific to this word, which is imperative in skilled word recognition. The basic argument of this theory is that phonological recoding/decoding acts as a self-teaching mechanism which allows a child to improve his/her orthographic knowledge independently, extending their knowledge of spelling patterns (orthography) beyond the limited set of phonic patterns taught through the structured phonics programmes in the classroom. According to Share (1995), this orthographic knowledge, in turn, is crucial for fluent and automatic reading.

Share (1995) highlighted that orthographic learning cannot be accomplished through direct instruction, contextual guessing and/or print exposure alone. The rationale behind that is that firstly by teaching children to read at a whole-word level, their attention is not focused on the orthographic details of the word; secondly, guessing words from the context is not efficient because in natural texts it is almost impossible to accurately guess the word; and lastly, because being exposed to print is not sufficient for the child to grasp the alphabetic principle.

The central features of this theory are the following:

1. Item based, not stage based
2. Lexicalization
3. Early onset
4. Phonology is primary and orthography secondary

Unlike the above mentioned models, Share's (1995) theory is not referring to stages or phases of reading development; instead, the self-teaching refers to specific items/words. All readers, regardless of their reading level (poor or skilled), may use both lexical and sub-lexical processes when reading. The differentiation lies on the fact that for familiar words, lexical processes are used more, and for unfamiliar words, the strategy used is decoding. This notion is similar to the dual route model of reading, which will be discussed later. Also, it has some similarities with Ehri's phases model as it is acknowledged that for unfamiliar words, the reader uses the alphabetic principle. Hence, beginner readers (in the partial and full alphabetic phase) use this strategy extensively as the majority of the words they encounter are unfamiliar due to limited print exposure.

The second feature of this theory is lexicalization. This concept refers to developmental changes in reading acquisition. It could be argued that it encapsulates the transition from the full alphabetic to the consolidated alphabetic phase (see above: Ehri, 1991). However, Share emphasizes that this is an "ever-changing and self-refining process", implying that the beginner reader is not able to assimilate the more advanced orthographic regularities. Nonetheless, as their word reading and therefore their print lexicon develops, they start understanding more complex orthographical correspondences and become more "lexicalized".

The third feature is that self-teaching has an early onset. This means that the children, after having developed their letter sound knowledge, some phonological awareness and the ability to use the context, are able to use phonological recoding as a self-teaching mechanism.

Finally, it is argued that phonology is primary and orthography secondary. As Share (1995) noted the phonological component (decoding) is the “sine qua non” of reading development. This means that it is impossible to become a skilled reader without being able to decode words at all. The orthographic component (lexical processes) also makes a unique contribution to word reading accuracy and fluency but it is secondary. Furthermore, it was maintained that “only phonology offers a functional self-teaching mechanism” (Share, 1995, pg. 169).

Even though this theory focuses on phonological recoding and its role on orthographic knowledge, Share (2008) found that more effective orthographic learning was influenced by working memory and cognitive style (specifically, reflective/less impulsive style) (cited by Share, 2011; pg. 60).In particular, the study aimed at examining factors that predict individual differences (in 80 3rd Grade children) in orthographic learning in shallow and deep orthographies. They found that rapid naming of digits and letters, meaning and syntax, did not account for variance in orthographic learning, but performance on measures of working memory and reflectiveness/impulsiveness appeared to influence orthographic learning.

2.3 Computational Models of Word Recognition

Computational Model's of Reading help researchers test and/or develop theoretical accounts of skilled reading, reading development and its difficulties. In the previous sections, some of the most influential models of word reading development were discussed in order to understand the strategies children need to acquire to become a skilled reader. In the following section, the most prominent nonconnectionist and connectionist computational models of skilled word reading are reviewed (Coltheart et al., 2001; Plaut et al., 1996; Seidenberg & McClelland, 1989). These models have been used by developmental theorists to conceptualize the processes involved in children's word recognition skills, particularly those experiencing difficulties learning to read (i.e., dyslexia) (e.g., Griffiths &Snowling, 2002; Harm & Seidenberg, 2004; Castle & Coltheart, 2004).

2.3.1 The Dual Route Model

According to the dual route model (Coltheart al., 2001), skilled readers employ two routes when reading words aloud. Through the direct route (lexical route) words are read as a whole and information is processed in parallel. Specifically, orthographic and phonological representations are activated in the memory when presented with a written word. The phonological route (sub-lexical route) is used in order to break down a word into its component sounds by using the grapheme-phoneme correspondence rules. The sub-lexical route is using serial processing of information as the reader processes the letters serially from left to right in order to "produce" the pronunciation of the word of unfamiliar letter strings. These two routes are activated in parallel and though separate they interact with each other.

The lexical route in skilled readers is used when reading familiar words (regular words, e.g., cat, pink, dragon; or irregular, e.g., pint, head, yacht) and the sub-lexical when reading unfamiliar words, assessed in research by lists of nonwords or pseudowords (e.g., jeal). The reader searches for the word in their mental lexicon, and in the case of real words and skilled readers these words will be present in this lexicon. The mental lexicon is comprised of 3 separate units representing the orthographic, the semantic and the phonological lexicon (spelling, meaning and pronunciation, respectively). However, in the case that the reader is presented with a non-familiar or a nonword, they will have to employ the sub-lexical route in order to read it accurately.

Beginner readers rely more on the sub-lexical route as their mental lexicon is not developed yet. However, it has been suggested (e.g., Jackson & Coltheart, 2001) that even beginner readers have a mental lexicon (even if it is not fully developed) and that the differences are quantitative, namely the difference lies in the number of words stored in the mental lexicon.

The dual route model manages to explain a range of phenomena in word reading, both in normal reading and in disorders of reading. Even in skilled readers, the reading times for exception words are typically slower than those for regular words (e.g., Rastle & Coltheart, 1998). According to the dual route model this is explained by the fact that that the two routes provide the reader with conflicting information. The pronunciation of the word differs if the reader uses the grapheme-phoneme correspondence rules to when he/she uses their mental lexicon. Hence, the reader in order to resolve this conflict needs more time and their reaction time when reading an exception word is longer. It also explains findings suggesting that low frequency words are read slower than high frequency words. Again, it is quicker for the reader to find a high frequency word in their mental lexicon (e.g., Tiffin-Richards & Schroeder, 2015).

This model also accounts for findings of studies regarding both developmental and acquired dyslexia. In the case of acquired dyslexia it has been found that people with surface dyslexia can read regular words and nonwords accurately but not exception words (Rapcsak & Beeson, 2004). These findings fit the dual route model as it suggests that regular and nonwords can be read through the phonological sub-lexical route. However, exception words cannot be read through this route but only through the lexical route (using the mental lexicon). As far as people with acquired phonological dyslexia are concerned, studies show that they can read regular and exception words but not nonwords (Coltheart, 1996). This is explained by the fact that regular and exception words can be read through the lexical route. However, nonwords can only be read through the sub-lexical route.

In the case of developmental dyslexia, there is evidence showing that some children with dyslexia struggle with nonwords (sub-lexical route) but their reading skills for regular and exception words (lexical route) are normal for their age and vice versa (Stothard, Snowling & Hulme, 1996; Castles & Coltheart, 1993). The first subgroup is considered to exhibit ‘phonological dyslexia’ and the second (i.e., normal exception and abnormal nonword reading) described as ‘surface dyslexia’. The validity of this theoretical model is reinforced by the computational Dual-Route Cascaded (DRC) Model (Figure 1). This model can simulate features of acquired dyslexia, and differences between reaction times when reading high and low frequency words, real words and nonwords, regular and exception words, pseudohomophones and non-pseudohomophones, short and long nonwords. It can also simulate the following phenomena: position of irregularity effect, the effect of regularity (mean latencies for high frequency exception words longer than for regular words), the effect of priming and the effect of the number of orthographic neighbours for a nonword.

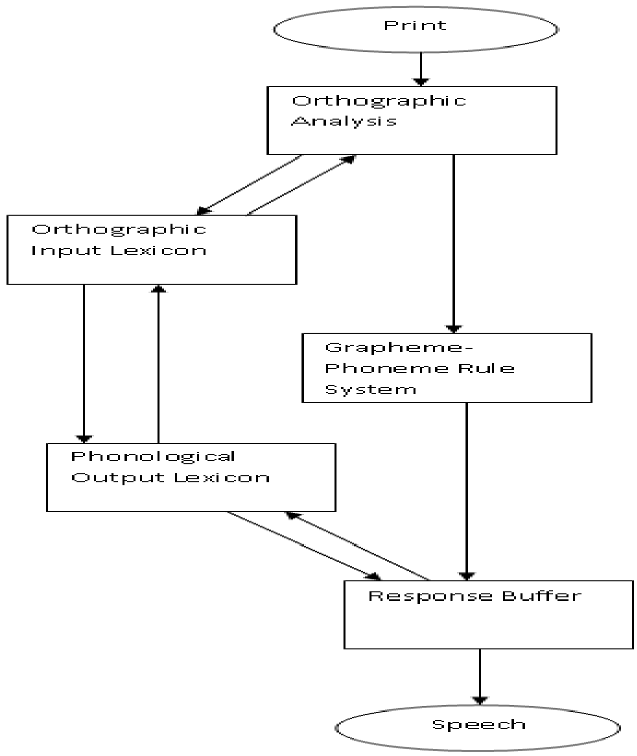

Figure 1: The Dual Route Cascaded (DRC) model for visual word reading (adapted from Coltheart et al., 2001)

Individuals with surface dyslexia tend to make regularization errors with exception words (Coltheart et al., 1983), however, Bryant and Impey (1986) suggested that 'surface dyslexia' type errors are made by typically developing children. Coltheart's approach has been criticized as in further studies only a few participants with a surface dyslexia profile were identified (see Manis et al. 1996; Stanovich et al., 1997).

It has also been suggested that regular word reading accuracy can be predicted using this model if we know the reading accuracy abilities of the reader on exception words and nonwords (Coltheart et al., 2001; Castles, Bates & Coltheart, 2006).

Overall, findings from studies both in normal reading and reading difficulties fit the dual route model. However, the DRC model has received criticism and has several limitations. As Coltheart (2001) highlighted one of the criticisms is whether the model is falsifiable (i.e., whether it is capable of being tested). The criticism is that if a model explains everything then the reality is that it explains nothing. Coltheart noted that the number of the parameters of the model were entered so as to explain one set of data and then other sets of data fitted the model as well (see Coltheart, 2001), providing further support for the theory. Other limitations of the DRC model are that it processes only monosyllabic words and it does not manage to account for masked priming effects. Moreover, the amount of variance of word reading reaction times that it accounts for is very low and the difference between the reaction times of word and nonword reading (by the model) is extremely large. Finally, this model is silent as to how children learn to read as it describes the end-point of reading development.

2.3.2 Connectionist models of skilled word reading: The Triangle model

Seidenberg and McClelland's (1989) SM89 model was one of the first connectionist models of skilled word recognition processes (also known as the Triangle Model) reported in the literature. It aimed to provide an account of the processes involved in word recognition in English, by simulating the behaviour observed from experiments with adults who had acquired dyslexia.

Subsequent connectionist models of reading have tried to consider word reading development (e.g., Seidenberg, 2007) by modeling profiles of developmental dyslexia (e.g., Harm & Seidenberg, 1999; also see Griffiths & Snowling, 2002). In line with the Dual route model, the connectionist triangle model is a model of reading aloud single words. The cognitive processes involved in reading are represented by units that are like neurons interacting with each other. The processing of the word is distributed in parallel. These units form a network in which activation begins by the orthographic representation of a word and spreads to other units (i.e., to phonological representation units). In other words, when the reader is presented with a word, different units are activated and there are interactions in the phonological pathway (print to speech) and the semantic pathway (print to speech via meaning). There are separate units for orthographic input and phonological output. The coloured units (see Figure 2) represent previous knowledge that influences the interactions between the input and output. The connections between the units influence the amount of activation which passes on the other units and they contain information regarding spelling-sound mappings. The words are seen as patterns which are distributed across the different units.

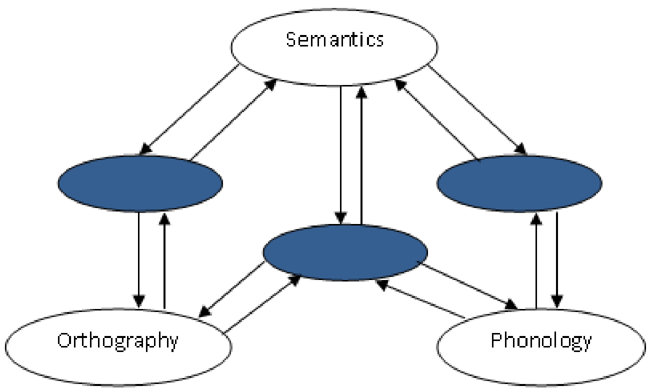

Figure 2. Triangle model of reading (adapted from Plaut et al., 1996)

In the computational triangle model of reading, relationships between orthography and phonology are learnt by presenting the printed form of the word, pronouncing it and then receiving feedback with the correct pronunciation. This way the system learns the correct pronunciation of the word. The hidden units are responsible for the learning that takes place in the network and they enable the model to learn to generalize its knowledge. Performance improves gradually, simulating children's learning.

Plaut et al. (1996) argued that the triangle model provides detailed information regarding the effects of word frequency and consistency both in normal reading and reading difficulties (e.g., acquired phonological and surface dyslexia). Specifically, this model suggests that in phonological dyslexia there is impairment on some parts of the phonological pathway, and a limited ability to generalize previous knowledge to new words. In surface dyslexia, it is suggested that the semantic pathway is damaged and that is why exception words cannot be read accurately; whereas, the phonological system is over-specialized for the pronunciation of regular words. Finally, this model manages to simulate the processes involved in children's learning to read words as there is a gradual increase in the knowledge provided to the computational model, in contrast with the DRC which simulates the reading of adults, namely, the endpoint of development.

2.3.3 Comparison of the Dual Route and the Connectionist Model of Reading.

The two models have various differences (Coltheart, 2006; Seidenberg, 2007; Treiman & Kessler, 2007). Firstly, in the dual route model the processing of the printed word is taking place serially. Namely, the reader starts processing the letters one by one starting from left. Whereas, according to the connectionist model the processing is in parallel, meaning that when presented with a printed word, several units of the reading system are simultaneously activated. It is worth noting that one of Coltheart's (2006) criticisms is that not all processing is parallel and as an example he referred to the effect of irregularity which is not simulated by the triangle computational model. Length effects are also not accounted for by the triangle model and it has been argued that this is evidence in favour of serial processing (Coltheart et al., 2001). However, it has also been suggested that these effects are generated by visual processes; those 'serial effects' can be produced by parallel models and explained by visual processing (Seindenberg & Plaut, 1998; Chang, Furber & Welbourne, 2012).

In addition, the dual route model suggests that each word corresponds to a specific unit in the lexicon in contrast to the connectionist model which postulates that the representation of words is distributed between several units and that each of these units represents parts of many different words. Nonetheless, it has been argued that not all processing is parallel, because if we assume that it is, then performance on lexical decision tasks cannot be explained. Specifically, he suggested that according to the dual route model, the representation of a word can be directly activated in the orthographic lexicon. However, he suggested that according to the connectionist models the different units that represent a word will be activated by both real and nonwords; and that lexical decision would not be possible to be achieved only through the semantic system as in that case people with semantic impairments would not be able to perform accurately in lexical decision tasks, which is in contrast with what has been previously found (Coltheart, 2006). According to the dual route model, nonword reading is achieved by applying pronunciation rules to the graphemes of the nonword; whereas in the triangle model, nonwords are read by analogy to similar whole words or parts of words, as the nonwords are typically treated as very low-frequency words.

Finally, the dual route model refers to skilled readers, whereas the connectionist model attempts to explain how learning takes place. In the connectionist model, the orthographic and phonological representations of words are presented to the computational model and reading is developed over a period of time. However, it has been argued that even though connectionist models are trying to explain learning, they are not accurate in regards to children's learning. In particular, it is argued that the model needs to be exposed thousands of times to a word in order to learn it, which is not valid for children. In addition, Coltheart noted that even when the model is presented with small sets of words (which is similar to how children are taught), it again fails to simulate children's learning as it tends to forget the words taught in previous sets, which is not what happens with children.

Seidenberg (2007) acknowledged the limitations of the 'Triangle' Connectionist computational model. Specifically, it was noted that the fact that there is feedback provided for each word is not ideal as when children learn to read there is not always direct corrective feedback. He also noted that there is over-simplification is some aspects of the model, nonetheless, he argued that it "may not be necessary to simulate any given child's exact experience in order to capture basic facts about the learning process" (pg. 8).

In support of the Connectionist model, Seidenberg (2007) also argued that it provides an insight into the causes of reading difficulties as it is developmental, and that it is theory driven, allowing the conceptualization of findings in a theoretical framework (in contrast to the DRC model which is data driven, i.e., tailored to reproduce the results of particular studies).

2.4 Summary

Both of the computational models manage to simulate human reading behaviour (normal reading and reading difficulties) and have been influential in conceptualizing individual differences in reading in typically developing children and children with reading difficulties (Treiman & Kessler,2007).

Nonetheless, one of the important differences (which is also specific to the purposes of this thesis) between the DRC and the triangle model is that the latter gives us an insight on how people *learn* to read (represented by the hidden units). Another difference is that the Dual Route model has separate lexical and sub-lexical paths, whereas these two paths (directly from orthography to phonology or indirectly via the semantics path) in the triangle model are closely related and operate in parallel. Both models have limitations and the decision regarding which model to use depends on the research questions. Namely, when considering the development of reading it might be more appropriate to employ the connectionist model.

2.5 Predictors of word reading

2.5.1 Introduction

The next section will consider the challenges children face when learning to read and the foundation skills required to be ready to learn how to read when formal instruction begins at school.

The main challenge facing children learning to read in English, is mastering the alphabetic principle (Perfetti & Marron, 1998). According to (Byrne, 1998) the 'alphabetic principle' refers to acquiring an understanding that words are made of letters which represent sounds and the ability of the early reader to use this knowledge in order to phonologically recode words. Byrne (1998) highlighted that "*It is far from obvious why words like* dog *and* den *are written the way they are and discovering why they are is not trivially easy"* (pg. 1). It has also been acknowledged that phonological processing and letter-sound correspondences knowledge are "essential if students are to progress in their knowledge of the alphabetic writing system and gain the ability to read fluently and broadly" (Texas Center for Reading and Language Arts, 1998).

There is a strong body of literature demonstrating that the most important foundation skills for early reading are spoken language skills (receptive and expressive vocabulary, phonological awareness skills (e.g., Nation & Snowling, 2004; Hulme, Bowyer-Crane, Carroll, Duff & Snowling, 2012) and understanding of the alphabetic principle and print concepts (e.g., Whitehurst & Lonigan, 1998; Durand et al., 2005; Muter et al., 2004; Bishop et al., 2009).

The following sections attempt to answer in detail these questions (i.e., what are the challenges facing children and what are the foundation skils for reading) by drawing evidence from longitudinal and cross-sectional studies regarding word reading accuracy as well as intervention studies.

2.5.2 Cognitive linguistic predictors of reading

2.5.2.1 Phonological awareness[1], letter-sound knowledge and RAN[2]

The importance of phonological awareness, letter sound knowledge and rapid automatized naming (RAN) in reading development has been robustly studied and there is strong evidence regarding their role as predictors of later word reading skills both in typical and atypical development, and across orthographies (e.g., Muter, Hulme, Snowling & Stevenson, 2004; Lervag, Braten & Hulme, 2009; Kirby et al., 2010; Caravolas et al, 2012). In this section, studies examining the role of phonemic awareness, letter-sound knowledge and RAN on reading will be discussed as well as those which challenge their importance in reading acquisition. The focus will be evidence from longitudinal and intervention studies as well as from studies looking at reading difficulties.

The longitudinal relationship between phonological awareness and later reading skills has been reported as significant and positive by a large body of research (Lundberg, Olofsson & Wall, 1980; Bradley & Bryant, 1983; Wagner &Torgesen, 1987; Torgesen, Wagner & Rashotte, 1994; Wagner et al., 1997; de Jong & van der Leij, 1999, Furnes & Samuelson, 2010; for a meta-analysis see Melby-Lervag, Lyster & Hulme, 2012). Additional evidence in favour of the hypothesis that there is a causal relationship between phonological awareness and word reading has been provided essentially from intervention studies (Ball & Blachman, 1991; Hatcher, Hulme & Ellis, 1994; for a meta-analysis see Ehri et al., 2001).

There is also strong evidence that the relationship between phonological awareness and learning to read is bidirectional (e.g., Compton, 2003). As Shaywitz (2003) noted "reading and phonemic awareness are mutually reinforcing: Phonemic awareness is necessary for reading, and reading, in turn,

[1] Phonological awareness is the ability to perceive and manipulate speech sounds within spoken words (Goswami & Bryant, 1990). Phonological awareness can include awareness that spoken words in English consist of different size units of sound (rhymes, syllables and phoneme). Studies have critically looked at which unit is the most important predictor of early word reading development (Goswami & Bryant, 1990; Lervag, Lyster & Hulme, 2012)

[2] Rapid Automatized Naming tasks (RAN) measure the speed with which individuals can name a series of familiar verbal stimuli (i.e., letters, digits, colours or pictures).

improves phonemic awareness still further" (pg. 55; also see Wagner et al., 1994; 1997).

Longitudinal studies have reported letter sound knowledge and phonemic awareness as independent predictors of early word reading and reading accuracy and fluency in older children and across orthographies (Muter, Hulme, Snowling & Stevenson, 2004; Kibby, Lee & Dyer, 2014; De Jong & van der Leij, 2002). Nonetheless, Blaiklock (2004) found that the predictive power of phoneme awareness on word reading became insignificant when controlling for letter knowledge. In the same study, letter sound knowledge was a significant predictor of reading even after controlling for the autoregressive effects (i.e., after controlling for letter knowledge at Time 1). It was suggested that letter knowledge and phoneme awareness may overlap and that the relationship between PA and reading might be mediated by letter sound knowledge.

Furthermore, letter knowledge has been shown to be a prerequisite for learning to read. It has been found to be the best predictor of later word reading skills (Adams, 1990; Wagner, Torgesen & Rashotte, 1994; for review see Hammill, 2004). In addition, letter-sound knowledge has been found to predict word reading even after controlling for letter name knowledge (Mann & Foy, 2003).

RAN has also been reported as a strong predictor of fluency, and phonemic awareness of decoding (Schatchneider et al., 2004; Moll et al., 2014); poor performance in RAN tasks has also been linked to poor performance on reading fluency tasks (Wimmer, 2010). However, Moll et al. (2014) found that English, when compared to 4 other languages (German, French, Hungarian and Finnish), was the only orthography where RAN was a significant concurrent predictor of reading accuracy above and beyond phonemic awareness.

Furthermore, rapid naming has been reported to become a stronger predictor in later grades (up to Grade 5) whereas phonological awareness becomes a weaker predictor losing its effect after Grade 2 (Kirby, Parrila & Pfeiffer, 2003). It was suggested that these results might indicate that rapid naming is possibly related to orthographic abilities and phonological awareness becomes less important because in later grades children shift from a phonetic to an orthographic approach. Similar findings have been reported by several studies proposing that RAN is more related to orthographic knowledge, which is essential to fluent, sight word reading, than to phonemic awareness, important for early, alphabetic skills and phonic decoding (e.g., Aarnoutse, van Leeuwe & Verhoeven, 2005; Clarke, Hulme & Snowling, 2005; Shapiro, Carroll & Solity, 2013). There is also general agreement that the cognitive skills underlying the relationship between RAN and reading include lexical access skills (Logan, Schatschneider & Wagner, 2011).

Rapid naming has been characterized as a microcosm of reading as in both tasks people have to attend serially to stimuli and access their mental representations (Kirby et al., 2010; Lervag & Hulme, 2009; for a review see Norton & Wolf, 2012).

It is worth noting that there is still no consensus regarding which cognitive skills underlie this relationship. RAN tasks have been suggested to tap executive processes (Stringer, Toplak & Stanovich, 2004; Clarke, Hulme & Snowling, 2005), visual attention span (Bosse, Tainturier & Valdois, 2007), phonological representations (Wimmer, Mayringer & Landerl, 2000), timing mechanisms and rapid serial processing (Wolf, Bowers & Biddle, 2000) as well as speed of processing (Kail, Hall & Caskey, 1999). There is need for further research which would look more closely at all the possible cognitive skills that are need in order to perform well in a RAN task. It could be the case that RAN taps on several skills as is the case for many other cognitive tasks (usually referred to as 'task impurity').

Studies of children with reading difficulties using group or correlational designs support the view that phonemic awareness and RAN are predictors of reading. Evidence suggest that phonological deficits are a cause of reading problems both in English and other languages (Vellutino et al., 1996; Olofsson & Niedersoe, 1999; Snowling, 2000) and that also found that RAN skills are persistently poor (over time) in children with reading difficulties (Powell, Stainthorp & Stuart, 2014).

Melby-Lervag, Lyster and Hulme (2012) in a meta-analytic review of group comparison and correlational studies with children with dyslexia and typically developed children found that phonemic awareness was the strongest predictor of individual differences in word reading, even after controlling for verbal short term memory and rhyme awareness.

More recently, Van Bergen, de Jong, Maassen and van der Leij (2014) conducted a longitudinal comparative study in Dutch with a group of preschool children at family risk for dyslexia (n=132) and a control group (n=70). They followed the participants in Grades 2 and 3. Out of the family risk group 50 children (38%) developed reading difficulties. They found that the at risk group with dyslexia performed worse in letter knowledge, rapid naming and phoneme awareness tasks and the at risk group without dyslexia also had a mild deficit in their phonological awareness skills but not in RAN and letter knowledge. The at risk groups (both with and without dyslexia) were poorer in reading fluency than the control group, but the at risk group without dyslexia performed within the average range on this measure.

Their results were argued to be in line with the double-deficit hypothesis (Wolf & Bowers, 1999) and that the pattern of the results for the at risk group without dyslexia might indicate that their phonological awareness difficulties hinder the development of their orthographic knowledge which would enable the child to become a fluent reader (also see Share's self teaching hypothesis); but because of the fact that their phonological processing and recall skills are intact, they are able to compensate for their difficulties and perform within the normal range. Whereas, the results for the at risk with dyslexia group show that the participants have a deficit in both areas. It is also worth noting that phonological awareness is a unique predictor of word reading accuracy across orthographies.

Intervention studies have revealed that phonemic awareness training has a significant positive impact on reading skills (Schneider, Roth & Ennemoser, 2000; for a metanalysis see Suggate, 2014). Similar results have been reported for interventions using letter sound knowledge training (in Hebrew; Levin, Shatil-Carmon & Asif-Rave, 2006). Combined training on phoneme awareness and letter-sound knowledge has also been reported as an effective intervention for reading difficulties and has also been suggested being more effective than phonological awareness training alone (Hulme, Bowyer-Crane, Carroll, Duff & Snowling, 2012).

There have also been alternative views challenging the hypothesis that phonological awareness is causally linked with reading difficulties. Castles and Coltheart (2004) in their review argued that there is no 'unequivocal evidence that there is a causal link from competence in phonological awareness to success in reading' (pg. 77). It was argued that a longitudinal correlation does not necessarily indicate causation as there is the possibility that a third factor accounts for this correlation. Moreover, this effect had to be specific to reading only and not other academic abilities and also the improvement in reading had to be specifically on letter sound correspondence skills.

Hulme, Snowling, Caravolas and Carroll (2005) argued that there is no reason why this training should be particular in letter sound correspondence skills only. Another requirement that seems to be unnecessary is that the children receiving training should be pre-literate with no letter sound knowledge at all. In agreement with Hulme et al. (2005), it is suggested that letter sound knowledge might moderate the relationship between PA and reading, but this does not imply that PA does not have a causal role on word reading.

In addition, there have been studies that have questioned the predictive power of RAN tasks in terms of later word reading performance. Swanson, Trainin, Necoechea and Hammill (2003) conducted a meta-analysis of correlation evidence. They included 35 studies reporting the relationship between RAN, PA and word reading. They found that the correlations between RAN, PA and word reading were as moderate as the correlations between vocabulary, orthography, memory, IQ and word reading. They also reported that the correlations between RAN, PA and word reading were weaker in poor readers. They concluded that the 'the importance of RAN and PA in accounting for reading performance has been overstated' (pg. 407).

Taking into account the findings of the studies reviewed, there appears to be a broad consensus regarding the role of letter knowledge, phoneme awareness and Rapid Automatized Naming as predictors of word reading. The generalizability of existing evidence from studies in English is strengthened through longitudinal and training studies across both transparent and opaque languages. Nonetheless, it should be noted that recently other variables have started to be the focus of research when examining reading development.

There is some evidence indicating that language skills, environmental factors and attention may also account for variation in word reading development. The evidence from these studies will be reviewed next.

2.5.3 Other predictors of word reading: beyond phonology

2.5.3.1 Language skills

The possible importance of oral language skills in reading has been highlighted by several researchers (Scarborough, 2001; Nation & Snowling, 2004) and has been suggested to be an additional predictor of early reading (Bowey, 1995; Bryant et al., 1990). It was also suggested that it has an indirect impact on word reading through its influence on emergent literacy skills (Lonigan, Burgess & Anthony, 2000).

Lonigan, Burgess and Anthony (2000) conducted a latent variable longitudinal study examining the role of letter knowledge (sounds and names), environmental print knowledge, print concepts knowledge, 'phonological sensitivity' (i.e., phonological awareness: blending, elision, rhyme and alliteration), oral language and cognitive ability measures on word decoding. Their sample was two groups of children with a mean age of 41.05 months (followed after 18 months) and 60.04 months (followed after 12 months). They found that phonological sensitivity and letter knowledge were unique longitudinal predictors of word decoding in kindergarten and Grade 1, accounting for 54% of the variance. They also reported that oral language skills have a significant impact on emergent letter knowledge and phonological sensitivity. This implies that vocabulary might not appear to be a predictor of word decoding, however it has an indirect impact on reading through its influence on the emergent literacy skills (evidence regarding the role of language skills on reading will be discussed in the following section). They suggested that letter knowledge and a global sensitivity to phonological features of language predict word decoding rather than phonological sensitivity[3] alone.

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[3]Phonological sensitivity is the ability to notice similarities between letter names and parts of spoken words (Bowey, 2005)

The focus of Ouellette's (2006) study was on the role of vocabulary in word reading and reading comprehension (results for reading comprehension will not be discussed as they are not relevant to the present study). They found that receptive vocabulary was the only predictor of decoding explaining between 5.8%- 7.4% of the variance depending on the order that the variables were entered in the model. In addition, they reported that decoding, receptive and expressive vocabulary as well as depth of vocabulary contributed independently to visual word recognition performance. Specifically, decoding explained 39% of the variance and the vocabulary variables combined explained in total 17.7%.

According to Oullette (2006), the relationship between decoding and receptive vocabulary could be explained by theories that propose the addition of new words in the lexicon involve encoding of phonological representations. Evidence from research in this area provides support for the view that both phonological and semantic factors are involved in sight word reading development.

Similar results were reported by Ricketts, Nation and Bishop (2007) who used expressive vocabulary measures (word definitions).Using regression analysis, they found that vocabulary was a concurrent predictor of exception word reading, even after controlling for age, decoding and regular word reading and accounted for 10.9% of the variance. Namely, sight word reading was predicted by expressive vocabulary (word definitions). However, this measure did not predict any other reading skills (i.e., regular word reading).

Ricketts et al. (2007)proposed their findings could be explained by the fact that vocabulary and visual word recognition learning are both related with the ability to map orthographic with phonological representations. A second possible interpretation was given in the context of the triangle model of word reading, suggesting that exception word reading can be achieved via the semantic pathway (orthography to phonology via meaning). This is in line with Ouellette's (2006) study which reported a word definitions measure predicted variation in visual word recognition (sight word reading) in a group of children that were approximately one year older than Rickett et al.'s sample.

One of the limitations of the studies reviewed until now is that they were not longitudinal studies, which would provide some indications regarding the direction of this relationship.

Gallagher, Frith and Snowling (2000) showed that preschool children with a family risk for dyslexia and who later developed reading difficulties, presented a profile of early language delay. Whilst letter knowledge at 45 months was the strongest predictor of literacy when the children were 6 years old, language (expressive and receptive vocabulary and expressive language) and speech at 45 months were also unique significant predictors of later literacy outcomes. In addition, Nation and Snowling (2004) found that language skills are concurrent and longitudinal predictors (after 4 years) of word recognition above and beyond decoding skills. One of the interpretations provided was that children use the context in order to read exception words and the effective use of context depends on their semantic skills, which are in turn influenced by vocabulary and broader language skills. Their second interpretation was that, in line with the triangle model of reading, the pronunciation of a word is produced via both phonological and semantic pathways. Nation and Snowling's (2004) findings are in consonance with both Ricketts et al.'s (2007) and Ouellette's (2006) findings.

An additional large scale longitudinal study involving 2,790 Dutch children from Grade 1 to 6 was conducted by. Verhoeven, van Leeuwe and Vermeer (2011) found that word decoding and vocabulary had a longitudinal reciprocal relationship. They concluded that word decoding skills facilitate the acquisition of associations between orthography and meaning.

The importance of oral language skills in the acquisition of reading has also been highlighted by a recent study conducted by Gooch, Hulme, Nash and Snowling (2014) in which it was found that language skills explained 31% of the variance in literacy skills. Their findings are in accordance with Snowling and Hulme's (2005) conclusion that "learning to read demands the interplay of different language skills that themselves may interact" (p. 405).This study will be reviewed in more detail in subsequent sections looking at attention as predictor of reading.

So far, it could be argued that there is evidence supporting the view that oral language skills do have an impact on later word reading skills. However, the nature of this relationship has not been established yet, in order to argue that vocabulary is a predictor of word reading; emerging evidence from recent intervention studies suggests that training of vocabulary can have a positive impact on early word reading development (e.g., Bowyer-Crane et al., 2008).In the next section working memory and specifically the sub-components that are relevant to the present thesis will be discussed in relation to reading.

2.5.3.2 Working Memory

According to Baddeley's (2000) model, working memory has got three sub-components with limited storage and processing capacity - three specialized systems: the visuo-spatial sketchpad, the phonological loop and the episodic buffer (see Figure 4). Those three components are controlled by the central executive, a supervisory system that involves attentional control (shifting, dividing of attention and inhibition control).

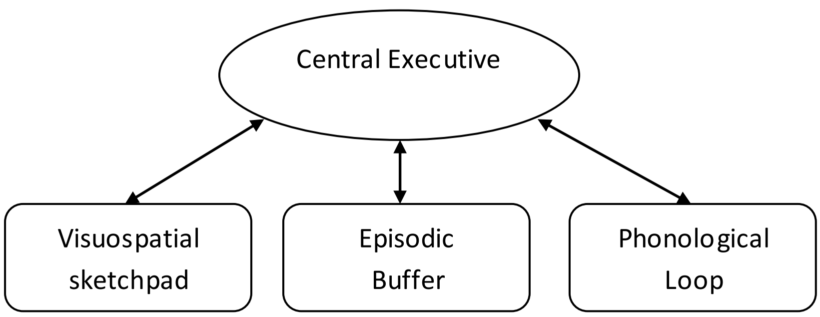

Figure 4: Baddeley's (2000) working memory model

The focus of most of the studies reviewed on working memory and word reading development is on the phonological loop. The phonological loop is a system comprising of a phonological store and rehearsal process. It is also suggested that the phonological loop plays an important role in oral language comprehension.

Phonological memory has been reported to be a reliable predictor of reading (Badian, 2000; Catts, Fey, Zhang & Tomblin, 2001). Verbal short-term memory had been found to correlate with reading. In particular, Griffiths and Snowling (2002) found that verbal short term memory accounted for 9.7% of the variance in nonword reading in a group of dyslexic children (9-15 years old), even after controlling for phonological awareness skills.

Singleton et al. (2010) in a review about cognitive factors of dyslexia argued that phonological awareness and working memory are "processes that underpin the acquisition of reading" (pg. 160).

However, the evidence is inconsistent as other studies have showed that verbal short term memory is not a predictor of word reading (i.e., McDougall, Hulme, Ellis & Monk, 1994). Alloway and Gathercole (2005) found that verbal short term memory was not a unique predictor of reading in a group of 6.5-11 years old children identified by their schools as having Special Education Needs (SEN). They reported that only verbal complex memory (as measured by a backwards digit recall, counting recall and listening recall tasks; WMTC-C) and sentence recall predicted reading performance. It should be noted though that performance in these two tests managed to explain only 1.9% of the variance in total. Probably, the results are not similar to Griffiths and Snowling's (2002), as the two studies used different age groups, measures of phonological memory, and most importantly different measures of decoding skills. Also, it should be highlighted that the participants in Alloway and Gathercole's (2005) study were identified as having SEN, but there is no information regarding the type of SEN.

It has recently been suggested that working memory deficits reported in children with reading difficulties might reflect deficits in their central executive, which, as already mentioned, is responsible for the control of attention. Wang and Gathercole (2013) found that performance in several measures of working memory in children with word reading difficulties was below that of an age and non-verbal reasoning skills matched group of typically developing readers. They also reported that poor readers performed worse in a dual task coordination measure than the control group. They suggested that their findings indicate that the deficit is on the central executive system as the performance of the group with reading difficulties was much worse when they had to combine two different cognitive demanding tasks (i.e., in tasks that required executive control).

Sentence recall has been reported to be a separate construct from the central executive and phonological loop (Alloway, Gathercole, Willis & Adams, 2004). However, it has been suggested that it taps on common mechanisms with working memory and specifically with the episodic buffer (Baddeley& Wilson, 2002). It has also been established that performance on sentence recall tasks is affected by phonological short term memory (e.g., Willis & Gathercole, 2001) and semantic information (e.g., Potter & Lombardi, 1990). Sentence recall tasks are used as a way to distinguish students with oral language problems and have been found to correlate with language and literacy measures (Carroll & Myers, 2010).

The studies reviewed provide an indication that children with reading difficulties exhibit deficits in their central executive system of working memory (even if their aim was not examine the role of attentional control in reading). This suggests that attention might play a role in reading development. The role of executive functions and attention on literacy development are discussed in more detail in the next chapter.

2.5.3.3 Environmental Factors

2.5.3.3.1 *Home Literacy and Socio-Economic status*

Apart from the cognitive-linguistic predictors of reading, there is a body of research examining the role of environmental factors in reading development. Print exposure has been reported to be a predictor of exception word reading (Griffiths &Snowling, 2002) and home literacy environment has been shown to correlate longitudinally with word decoding (Burgess, Hecht & Lonigan, 2002). In addition, it has been proposed that socially disadvantaged children perform worse in tasks of phonological awareness and the growth in their reading skills is not equal to their peers from middle class families (Lonigan, Burgess, Anthony & Barker, 1998; Raz & Bryant, 1990).

Print exposure has been found being a unique predictor of word recognition above and beyond phonological decoding skills (McBride-Chang, Manis, Seidenberg, Custodio & Doi, 1993). This corroborates with Griffiths and Snowling's (2002) findings regarding the role of print exposure as a predictor of sight (exception) word reading.

Mol and Bus (2011) in their meta-analytic review, reported that there is an "upward spiral of causality" (pg. 21) regarding print exposure and reading skills as the variance it predicted increased throughout development. They suggested that shared book reading might be part of a continuum that enhances language and reading skills.

According to the Home Literacy Environment model (Senechal & LeFevre, 2002), it is suggested that there are two types of home literacy experiences: storybook exposure and parent tutoring and that these are related to early literacy, phoneme awareness and language skills. Specifically, they found, in studies including both English speaking and French speaking preschoolers (Senechal & LeFevre, 2002), that story book exposure is a predictor of vocabulary and parent tutoring a predictor of early literacy skills (i.e., it predicted reading fluency in Grade 4); the later was also indirectly related to phoneme awareness. Similar results were reported by Foy and Mann (2003) who tested the hypothesis that Home Literacy Environment is related to phoneme awareness, letter knowledge, vocabulary and reading.

In addition, Senechal and Young (2008) conducted a meta-analytic review 16 studies on family literacy interventions (kindergarten to Grade 3) and reported that parental tutoring and parent listening to the child reading books improve the children's literacy skills; parental tutoring was a more effective intervention than just listening.

Turning to the factors of SES and early reading development, Lonigan et al. (1998) investigated the phonological skills of children (2 – 5 years old) from middle and low class families. In their analyses they found that children with a low SES status performed significantly worse in tasks of rhyme oddity, alliteration oddity, blending and elision at the group ages of 4 and 5 years. They also had poorer receptive and expressive vocabulary. Additionally, it was reported that none of the children (at 4 and 5 years of age) from the low SES could read any words in contrast with the middle SES children, for whom it was reported that 38% could read at least one word. They concluded that social class differences have an impact on phonological sensitivity and their effect is present from an early age.

To conclude, the role of environmental factors on word reading are not as extensively studied as the role the cognitive-linguistic predictors; however, there is clear evidence which indicate the possible role of socio-economic status, home literacy and print exposure as factors influencing early word reading skills. As Noble et al. (2006) noted “cognitive, social, and neurobiological influences on reading development are fundamentally intertwined” (pg. 642).

2.6 Summary

Thus far, the studies reviewed showed that the development of word reading skills influenced to different degrees by cognitive and linguistic skills including phonological skills, letter knowledge, rapid naming and language skills. Although not the focus of this thesis, it is important to note the contribution of environmental and socio-economic factors on emerging reading development.

In the following chapter, evidence regarding the role of attention in word reading accuracy is reviewed, starting with a description of the attentional framework that was employed in this thesis, as well as the cognitive and behavioural measures more frequently used to assess attention.

Chapter 3: Attention and Word Reading

3.1 Introduction

The following chapter will review studies examining attention skills and word reading, and discuss current understanding about the role of attentional processes in word reading development and difficulties in learning to read. The chapter will initially outline a model of attention, based on research on adults, and more recently, children, which has influenced assessment tools used in several studies included in the review. It will introduce the concept of attention and its subcomponents, to outline the theoretical framework used in this thesis. Studies of attention deficits in samples of children or adults with dyslexia will be reviewed to outline current understanding of the role of attention as a possible cause of reading difficulties. The review will then turn to the small body of research which has investigated the role of different attentional skills as concurrent or longitudinal predictors of variation in reading outcomes in typically developing children. The chapter will conclude by briefly reviewing the theoretical models of reading which emphasize the role of attention.

3.2 Posner & Petersen's (1990) Model of Attention

In order to provide the theoretical framework to consider the development of attention skills and their possible role in reading acquisition, Posner and Petersen's (1990) model of attention will be outlined. This model is used in this thesis since there is evidence supporting it both from empirical studies of cognitive behaviour in adults and children, and neuroscience. This model was originally developed through studies using adult participants. However, more recently a small number of studies have used it to consider the development of attention and its sub-components in children as young as 4 ½years old (e.g., Breckenridge et al., 2013).

According to Posner and Petersen (1990), the attention system is a separate system to other processing systems of the brain; it employs a network of areas of the brain and these areas are responsible for the functions of attention which are related to cognitive abilities. Specifically, it was argued that the attention system comprises of 3 networks which are responsible for orienting, alerting and executive control. The terms that will be used throughout this thesis will be Selective attention (orienting), Sustained Attention (alerting) and Attentional Control (executive control) for reasons of simplicity as the majority of the studies reviewed use these terms when referring to the sub-components of attention.

The existence of these neural mechanisms and the sub-components of attention has been validated at the cognitive level by studies using exploratory factor analysis (Test of Everyday Attention; Robertson, Ward, Ridgeway & Nimmo-Smith, 1996). It was found that there are 4 separate factors: visual selective attention, attentional switching, sustained attention and auditory verbal working memory.

After their original paper introducing the model of attention in 1990, Petersen and Posner (2012) reviewed their framework taking into account evidence from studies during the last two decades. The basic concepts discussed in their first paper remained the same but the new evidence permitted them to elaborate on their framework.

3.3 The sub-components of attention in children

The existence of these attention sub-components in children was initially examined by Manly et al. (2001), who adapted the Test of Everyday Attention (Robertson et al., 1996) for use as an assessment tool with children from 6 years of age to 16, known as the Test of Everyday Attention for Children (TEA-Ch, Manly et al., 2001). The subtests of TEA-Ch comprise of Score! (counting task), Score DT (counting and identifying an auditory target), Code Transmission (listening to auditory information and trying to identify a target), Walk Don’t Walk (Go-No Go type task), Sky Search and Map Mission (visual search tasks), Creature Counting (switching task), Opposite worlds (verbal inhibition) and Sky Search DT (visual search and counting).

Using structural equation modelling, they obtained 3 factors: Selective attention (Sky Search and Map Mission), Attentional control (Creature Counting and

Opposite Worlds) and Sustained attention (Score!, Score DT, Code Transmission, Walk Don't Walk). They also conducted confirmatory factor analysis assuming that attention is a unitary construct and they found that this model had a poor fit.

Manly et al. (2001) noted that these subtests are not measures of attention but that the performance on them depends significantly of the efficiency of the separate constructs of attention. This is in line with Fan and Posner's (2004) suggestion regarding the impurity of attention measures. Finally, they highlighted the possibility that performance in these tests might not reflect children's attention skills in real life (i.e., in a noisy classroom) and thus noted that behavioural measures of attention (i.e., teachers' ratings) should be administered as well.

More recently, Breckenridge, Braddick and Atkinson (2012) examined the organization of attention in preschool children and developed a cognitive test appropriate for this age group (3-6 years old), the Early Childhood Attention Battery (ECAB). The sample of 154 children was separated in groups according to their age. Their measures included a Visual Search task, a Flanker task, a visual Continuous Performance Task (CPT), an auditory CPT, a visual and auditory CPT, a Day-Night type task, a counterpointing task, a WCST type task (Balloon sorting) as well as a parent/teacher rating scale of inattention and sub-tests of the TEA-Ch for the follow-up assessment.

They conducted exploratory factor analysis and reported that for children from 3-4½ years old the sub-tests loaded in two factors only: Selective attention and Sustained attention. For the age group 4 ½ - 6 years old, their findings fit Posner and Petersen's (1990) model, as the sub-tests loaded in 3 factors: Sustained attention, Selective attention and Attentional Control. In particular, Visual Search, Flanker and Balloon Sorting loaded onto the Selective attention factor; all CPTs and the Day-Night task loaded onto Sustained attention; and Counterpointing and Balloon Sorting loaded onto attentional control.

It should be noted that Balloon Sorting, even though it was designed as an attentional control measure, it also loaded onto selective attention. This provides us with a further indication regarding whether it is possible to have a pure measure of a sub-component of attention and is in line with Callejas et al. (2004) proposal that selective attention interacts with attentional control. Breckenridge et al. (2012) concluded that the 3 attentional systems are not fully developed in children younger than 4 ½ years old.

Steele et al. (2013) examined the role of attention in emerging literacy and numeracy skills (findings of which will be discussed in a following section) and identified two attention factors. Their group consisted of 3-6 years old children and their components analysis was conducted for the whole group in contrast with Breckenridge et al. (2012) who separated their sample into age bands, given the wide age range. They used a CPT, a visual search task and a spatial conflict task. In their Exploratory Factor Analysis, they found that the variables of the CPT (RT and omission errors) loaded onto the same factor as the visual search task (RT and errors), which was named sustained selective attention. The commission errors of the CPT (recall that commission errors measure inhibition) and the spatial conflict (accuracy and RT) loaded onto the second factor, which was named executive control (i.e., attentional control).

In contrast to Breckenridge et al.'s (2012) finding of 3 factor model, Steele et al. noted that in children from 3-4½ years old only two sub-components of attention are exhibited. It is noteworthy, that approximately half of Steele et al.'s (2013) sample was younger than 4½ years old, which may have affected their results. Also, Steele et al. (2013) used a smaller sample and fewer attention measures than Breckenridge et al. (2012). It might be the case that the tasks employed in the former study were not sufficient for the identification of all three attentional sub-components.

In the following sections, the 3 sub-components of attention will be discussed in the view of the latest developments as discussed by Petersen and Posner (2012), and assessment measures used in the literature for each subcomponent will be outlined.

3.3.1 Selective Attention

According to Petersen and Posner's (2012) model, the orienting network is responsible for our ability to orient our attention to the stimuli that are relevant to our task in order to “prioritize sensory input” (pg. 75). Hence, it is our ability to select relevant information in space and filter out and ignore distractors (Atkinson & Braddick, 2012; Wang & Fan, 2007). This means that effective selective attention reduces “the influence of other competing stimuli” (pg. 79). Selective attention has been found to be controlled by frontal and posterior areas of the brain. It has been argued that selective attention might be involved in visual pattern recognition (Posner & Petersen, 1990), which is relevant to lexical word reading.

3.2.2.1 Measures of Selective Attention

In order to measure visual selective attention researchers have typically employed *Visual Search tasks* (as noted by Muller & Krummenacher, 2006). In these tasks the subject is presented with a number of stimuli simultaneously and they are required to scan the display and to identify a specific target from an array of distractors. The target has similar features to the distractors, i.e., the subject may be asked to find the red apples in a display with red strawberries (manipulating the similarity of visual (colour and shape) and semantic categories). The variables measured are reaction time and false responses.

Another commonly used measure is the *Flanker task* (Eriksen & Eriksen, 1974) which assesses the influence of distractors which are compatible or incompatible with the target. For example, in an arrow flanker task, the subject is required to indicate the direction towards which the central arrow is indicating. In the compatible condition, all the arrows indicate towards the same direction. In the incompatible condition, the central arrow indicates towards the opposite direction of the other arrows. Reaction times are slower in the incompatible condition and also there are more errors. The difference in the performance in the two conditions indicates the ability to ignore the distractors, namely, it indicates the efficiency of selective attention. Some researchers use the Flanker task as a measure of attentional control as well, since participants have to inhibit a response that is pre-potent (all the stimuli indicate towards one direction, apart from one target which indicates the opposite direction). It is very difficult to have a task that is absolutely pure in terms of the specific cognitive ability being measured, and this issue will be discussed in more detail later in this thesis.

3.2.2 Sustained Attention

The alerting network is responsible for our ability to sustain our attention for a prolonged period of time so as to enhance performance (Petersen & Posner, 2012). As Mirsky et al. (1991) noted it is "the capacity to maintain focus and alertness over time" (pg. 112). The brain mechanisms controlling sustained attention are the frontal and parietal regions of the right hemisphere. Sustained attention also interacts with the other attention sub-components (Posner & Petersen, 1990).

3.2.2.1 Measures of Sustained Attention

Continuous performance tasks (CPT) are the most popular clinical measures of sustained attention (DuPaul, Anastasopoulos, Shelton, Guevremont & Metevia, 1992). CPTs require the subject to maintain their concentration and press a key when a target appears. In a CPT, the participant is presented with rapidly and continuously changing stimuli (visual or auditory) with a designated target stimulus and is required to press a button only when a specific target appears. The duration of CPTs varies according to the age group tested but is intended to be sufficient so as to measure sustained attention (for preschool children the duration is usually approximately 5 minutes). The variables measured are reaction time, number of commission errors (false responses, i.e., responses to stimuli other than the target), omission errors (missed targets) and d-prime (sensitivity to changing stimuli).

The frequency of the targets and their modality (visual or auditory) varies according to the focus of the research. Paradigms that use 20% targets and 80% non-targets measure sustained attention. The number of commission errors has been found to represent inhibition control, while reaction times are believed to be a secondary indication of inattention (Halperin, Wolf, Greenblatt

& Young, 1991; Riccio, Reynolds, Lowe & Moore, 2002) and d-prime an indication of selective attention (Dye & Hauser, 2014).

It should also be noted that auditory CPTs have been reported to contribute uniquely in the measurement of attention (independent of visual sustained attention tasks) and have been suggested to be more representative of the skills children use daily in the classroom environment, in which they have to attend to auditory information (Aylward, Brager & Harper, 2002). They are the same as visual CPTs with the only difference that the stimuli are auditory instead of visual.

3.2.3 Attentional Control

The executive control network is responsible for our ability to voluntarily control our attention so as to resolve conflict. Cornish and Wilding (2010) noted that it is the "ability to maintain an appropriate problem-solving set for attainment of a future goal" (pg. 316). Petersen and Posner (2012) suggested that there are two control networks/brain regions (i.e., frontoparietal network and cinguloopercular network) for executive control in adulthood; however, these may be common in early development. It should be noted that some studies refer to this sub-component as focal attention. The function of this sub-component of attention matches the central executive system of Baddeley's model of working memory. According to Miyake et al. (2000) attentional control involves shifting of attention, inhibition control and updating of working memory.

3.2.3.1 Measures of Attentional Control

"*Go – No Go"* type of tasks are used in order to measure an individual's ability to inhibit a pre-potent response. An example of this paradigm which is appropriate even for young children and requires the same skills, i.e., inhibition control, is the *Day-Night task* (Gerstadt, Hong & Diamond, 1994). In this task, the subject is presented with pictures of the sun and the moon and they have to say day when they see the picture of the moon and night when they see the picture of the sun. Similarly, to the Stroop task the subject has to inhibit a pre-potent response and say the opposite of what they see.

An additional measure of inhibition appropriate for children is the *Head-Toes-Knees-Shoulders* (Ponitz et al., 2008). In this task, the child is required to do the opposite of the verbal instructions given. For example, if they are asked to touch their head, they have to touch their toes. One of the advantages of this task is that it does not require the children to read anything or even give a verbal response. Previous research has shown that the HTKS taps on executive function skills including working memory (e.g., McClelland et al., 2007; Ponitz et al., 2009; Lan et al., 2011), but it has been suggested that it mainly taps on inhibition control (Fuhs & Day, 2011; Lan et al., 2011).

A computerised task for shifting of attention is the *Dual Search task* (Visearch; Wilding et al., 2001). This is very similar to simple visual search tasks with the difference that the subject has to identify alternating targets. Namely, they are asked to tap on a black hole, then on a brown hole and a black hole again until they find all the targets. This task requires the participant to shift their attention from one target to another and has been reported as a sensitive measure of children's shifting of attention skills (Rezazadeh, Wilding & Cornish, 2011).

3.4 Conclusion

In conclusion, current evidence suggests that the model of attention developed by Posner and Petersen (1990) is applicable to young children after the age of 4½ years old. Selective attention, Sustained attention and Attentional control appear to be constructs that can be measured separately using well known cognitive measures/paradigms of attention adapted for children.

It is very challenging to find a cognitive task that will be a pure measure of each sub-component of attention without tapping on other cognitive skills and/or sub-components of attention that are not the target. For example, as discussed CPTs are employed as measures of sustained attention, however, they tap on mechanisms of selective attention as well because the subject has to ignore the distractors. Nonetheless, the demands of selective attention in such tasks are quite low compared to i.e., visual search tasks where the subject is presented with a lot of stimuli simultaneously and has to identify the targets as fast as they can. Moreover, as already mentioned Flanker tasks are used as a measure of selective attention but also as measures of inhibition control. Fan and Posner (2004) noted that the majority of attention tasks used tap on all the sub-components of attention. In addition, Callejas, Lupianez and Tudela (2004) noted that selective attention interacts with attentional control and sustained attention has an impact on both selective attention and attentional control. Hence, the relative impurity of the measures should be taken into account when interpreting the results.

3.5 Attention and Reading development

3.5.1 Introduction

In the following sections evidence from studies examining the association between attentional processes and word reading accuracy in typically developing children and children with reading difficulties will be reviewed. Research reporting the co-occurrence between poor attention and reading difficulties will also be discussed.

Attention could have an impact on both routes (sub-lexical and lexical word reading) of the Dual Route model of reading (e.g., Inhen, Petersen & Schlaggar, 2015). Dally (2006) postulated that readers with attentional difficulties might “face a penalty in both routes to word identification” (pg. 421), and suggested that inattentiveness to the orthographic details of a word may impair sight word reading, and lack of conscious awareness of grapheme-phoneme correspondence rules could impair decoding. Dally (2006) based this view on Share’s (1995) argument that: “Other factors such as the quantity and quality of print exposure together with the ability and/or inclination to attend to and remember orthographic detail will determine the extent to which these opportunities are exploited” (pg. 169).

Visual Selective attention has been noted as an important factor in efficient word reading in recent research (for a review see Stevens & Bavalier, 2012) and that it may be crucial in early reading acquisition (e.g., Valdois et al., 2004, Vidyasagar & Pammer, 2009). There is also some preliminary evidence that training of selective attention can lead to growth in reading skills (Fransceschini et al., 2013).

Sustained attention, measured by CPTs, has been reported to correlate with reading skills (Lam & Beale, 1991) and precursors of reading, such as letter knowledge (Sims & Lonigan, 2013). However, the evidence is inconsistent as other studies using similar attention tasks have shown that there is no significant correlation between the two (Steele et al., 2013).

In addition, executive functioning (including attentional control) is involved in academic skills such as reading (Daneman & Carpenter, 1980; Gathercole &

Pickering, 2000). There is also evidence that children who experience difficulties with the acquisition of reading show deficits in executive functioning (Bull & Scerif, 2001; de Jong, 1998; Swanson & Sachse-Lee, 2001).

In educational practice, teachers and parents commonly report difficulties with concentration in children with dyslexia (Marzocchi et al., 2009). There is also evidence that those dyslexic children with the most severe and persistent word reading difficulties are more likely to have co-occurring inattention than those with a family risk for dyslexia but more positive literacy outcomes (e.g., Snowling, 2008) and inattentive behaviour has also been linked to lower levels of response to early reading intervention (e.g. Hatcher et al. 2006; for reviews see Duff et al., 2008; Griffiths & Stuart, 2013). Whilst there is evidence from research linking dyslexia with attentional problems for some children (Bosse, et al. 2007; Facoetti et al., 2006, Facoetti et al., 2010; Rose, 2009) there is no strong evidence for a causal relationship between the two and there is dispute about the causal direction (Marzocchi et al., 2009; see Snowling, 2009 for a review).

To conclude, the role of attention in reading development and dyslexia has not been established yet and the existing literature reports mixed results. A more detailed review of the evidence follows, starting with papers reporting the frequent comorbidity of attention and reading difficulties and continuing with studies which have used behavioural and/or cognitive measures to assess attention in relation to word reading in typical development.

3.5.2 Comorbidity of Attentional and Reading Difficulties

The frequent comorbidity of reading and language learning disorders with ADHD/ADD raises the issue of whether there is a common causal mechanism involved for some children with complex learning difficulties (see Hulme &Snowling, 2009 for a review). ADHD is the most frequent co-occurring disorder in dyslexia (Kronenberg & Dunn, 2003). However, it has been suggested that attention difficulties could be a consequence rather than a cause of learning difficulties for some children (Rose, 2009).

Morton and Frith (1995) presented a causal model framework for dyslexia, emphasising the importance of considering evidence from research at different levels of description (behavioural, cognitive, biological and environmental). This framework could possibly explain the comorbidity of dyslexia with attentional deficits. Specifically, they noted that at the cognitive level an attentional deficit might be an additional factor hindering academic achievement (i.e., 'leading to poor learning in a formal instructional setting'; pg. 12); and its co-existence with a phonological deficit which hinders reading would exasperate the reading difficulties of the individual.

Germano, Gagliano and Curatolo (2010) reviewed evidence from genetic, epidemiological and neuropsychological studies regarding the comorbidity of ADHD and reading difficulties (RD). They reported that the high co-occurrence of ADHD and RD shows that it certainly is not based on chance, with studies showing that approximately 18-45% of children with ADHD have RD as well and 18-42% of children with RD have ADHD. Genetic studies have provided evidence of risk loci shared by ADHD and RD and neuroimaging studies have revealed that there are anomalies in common brain regions/neural networks. Studies trying to explain the comorbidity between ADHD and RD have suggested that attention problems might be a cause of reading difficulties or that they share cognitive risk factors (e.g., working memory deficit).

Recently, Gooch, Hulme, Nash and Snowling (2014) reported that executive function difficulties co-occur with language impairments which in turn affect the acquisition of reading. However, the patterns of the cognitive deficits have been reported to be separate and to have an additive effect in children with dyslexia and ADHD (Gooch, Snowling & Hulme, 2011). This study will be reviewed more closely in the next section.

In summary, it is widely acknowledged that attention deficits co-occur with reading difficulties; however, there has not been an adequate causal explanation, with some researchers considering the two conditions as completely separate with distinct underlying causes. Either way, there is agreement that attention impairments add to the difficulties that children with reading deficits face. Consequently, there is need for more research to better understand the role of attentional processes in learning to read and reading difficulties.

3.5.3 Attention and word reading in reading difficulties

There is some evidence from research on developmental disorders which indicates a relationship between attention and reading difficulties in English as well as in other languages.

It has been argued that children with reading difficulties (dyslexia) may have poor inhibition control, sustained attention and may be more impulsive than typically developed children (Miranda et al., 2012[4]). Word reading accuracy has been suggested to be associated with components of attention/hyperactivity and working memory and nonword reading accuracy with phonemic deletion, response inhibition and working memory (Bental & Tirosh, 2007).

Similarly, Lima et al. (2011, 2013) in Brazil, suggested that children with dyslexia have an impairment in various aspects of attention and executive functions including selective attention, auditory attention, shifting and inhibitory control. It should be noted that the measures used(Cancellation and Trail Making test) for sustained attention in this study, also involve selective attention abilities as well as shifting. The results should also be interpreted with caution as the number of participants in each group was extremely limited (7 to 20 participants). Lima et al. (2013) suggested that even though attention problems may not be the core deficit in dyslexia, they coexist with the phonological deficit.

Sireteanu et al. (2006) examined sustained-selective visual attention in a group of children with dyslexia and an age-matched control group of children aged between 7 and 18 years old. They administered tests of nonverbal IQ, vocabulary and arithmetic, writing proficiency, sustained selective attention, short-term memory and phonological awareness. The groups were matched in basic visual functions (e.g., contrast sensitivity, visual acuity etc.).

The group with dyslexia had significantly shorter reaction times in both tasks and in both conditions but made more errors than the control group. In their

[4]Participants were 7-10 years old children in Brazil and attention was measured by Conner's CPT

third experiment they used a pop-out visual task which is known to not require attention resources. There was no significant difference in the performance of the two groups but dyslexics were more easily tired.

The authors concluded that individuals with dyslexia have difficulties in allocating and sustaining their attention. However, it is possible that these findings indicate a deficit in inhibition control as the participants tended to respond more quickly and make more errors in the visual search task. One of the limitations of this study is that the age range used is very wide (7-18 years) and thus the participants are in different developmental stages. Namely, in this study the researchers included in the same group individuals with fully developed and still developing selective attention skills.

Altmeier et al. (2008) argued that in beginner readers inhibition and switching are needed in order “to suppress irrelevant codes during phonological retrieval of sounds for letters or names for the whole written word and to switch among the constantly changing letters and written words” (pg. 602). They also suggested that children with dyslexia may exhibit less variance, as their executive functions are not within the normal range or that they might not use their executive functions in reading in the same way as typically developing children. They concluded that children with dyslexia may have an impairment in executive function even if that does not uniquely predict their literacy outcomes.

This view is in line with findings from other studies which have found that children with dyslexia as a group perform worse in executive function tasks than typically developing readers(e.g., Lima et al., 2011); as well as with studies which do report a correlation between executive function and word reading or its predictors, but in their regression analysis they do not find any significant contribution of these executive functions in literacy outcomes.

However, the evidence is inconsistent as there are studies which have been unable to find a reliable relationship between reading problems and attention. In a study conducted in Netherlands (van der Sluis, de Jong & van der Leij, 2004), inhibition and shifting in 21 children with reading difficulties and 19 age matched controls (Grades 4 and 5; mean age 127.37 and 131.29 respectively) was assessed using the Quantity Inhibition task and the Objects Inhibition task (adapted versions by Bull & Scerif, 2001)[5] and the Objects Shifting task[6] as well as a Making Trails task and the Object Naming task. Their reading skills (single word reading fluency) were assessed using the One Minute Reading test and their verbal reasoning through the verbal analogies subtest of RAKIT. They observed similar levels of performance across the inhibition and shifting task across both groups of children.

In a confirmatory factor analysis of the data, van der Sluis et al. (2004) obtained three factors: Naming (which has loadings from all the measures), Shifting and Updating. Shifting and Updating were significant predictors of reading, explaining 2.7% and 6.1% of the variance respectively. The factor Naming was considered a non-executive functions factor and explained 29.3% of the variance. However, it could be argued that considering the Naming factor as non-executive is not accurate. It should be noted that this factor had high loadings from executive control measures, such as the verbal inhibition measure (Quantity inhibition, Bull &Scerif, 2001) with a loading of more than .70. Nonetheless, it should be noted that children were assessed in terms of reading fluency and not decoding. This might explain why their findings are inconsistent with previous studies, which reported that inhibition is related to decoding (i.e., Bental & Tirosh, 2007).

Furthermore, it has been reported that children with reading difficulties exhibit deficits in phonemic fluency but not executive function. Marzocchi et al. (2008) in a study with 87 students (7-12 years old) from Italy employed several cognitive attention tasks with high reliability as well as control tests for the non-executive function demands of each attention task.

Inhibition control was measured with the Change task (the Go MRT variable was used as the control task) and Circle Drawing Task (control task: Visual Motor Integration)[7]. Attention switching was measured with the Opposite Worlds

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[5]In the Quantity inhibition task the participants were required to name the quantity of digits in an array (i.e., when presented with '222', they had to respond 3). In the Object inhibition task, they were presented with an object within a larger object and they were required to name the smaller object.

[6] In the Objects shifting task the participants were presented with a digit in a figure. Depending on the colour of the object they had to name either the digit or the object.

[7]For details on these tasks see Logan & Burkell (1986) and Bachorowski & Newman (1990)

(TEA-Ch; control task: rapid naming from Opposite Worlds). Planning was measured with the Tower of London (control task: spatial span memory; Corsi Block Tapping test) and flexibility with the Wisconsin Card Sorting Test (control task: semantic categorisation from WCST). They also used the Self-Ordered Pointing task as a measure of working memory (control task: Benton Visual Retention Test; visual short-term memory). Fluency was measured with a semantic fluency task and a letter fluency task. Reading accuracy and speed were measured using a 4 minutes reading task and a list of words and pseudowords. They found that the group with reading difficulties performed significantly worse than the control group only in the measures of flexibility and letter fluency.

In a subsequent study, Marzocchi, Ornagni and Barboglio (2009) found that a group with dyslexia of similar age to their previous study (7-12 year olds), performed worse than a control group of children across most attention tasks. In particular, they used the TEA-Ch test to assess selective attention, sustained attention and executive attention (switching) as well as an auditory Continuous Performance task (sustained attention). It was reported that the students with dyslexia had impaired visual and auditory sustained attention, as well as executive attention compared to the control group. They were also rated by the teachers and their parents as more inattentive, hyperactive and impulsive. It should be noted that the children with dyslexia were screened for ADHD (DSM-IV criteria) and the participants who met the diagnostic criteria were excluded from the analysis, thus those attentional difficulties are unlikely to be due to comorbidity. However, the groups' differences for the Score! (sustained attention) and Opposite Worlds (executive function) tasks were no longer reliable after controlling for variance due to digit span and digit rapid naming.

Marzocchi et al. suggested that children with dyslexia have a verbal working memory deficit and that this probably indicates that the deficit shown in their sustained attention is due to the impact of working memory on the performance in the sustained attention tasks. Nonetheless, it should be noted that rapid naming tasks have been suggested to tap executive function mechanisms (Denckla & Cutting, 1999), thus it is somehow expected that when entered in the analysis they might mask the effect of other executive function tasks. In addition, they proposed that their poor performance in the Opposite Worlds task was due to phonological processing difficulties. Moreover, when age was controlled there was no significant difference between the performance of the two groups in the Auditory CPT task, apart from the RT variable. It was suggested that this was due to impaired speed of processing and not impaired attention. Marzocchi et al. argued that inattentive behaviours are due to their slowness in verbal processing that produce early distractibility and hence the impairment in these attention processes could be a consequence of the learning disorder.

In a very recent study, attention and EF skills were examined longitudinally in preschool children with a family risk for dyslexia. Gooch, Hulme, Nash and Snowling (2014) examined the comorbid difficulties in preschool children at family risk of dyslexia with and without language impairment. They used 4 groups: 83 children at family risk (FR), 32 with language impairment (LI), 28 at family risk with LI (FRLI) and 69 typically developed children. They were tested in two times, when 3 ½ and 4 ½ years old. In order to identify the children with LI, they employed the Basic Concepts, Expressive Vocabulary and Sentence structure subtests form CELT and the Test of Early Grammatical Impairment. Children who failed 2/4 tests (85 or below) were identified as having language impairment.

Executive function skills and motor skills were measured at both Time 1 and Time 2. Selective attention was tested using a Visual search task (Apples search Breckenridge et al., 2012), sustained auditory attention was tested with an ACPT task (age appropriate adapted paradigm from Mahone, Pillion &Hiemenz, 2001), inhibition was tested with a Go/No-Go and the HTKS tests and visuo-spatial memory was tested with the Block recall task. Motor skills were assessed using 3 subtests from the Movement Assessment Battery for Children-2 as a control task for the red apples visual search task. Early literacy skills were tested only in Time 2 with the YARC test and a letter writing task. They used confirmatory factor analysis and they found three factors: Language, Motor, Executive function (T1); Literacy, Motor, Executive function (T2).

At Time 1 the Language impaired (LI) and the at Family Risk with Language impairment (FRLI) groups were worse than the Typically developed (TD) and at

Family risk (FR) groups for the Executive function factor score (also in each measure of executive function). They also reported a very strong relationship between executive function and language ability at T1, even after controlling for age which was weakened by T2. There was also a strong relationship between motor skills and executive function at both times.

In their regression analysis they found that executive function was not a separable predictor of literacy after language skills were controlled, in particular it accounted for only 1% of the variance. However, in T2 there was a strong correlation between literacy and executive functions (0.56). It was suggested that children with dyslexia without a significant language impairment are less likely to have comorbidities (i.e., executive function difficulties).

They also argued that there are common factors which influence the development of executive functions (attention and behavioural control) and place an individual at risk for language difficulties. These language difficulties in turn may play an important role in mediating the relationship between executive function and literacy development. Finally, they highlighted the importance of future research that will investigate the role that executive functions play in literacy development and specifically in reading fluency, reading comprehension and spelling.

In summary, the majority of the studies comparing the attention skills of students with dyslexia and control groups demonstrate that attention is an area of concern in reading difficulties (e.g., Bental & Tirosh, 2007; Miranda et al., 2012; Lima et al., 2013; but see van der Sluis et al., 2004). Some of the researchers have proposed that this means that attention and reading difficulties are co-occurring conditions (e.g., Gooch et al., 2014) and that inattention may indicate poor verbal processing (e.g., Marzocchi et al., 2009). In the next section, developmental studies of early reading and attention in typically developing children will be reviewed.

3.5.4 Attention, foundation literacy and early word reading in typical development

In this section studies examining the relationship between attention skills and early reading in typically developing children is reviewed, as evidence regarding the role of attention processing in the early phases of learning to read at school or in preschool. The focus is on the possible concurrent and/or longitudinal relationship between attention and reading accuracy in preschool and the first few years of formal literacy instruction.

Studies examining the predictive power of both cognitive and behavioural measures of inattention (teacher and/or parent rating scales) in relation to word reading will be discussed in the subsequent sections. The most commonly used behavioural measures are the SWAN teacher rating scale (SWAN; Swanson et al., 2001) and Conners' teacher rating scale. The mostly common cognitive measures of attention have been discussed previously (see Chapter 3, pg. 38).

3.5.4.1 Concurrent predictors

3.5.4.1.1 Cognitive measures

In a recent study, Sims and Lonigan (2013) measured sustained attention using a CPT task, where performance on this task was reported to correlate with early literacy skills (Sims and Lonigan, 2013) in a group of 204 typically developing preschoolers (3-5.8 years old; mean age: 4 ½ years old). More specifically, omission errors (sustained attention) and commission errors (inhibition) both correlated with print knowledge (r= -.20**; alphabet knowledge, word and letter identification etc.) and phoneme awareness (r=-.22**; sound elision and blending) even after controlling for age, income, sex and non-verbal abilities. For the correlation, standard scores were used for the print knowledge and phonological awareness tasks, whereas for the attention measures, they used the raw scores.

CPT omission errors were a significant unique predictor of letter knowledge, phonological awareness and vocabulary, even after controlling for income, age, sex, month of testing, and Stanford-Binet Copying subtest scores. However, when teacher ratings of inattention score was entered into the regression, the variable CPT omission errors lost its predictive power. This possibly indicates that the teacher ratings and the CPT omission errors tapped on the same cognitive skills. In this second regression, teacher ratings of inattention (measured by the Conners' teacher rating scale re-standardized) predicted uniquely the performance in both print knowledge and phonological awareness.

One of the limitations of this study is that the range of ages used was quite broad, considering the rate of development both in attention and emergent literacy during early childhood. A more discrete age group (e.g., 4-5 years old) might have enabled the researchers to examine better the attention and literacy skills of the participants, during a shorter period of development. It should also be taken into consideration that the three subcomponents of attention are exhibited, as already mentioned, in children older than 4 ½ years old, which means the Continuous performance test might not have been appropriate as a measure of sustained attention for the group of the participants that were between 3-4 years old.

Another study using measures of attentional control (inhibition) has reported that inhibition correlates and/or is a predictor of word reading. Wanless et al. (2011) conducted a study with English speaking participants between 4.14 and 6.24 years old (M=5.48). Their literacy skills (letter name knowledge and real word reading accuracy) and expressive vocabulary were measured through the Woodcock-Johnson Psycho-Educational Battery-III Tests of Achievement (WJ-III; Woodcock & Mather, 2000). They reported significant correlations between HTKS scores and early literacy and vocabulary scores (r=0.63 and 0.29 respectively), even after controlling for age, gender, parent education and teacher ratings of behavioural regulation. They suggested that inhibition control allows children to behave in a way that does not contradict with classroom rules and the ability to pay attention and remember rules enables children to acquire skills that enhance their learning.

In line with this, Connor et al. (2010) found that performance on the HTKS was a concurrent predictor of vocabulary and word reading skills of first grade children. It was suggested that children who have good attentional skills are enabled to take advantage of instructional activities more effectively. In the same vein, Burrage et al. (2008) reported positive correlations between word decoding and the HTKS scores in a group of 4-5 year old children ($r = .42$, $p < .01$). Performance on the HTKS task has also been reported to predict early literacy (letter name knowledge and real word reading accuracy) and expressive vocabulary longitudinally (over a period of approximately 5 months, from Autumn to Spring term) in preschoolers (Ponitz et al., 2009). They suggested that this pattern of results is observed as the skills needed in order to perform well in the HTKS (inhibition control, working memory and attentional focus) are also known to enhance academic performance. One of the limitations of the above studies is the fact that they did not include measures of speed of processing which might explain the predictive power of the HTKS (Ponitz et al., 2009). The above studies also have not controlled for other predictors of word reading like phonological awareness, letter knowledge and rapid naming.

Contradictory results were reported by Davidse et al. (2011) who examined concurrent predictors of emergent literacy skills in a group of 228 Dutch kindergarten children (mean age: 54.29) using cognitive measures of attention. They assessed IQ, short-term memory (forwards digit span), inhibition control (peg tapping task[8]; Diamond & Taylor, 1996); the child had to tap once when the experimenter tapped twice and vice versa), sustained attention (sustained attention subtest of the computerised Amsterdam Neuropsychological Test respectively (duration: 10')), book-cover recognition, receptive vocabulary (PPVT-III-NL), letter knowledge and home literacy environment (parent's survey).

Letter knowledge and vocabulary correlated strongly with inhibition, and moderately with sustained attention. Inhibition and sustained attention were weakly correlated with book-cover recognition and only inhibition correlated with home literacy. There was also a moderate relationship between home literacy and letter-knowledge. Regression analysis showed that inhibition and sustained attention were not concurrent predictors of emerging literacy. Home literacy was found to predict both vocabulary and letter-knowledge. They suggested that attention skills might start influencing reading skills later in reading development

[8]In the peg tapping task the child has to tap twice with the dowel when the experimenter taps once and vice versa.

as decoding for example is a more complex task which requires more cognitive skills than letter knowledge.

In regards to shifting of attention, May, Rinehart, Wilding and Cornish (2013) reported associations between performance on a Dual Visual Search task (Visearch; Wilding, 2001) and word reading (p = .33) for a group of 7-12 year old typically developing children. However, the regression analysis revealed that, after controlling for age and short-term memory, shifting was not a unique predictor of word reading accuracy. In addition, Kieffer, Vukovic and Berry's (2013) study with 4th graders, in which it was found (using path analysis) that shifting of attention (WCST) and inhibition control (Stroop paradigm) had a direct influence on reading comprehension but not on word reading accuracy.

In conclusion, there is some limited evidence that sustained attention predicts emerging literacy skills (Sims & Lonigan, 2013) and that attentional control is a unique predictor of word reading accuracy (e.g. Wanless et al., 2011; Ponitz et al., 2009; but see Davidse et al., 2011; May et al.., 2013). In the next section, evidence from research using rating scales of inattention will be reviewed.

3.5.4.1.2 Behavioural, teacher or parent rating scales of attention

Teacher ratings of attention were employed in a study conducted by Saez et al. (2012). Their hypothesis was that selective attention (by this term they mean the ability to focus, sustain and control attention) would be a predictor of word reading skills above and beyond the contribution of phonological awareness and vocabulary knowledge. Their study involved 432 kindergarten children in the U.S.A. (mean age: 5.8 years, 60% low SES). Their emerging literacy skills were tested using 3 phonological awareness tasks (phoneme segmentation, DIBELS; elision and blending, CTOPP). Vocabulary knowledge was tested through the Picture Vocabulary subtest (WJ-III) and word reading through Letter Naming fluency (DIBELS), Letter Word Identification (WJ-III) and Sight Word Efficiency (TOWRE). Attention skills were measured with a behavioural teaching rating scale (SWAN).

Through principal component analysis they identified three separate factors deriving from the SWAN: attention-memory (which included updating of working memory, selective and sustained attention), attention-set shifting and attention-inhibitory control. They found that all these attention factors were significantly concurrently correlated with the measures of literacy predictors. However, attention-set shifting and inhibitory control had a moderate correlation with phonological awareness, word reading and vocabulary, whereas attention-memory had the strongest correlation with them. They also reported that attention-memory predicted word reading even after controlling for phonological awareness and vocabulary (through hierarchical linear modelling).

3.5.4.2 Longitudinal Predictors

3.5.4.2.1 Cognitive measures

Steele et al. (2012) conducted the first longitudinal study examining the role of each of the three sub-components of attention as concurrent and longitudinal predictors of emerging literacy skills. The sustained, selective and executive attention of 83 preschoolers (3-6 years old, typically developed) was measured using a CPT, a visual search task and a spatial conflict task only at Time 1. A behavioural measure of inattention was also included (Conners' teacher rating scale- Revised: Short Version, 1997). Emerging literacy skills were assessed using measures of letter knowledge, receptive vocabulary and non verbal ability at Time 1 and word reading at Time 2.

Through an exploratory factor analysis it was revealed that the spatial conflict task and the commission errors in the CPT were loading in the executive attention factor, whereas the rest of the variables were clustered together as selective-sustained attention (reaction time and errors in visual search, reaction time and omission errors in CPT). The reliability of these factors was higher than for the individual tasks, hence they were used in the correlational analyses. The executive attention factor was a concurrent predictor of letter sound knowledge and vocabulary (*r*= .25* and .22*), but in contrast, the selective-sustained attention (clustered together) did not correlate with any of the precursors of early literacy after controlling for age and non-verbal abilities. The only unique longitudinal predictors of word reading were vocabulary and letter knowledge.

However, it should be noted that the findings reported refer to the whole group of children across the wide age range from 3-6 years. The inclusion of scores from the 3 year old children on tests of phoneme awareness and letter sound knowledge which were at floor might have masked any possible correlations between attention and literacy. This happens as when there are floor effects in the data, the variance is minimized and the correlations become weaker.

There is also some evidence regarding the role of selective attention, as measured by visual search tasks, and reading development. Plaza and Cohen (2007) conducted a longitudinal study with 75 French speaking preschoolers, who were retested after 12 months (end of Grade 1). They administered tests of phonological processing (phoneme identification, syllable inversion and digit repetition), rapid automatized naming and visual selective attention (visual search task with non-linguistic stimuli). At the end of Grade 1, these tasks were repeated and they also used word discrimination and reading tests (real and nonword reading). They found that visual selective attention in preschool was a significant predictor of word discrimination and nonword reading in Grade 1, even after the influence of phonological processing and RAN was controlled for. They suggested that selective attention plays an important role in emerging literacy as the children need to use visual attention skills (i.e., scanning and visual analysis) in order to learn to read. They concluded that 'early foundations of reading ability thus include a visual attention component' (pg. 73).

Nonetheless, contradicting evidence was reported by Shapiro, Carroll and Solity (2013) in a study with preschoolers (beginning of Reception Year) who were followed longitudinally after 8 months (end of Reception Year). They measured their print knowledge, phonological awareness, rapid naming, short-term memory, auditory processing, visual selective attention (visual search task) and vocabulary. Their outcome measures were nonword reading and single word reading. They found that the only predictor of word reading was print knowledge and of nonword reading was print knowledge, short-term memory, phoneme isolation, and RAN. Visual selective attention was not a unique predictor of either word or nonword reading. They suggested that this might have been due to the young age of the participants and selective attention might be more important in later stages of reading, when children become fluent in their decoding. Selective attention might influence only sight word reading which is used as a strategy by more fluent readers.

Moreover, the differences in findings across these two studies could reflect differences in the orthographies in French and English. Children acquire phonic decoding more quickly in more transparent writing systems relative to English. Hence, selection attention measures may be more sensitive to picking up variation in reading in French, than PA since there may be less variation in phonic decoding skills since most children have mastered it by the end of grade 1 in the Plaza and Cohen (2007) study.

Leppanen et al. (2006) examined the role of several variables on reading fluency and reading comprehension skills in Grade 1 and 4 of 158 Finish preschool children. They measured letter sound knowledge, phoneme awareness, vocabulary, listening comprehension, meta-cognitive awareness, cognitive ability, parental education and visual selective attention when the children were at the autumn term of kindergarten. They found that phoneme awareness, letter knowledge and visual selective attention in Time 1 predicted reading fluency in Grade 4, even after controlling for early reading skills in Grade 1. Phonological awareness effects on reading at Grade 4 were mediated by reading skills in kindergarten and Grade 1. It was argued that letter knowledge was a much stronger predictor than PA and selective attention. However, the relationship between selective attention and fluency might be linked to orthographic processing.

Welsh et al. (2010) using a composite score of inhibition and shifting of attention (named attention control) found, through path analysis, that attentional control in the beginning of prekindergarten predicted longitudinally emerging literacy skills at the end of prekindergarten. In addition, attentional control at the end of prekindergarten uniquely predicted word reading in kindergarten, even after controlling for the growth in emergent literacy skills. Their interpretation was the same as in Wanless et al. (2011), namely attentional control enables children to follow rules and pay attention, hence promoting their potential for learning.

3.5.4.2.2 Behaviouralteacher or parent rating scales of attention

Few studies using longitudinal designs to investigate attention as a predictor of reading in children have used teacher-rating scales. The longitudinal relationship between attention and early reading skills was investigated in a study involving 132 children (mean age: 5 years 7 months) in Australia (Dally, 2006), using the Rowe Behavioural Rating Inventory (RBRI-Parent and Teacher Forms). The hypothesis was that adequate phonological skills and attention are necessary for learning the letter-sound correspondences and for the acquisition of word reading. These children were tested in kindergarten, 1stand 2ndGrade. Phonological processing, phonological awareness, letter knowledge, word recognition and reading comprehension were tested.

They reported that phonological awareness and Rapid Naming in kindergarten were correlated, as expected, with word recognition and nonword reading in 1st and 2nd Grade. Of particular interest for the present research is their finding that rated inattentiveness was moderately correlated with word recognition and nonword reading, both in 1st and 2nd Grade (r= -.56, -.48 and -.40, -.41; $p<.01$). In order to examine whether inattention contributed uniquely to literacy outcomes they used regression analysis. They reported that kindergarten inattentiveness directly predicted 1st Grade word reading and thus had an indirect influence on 2ndGrade Reading Comprehension. Similar findings have been reported by Rabiner and Coie (2000) who found that teacher ratings of inattention in kindergarten, first and second grade had a significant and strong relationship with both first and fifth grade reading achievement.

Dally (2006) also examined the reciprocal relationship between early reading and later phonological skills and inattentiveness. It was found that letter knowledge (sounds and names), word recognition and reading comprehension in kindergarten correlated with both phonological awareness skills and inattentiveness in 2nd Grade. However, in their regression analysis, the correlation between kindergarten inattentiveness and 2ndGrade phonological awareness skills remained significant only for the deletion subtest (but not for blending). This could possibly reflect the greater working demands of the deletion task.

Similarly, Walcott, Scheemaker and Bielski (2010) reported that teacher-reported attention problems as measured by a behavioural rating scale (BASC-2)predicted longitudinally phonemic awareness and letter knowledge one year later above and beyond initial language ability and emerging literacy skills in preschool. Of interest is also their finding that 5 year old children's literacy skills did not predict variation in attention skills in kindergarten at 6 years of age. This is an indication that attention problems exhibited by students with reading problems may not be a consequence of their reading difficulties but a possible cause or co-occurring difficulty. Namely, if difficulties in reading were leading to difficulties in attention, then literacy skills would be expected to predict poor scores in attention. However, in the Dally (2006) study only the opposite pattern was observed (i.e., attention predicted literacy). One of the limitations of this study is the limited number of participants (n=47), however, it should be noted that they still had statistical power taking into consideration the number of variables and the number of participants used. Their findings are in line with other studies reporting a relationship between attention and phonological awareness skills (e.g., Dally, 2006).

In a recent study, Dice and Schwanenflugel (2012) conducted a longitudinal study with 250 children from prekindergarten (mean age: 4.5) to the end of their kindergarten year. Their attention was assessed through a short-form of a teacher-rating scale (TRS-P BASC; attention only). Emergent literacy skills were assessed using an experimental alphabetic knowledge task (letter shape, name and sound recognition task), phonological awareness (PAT: rhyme discrimination, syllable segmentation, initial phoneme isolation, phoneme blending). Receptive (PPVT-III) and expressive vocabulary tests (EVT) were also administered. In Kindergarten reading ability was assessed using the Early Decoding Test (reading of 15 words).

Reliable, moderate correlations between kindergarten decoding skills and earlier attention skills in prekindergarten were observed, as well as associations between attention and emerging literacy skills in prekindergarten. They conducted Confirmatory Factor analysis and hypothesised that emergent literacy skills would mediate the relationship between prekindergarten attention and kindergarten decoding skills. Their hypothesis was supported by their findings and they concluded that attention as measured by teacher-ratings predicts the development of emergent literacy skills and consequently reading skills a year later.

However, since the studies reviewed in this section (Dice & Schwanenflugel, 2012; Rabiner & Coie, 2000; Saez et al., 2012) used only a behavioural measure of attention (rating scales), the results should be interpreted with caution. There is some evidence that the classroom behaviours measured by rating scales correspond to their related cognitive processes. For example, Isquith, Gioia and Espy (2004) found through principal components analysis that a teacher/parent rating scale that they developed corresponded to the subcomponents of executive functions as defined by Miyake et al. (2000), namely, shifting, updating and inhibition.

Nonetheless, later studies have shown only a small correlation between attention performance as measured by cognitive tasks and attention as measured by teacher ratings (Sims & Lonigan, 2013); others have failed to find any reliable significant correlation (Steele et al., 2012). One of the explanations suggested is that the attention required by children during cognitive tasks is different to the attention required during classroom activities, as the former requires children to attend to specific stimuli during a limited time whereas the later involves more complicated processes (e.g., social interactions during routine classroom activities). Gathercole and Alloway (2004) have also argued that teacher ratings of attention frequently reflect the students working memory skills instead of their attention, as a child with poor working memory might appear inattentive. Therefore, any association between teacher ratings and academic outcomes (in this case word reading) might be due to working memory.

3.6 Further evidence from reading intervention studies and non-responders to intervention

Intervention studies are essential in testing the possible causal relationship between cognitive-linguistic skills and reading (see Castles & Coltheart, 2004). Specifically, it is suggested that in order to test a causal hypothesis, children should be trained in the key skill and then examine the effect of the training on word reading. Some of these intervention studies were reviewed in the previous sections.

The focus of this section will be on the non-responders of otherwise effective reading interventions. The reason why it is important to focus on non-responders is because their cognitive profiles might give a useful insight into the possible factors that influence reading acquisition, which have not been untangled yet. A brief discussion of intervention studies aiming at enhancing reading skills and the predictor of their effectiveness follows.

To begin with, Torgesen et al. (1999) have reported that growth of word reading skills was predicted not only by phonological skills but also by socio-economic background and teacher's ratings of inattention and behaviour. This shows that the research of reading needs to take into account cognitive, environmental and behavioural factors when trying to explain individual differences in reading development and its difficulties.

Griffiths and Stuart (2013) in their review paper regarding evidence based interventions for students with reading difficulties noted that one of the factors predicting poor readers' variation in the response to reading intervention is inattention. It has been suggested that children with co-occurring attention problems do not benefit as expected from otherwise effective word reading interventions for dyslexia. For example, Torgesen et al. (2001) in their intervention study of 4thGraders with severe learning difficulties reported that the most consistent predictors of effective response to intervention as measured by reading outcomes during the follow up period (1 and 2 years after the intervention) were teachers' attention and behaviour ratings.

Stage, Abbott, Jenkins and Berninger (2003) reanalyzed previously reported data from an intervention study (Berninger et al., 2000), in order to determine which factors predict response to early reading intervention. They specifically examined the role of verbal IQ, phonological awareness, rapid naming, orthographic skills and attention. They used teacher ratings of selective, sustained and switching attention during the tutoring session. They found that attention correlated significantly with all other measures apart from verbal IQ. In their regression analysis they found that the strongest predictors of word and nonword reading growth were rapid naming and attention, explaining approximately 3.5% of variance in real word reading and 1.5% of variance in nonword reading. They concluded that their findings indicate that early intervention might be effective to include instruction aiming at enhancing students' attention to verbal instruction.

Similar results were reported by a large scale (n=581) study conducted by Rabiner and Malone (2004) with children in Grade 1. They separated the sample into two groups: children with and without attention problems as rated by teachers. They found that children with reading difficulties and inattention did not benefit at all from the reading intervention, whereas for children with reading difficulties but no attention problems the intervention was extremely effective. They suggested that inattention was an important moderator of the relationship between intervention and reading outcomes.

Interestingly, it has been recently reported that training of visual sustained and selective attention improves reading speed (Fransceschini et al., 2013). In particular, the study involved 20 Italian children with dyslexia who received an intervention of playing action video games (which did not involve any reading training) for 12 hours in total. They found that the intervention group made a significant higher improvement in attention skills as well as in word and nonword reading than the control group. Also, the attentional growth accounted for 50% of the variance of the growth in reading. It was shown that action video games might improve selective attention and reading. However, it should be noted that at present there have not been any studies replicating this finding. Also, according to Goswami's (2015) recent paperthe improvement in reading might have been 'caused by the increased speed of phonological recoding found for the active gamers' (pg. 48). Specifically, participants also improved their speed in nonword reading (i.e., phonological recoding) and due to this fact there is need for further research in order to establish whether attentional training leads to better reading skills.

The above studies demonstrate that attention might be an important factor affecting early reading skills and reading development. However, the possible relationship between the two is still unclear.

3.7 Conclusion

In conclusion, the number of the studies examining the relationship between attention and predictors of early reading and/or word reading skills in typically developed children is quite limited. Only recently, in the last 2-3 years, has the impact of attention on reading acquisition been the focus of research, to try to better understand the co-occurring difficulties. Even more limited is the number of studies that have examined this relationship longitudinally.

It has been shown that visual sustained attention, executive functions (inhibition and switching) and selective attention correlate with foundation literacy skills (e.g., Sims & Lonigan, 2012; Ponitz et al., 2009) and predict variation in reading outcomes. However, only in a few studies this relationship remained significant after controlling for other factors related to reading (i.e., Davidse et al., 2011; Steele et al., 2012). The majority of the studies that used behavioural measures of attention showed that ratings of inattention predicted uniquely emergent literacy and/or reading skills (i.e., Dice & Schwanenflugel, 2012; Walcott, Scheemaker & Bielski, 2010). Preliminary results from intervention studies also indicate a possible causal relationship between attention and reading (Fransceschini et al., 2013) and indicate that attention might influence the effectiveness of reading interventions (for a review see Griffiths & Stuart, 2013).

It should be noted that whereas all the studies reviewed examine the role of attention in relation to early foundation reading skills through the same theoretical framework (e.g., by measuring phonological awareness and letter knowledge), they differ in the definition of attention and consequently in the measures they use in order to assess attention. Some of them employed behavioural rating scales and others cognitive measures, with only a few using a combination of methods (e.g., Steele et al., 2013). Furthermore, they differed in terms of the sub-components of attention and the modality (visual or auditory) measured.

These methodological differences might explain the inconsistency in findings reported from different researchers and creates the need for a study that would include the investigation of all the sub-components of attention (as defined by Posner & Petersen, 1990) and for both modalities. Further research is needed to explore the influence of the different components of attention on the early development of foundation literacy and word reading skills, which is the focus of this thesis.

3.8 Theoretical models of the role of Attention in word reading acquisition and dyslexia

3.8.1 Introduction

In this section, the focus is on research and theories of reading involving attention, hence papers referring to attention in relation to reading are discussed. The purpose of this section is to present a broader view regarding the possible role of attention in reading. Bosse et al.'s (2007) and Facoetti et al.'s (2009) are two of the major studies which propose that attention difficulties are a cause of reading difficulties and hence they are briefly reviewed in this section. The terms that the original papers used when referring to different aspects of attention were used, but there are comments, when appropriate, explaining how their attention tasks are linked to the sub-components of attention that are of interest in the present thesis. However, it should be noted that the theoretical framework and experimental paradigms used in these studies are not comparable to the ones employed in the present thesis, as they would be insufficient in answering the research questions (i.e., the paradigms used in Bosse and Facoetti's studies were not appropriate for testing the sub-components of attention, which were the focus in the thesis).

According to Feature Integration Theory (Treisman & Gelade, 1980), word reading is related to focal attention (attentional control) as the reader must be able to bind the 'elementary features' of words (i.e., letters) using their focused attention before they are able to access mental representations of the words. In line with this view, McCann, Folk & Johnston (1992) argued that word processing is affected by the presence or absence of spatial attention. They suggested that when readers process words, their attentional skills are involved, specifically at the stage of pre-lexical processing. In addition, it was claimed that a "central attentional resource" plays a role in lexical processing.

The involvement of attention when reading is also implied in the Multi-trace model of polysyllabic word reading (Ans et al. 1998). It is postulated that readers use two procedures: the global procedure (whole word reading) and an analytic procedure (syllabic segments), similar to the Dual Route Model. Through this model an account of developmental phonological and surface dyslexia is provided by suggesting that children with phonological dyslexia might have difficulty in creating segment traces. Children with surface dyslexia might have difficulty in creating whole word traces due to a narrow visual attention window.

Moreover, Risko, Stolz and Besner (2011) argued that spatial attention does play a role in reading. In their spatial attention task, the participants (undergraduate students) had to read aloud words which appeared above or below a fixation point. There was a spatial cue presented before the words which was either valid or invalid. I would argue that this task involves different aspects of visual attention, such as sustained attention and attentional control (shifting of attention). They also used a condition in which a set of two words were repeated and a non-repetition condition. They found that reaction times in the repetition condition were shorter and also that the effects of the cue validity and word repetition interacted. In particular, the effects of the cue were weaker for the repetition condition. It was suggested that the spatial attentional requirements of word processing are reduced when the stimuli is repeated, namely in familiar words.

In conclusion, in the context of the Feature Integration Theory and the multi-trace model, attention appears to be an important skill in word reading. Nonetheless, there is need for more evidence regarding this possible relationship and on how attention influences reading. In the following section, studies providing a theoretical explanation regarding the role of attention in reading are discussed.

3.8.2 Bosse's Visual Attention Span and dyslexia

Research conducted by Bosse and colleagues aimed at providing a theoretical account regarding the possible causal role of attention on word reading performance.

Bosse et al.'s (2007) paper provided evidence that the phonological processing deficit and the Visual Attention Span (VAS) disorder in developmental dyslexia are independent and demonstrated that the VAS deficit explains the unique variance in the reading performance of dyslexic participants beyond their phonological skills. They referred to Visual Span as the “amount of distinct visual elements which can be processed in parallel in a multi-element array (pg. 198).

They conducted two experiments, one was with French participants and the second was a replication of the first with English participants. The sample of this study, in the 1st experiment, was 68 dyslexic children with a mean chronological age of 11 years 6 months. They had received some degree of intervention in reading, spelling or oral language skills. They had a mean reading delay of 42 months. There was a control group of 55 typically developed children matched in chronological age, but with significantly higher reading age.

The visual attention span tasks were a whole report and a partial report task. In the whole report condition the participants were presented with twenty randon 5-letter strings. At the start of each trial, a central fixation point was presented for 1000ms followed by a black screen for 500ms. A letter string was then presented at the centre of the display for 200ms. The participants had to report verbally all the lettersregardless of letter positions immediately after they disappeared. In the partial report condition, the participants had to report a single cued letter among the 5 letter string. The procedure was exactly the same as in the whole report task, apart from the probe indicating the letter to be reported.

They found that the dyslexic children performed worse than controls on the three reading tasks (regular, exception and nonword reading), on two of the phonological tasks (deletion and acronym) and on all of the three VA measures (whole report string, whole report letters and partial report). Moderate to strong partial correlations (controlling for age) were found between the measures of reading and the three measures of visual attention span. VA span and phonological abilities did not correlate significantly.

They conducted principal components analysis and used the factor scores (VAS and phonological factor) for the regression analysis. It was revealed that both the phonological and VA factor scores were significant and independent predictors of reading performance, after controlling for age. VAS was a stronger predictor of regular and exception word reading than phonological abilities. This might imply that as expected phonological abilities are more important in decoding (sub-lexical reading) and that attention span might be more influential in sight word reading (lexical reading). Moreover, VA span accounted for 29.4% and 36.4% of unique variance in exception word and nonword reading, respectively. They emphasised the existence of a strong relationship between reading performance and VA processing skills in dyslexic children.

Another interesting finding of this study is that 44% of the dyslexic children exhibited a VA span deficit without having a phonological deficit. This is in accordance with Griffiths and Snowling's (2002) paper, in which it was reported that phonological skills contribute only slightly to exception word reading in readers with dyslexia. Bosse et al. (2007) concluded that their findings indicate that dyslexia might be caused by different underlying cognitive deficits.

In their second experiment, they tested 29 British children (mean age=10 years 5 months) and 23 age matched controls. They used the same VAS task as in the first experiment and also tested the participants in terms of regular, exception and nonword reading, phonological skills (spoonerisms, rhyme fluency and alliteration), vocabulary, letter identification, semantic fluency and non verbal IQ. They found that the group with dyslexia performed significantly worse in all the reading tasks, vocabulary, spoonerisms, rhyme fluency and all the VAS tasks. They used factor scores for the regression and reported that after controlling for age, IQ, vocabulary, letter identification, semantic fluency and phonological skills VAS was a significant predictor of regular and exception word reading explaining 24.7% and 8% of the variance respectively. These findings are in line with their 1st experiment in French.

They concluded that VA span is a strong independent predictor of reading speed and that phonological and VA span disorders contribute independently to developmental dyslexia. Moreover, they argued that the tasks they used, measured specifically visual attentional performance and not other skills, like iconic memory, single letter processing and verbal short term memory. Their results are explained in the context of the multi-trace model (Ans et al., 1998), which suggests that sight word reading relies on global processing. They suggested that the multi-trace model of reading proposes a causal relationship between the VA span disorder and reading difficulties.

Adding to the evidence, Bosse and Valdois (2009) also conducted a cross-sectional correlational study, in which they tried to find the possible associations between reading performance, phoneme awareness, visual attentional span and several control tasks. They reported that phoneme awareness and VA span improved with grades. Moreover, comparisons indicated that 1st Graders performance was significantly worse than that of the older children. As expected, they found strong correlations between phonological skills and reading. One important finding is that there was a strong correlation between letter report tasks and reading performance. The factor analysis suggested that VA span tasks and phoneme awareness tasks measure different cognitive skills. Their results show that the two factors (VA span and phonological factor) are significantly related with all the reading measures. In the 5th Grade the phonological factor correlated only with regular and nonword reading scores, whereas the VA span factor correlated with all reading measures. At all grades, a significant negative correlation was found between reading rate and VA span. The phonological factor also correlated negatively with reading rate, except in the 5th Grade.

In 1st Grade, the unique contribution of the VAS factor to reading was larger than in later grades for reading accuracy of regular words and pseudo-words. In 5th Grade, the unique contribution of the VA span factor remained significant to both reading accuracy and reading rate, whilst, the phonological factor contributed to reading accuracy only. The contribution of the VA span remained stable over grades for the exception words. They also argued that there is a specific link between VA span abilities and performance in exception word reading, which as already mentioned, might indicate the importance of visual attention in sight word reading, where decoding is not involved (see Dual Route Model of reading).

3.8.3 Facoetti's Focused Spatial Attention and Reading

Brannan and Williams (1987) demonstrated that compared to control groups, poor readers were not able to change rapidly the focus of their visual attention. Moreover, Hari et al. (1999) found that the attentional blink was longer in dyslexic than in normally reading adults and that they had difficulties in rapidly shifting and focusing their auditory attention (Renvall & Hari, 2002).

Based on this evidence, Facoetti et al. (2005) aimed at establishing the time course of visual and auditory spatial attention in control and dyslexic children. The main result of their study is that dyslexic children show a slower time course of both visual and auditory attentional capture than both the CA and RA groups. This is in line with Hari and Renvall's (2001) Sluggish Attentional shifting theory. Based on their results they suggested that auditory attention might be crucial not only for phonemic but also for syllabic segmentation of speech. They concluded by arguing that sluggish multimodal attentional focusing in dyslexic children may hinder the development of phonological and orthographic representations that are crucial for learning to read.

Further research supports their findings and they suggested that sluggish multimodal attentional focusing impairs decoding. In particular, Facoetti et al. (2009) studied the visual and auditory spatial attention of 22 children with dyslexia (mean age: 10.75 years) and of 31 controls. They separated the dyslexic children in two groups depending on their nonword reading abilities. Their spatial attention was tested with an auditory and a visual test. They found that only the group with low nonword reading abilities had a deficit in both the auditory and visual spatial attention. They also reported that effective orienting of spatial attention predicted reading performance even after controlling for age, IQ and phonological skills. They concluded that, since spatial attention performance was poorer than both the chronological and reading age matched controls, spatial attention deficits are the cause of reading problems.

It should be noted that all the studies conducted by Facoetti and colleagues were in Italian which is a transparent language and that phonological skills are a weaker predictor of word reading in transparent orthographies (Ziegler et al., 2010).

The papers reviewed in this final section of the chapter present a different theoretical perspective to the one adopted in the current thesis, but nonetheless provide an important background to this thesis, in their consideration of attentional processes above and beyond the well-established predictors of word reading, namely, letter knowledge, phonological awareness and rapid naming.

3.8.4 Summary

In sum, there is evidence that the 3 sub-components of attention as postulated by Posner and Peterson (1990) are exhibited in children after the age of 4 ½ years old. In the past decade, there has been an attempt to explain reading and its difficulties through reading theories which include attention as an important factor affecting reading development (i.e., Bosse's VAS and Facoetti's FSA). In addition, comorbidity studies have revealed that there is a high co-occurrence of reading and attentional difficulties.

Moreover, studies on reading difficulties show that children with reading difficulties perform worse in a variety of attention measures compared to typically developed children. Finally, there are some indications, from studies in typical development, that attention is a predictor of later literacy outcomes. However, the evidence is not conclusive. There is a lack of studies exploring the role of the different sub-components of attention in the visual and auditory modalities, using cognitive measures with children at the early stage of literacy instruction. The majority of studies have been with older children, when it is harder to rule out attention problems arising as a consequence of pre-existing reading difficulties.

Chapter 4: Rational, Research questions, Methodology and Preliminary analysis

4.1 Rational

There has been extensive research on the precursors of literacy and it has been reported that the cognitive linguistic predictors of early reading skills are letter sound knowledge, early word reading, phonological awareness and RAN (Caravolas et al., 2012; for review see Snowling & Hulme, 2013).

In addition, attention has been proposed by many researchers to contribute significantly in learning and academic outcomes (Posner & Rothbart, 2007; Lan, Legare, Ponitz, Li & Morrison, 2011). It has also been reported that there is a high comorbidity of ADHD and reading difficulties (for review see Snowling, 2009) as well as a relationship between dyslexia and attention deficits (Bosse & Valdois, 2009; Facoetti et al., 2006). However, the evidence is contradicting (Marzocchi, Ornaghi & Barboglio, 2009; Ziegler et al., 2010) and the majority of the studies which report a significant impact of attention on reading have used teacher and parent ratings of attention. Furthermore, there are limited studies examining the role of attention in literacy from a developmental perspective (Steele et al., 2012, Sims & Lonigan, 2013).

Hence, recently there has been an increased interest on attention and its role in learning and reading, nonetheless the existing evidence is only correlational and not robust enough so as to elucidate which aspects of attention correlate with reading and/or its predictors.

As already mentioned, in the present study the model of attention developed by Posner and Petersen (1990) was used as there is strong evidence both from neuroimaging and cognitive studies (with adults) supporting the existence of different neural mechanisms which are responsible for the function of selective attention, sustained attention and attentional control. There is also evidence that this model applies to 6 years old children (Manly, 2001). In addition, these sub-components of attention have recently been shown to be developed in children as young as $4^{1/2}$ years (Breckenridge, 2012). This finding provides the researchers with the opportunity to be able to study the role of attention before or at the beginning of formal literacy instruction, so as to ensure that any existing reading difficulties do not influence the children's attention skills.

4.2 Aims, Hypothesis and Research Questions

The current research aims to examine the relationship between the development of the three sub-components of attention and early literacy skills; the focus is on whether any of these attention components is a unique concurrent and/or longitudinal predictor of early literacy skills and specifically word reading accuracy.

In addition, taking into account the computational models of reading, this study explores whether the different sub-components of attention have an impact only on specific pathways of word reading. Finally, another aim of this study is to explore whether children at risk of reading difficulties also exhibit an attentional difficulties profile.

The hypothesis is that, as Dally (2006) noted, good phonological skills and attention will be essential for the acquisition of grapheme-phoneme correspondence rules and the development of word reading. In particular, attentional control is assumed to be an independent predictor of word reading accuracy (see Wanless et al., 2011; Connor et al., 2010, Burrage et al. 2008; but see May et al., 2013). Also, sub-lexical reading (i.e., decoding) has been shown to be predicted by attentional control. Specifically, nonword reading is associated with inhibition control (Bental & Tirosh, 2007) and decoding with both inhibition and switching (Altmeier, Abbott & Berninger, 2008).

It is also expected that visual sustained attention will play a role in reading acquisition, possibly in an indirect way through its influence on letter sound knowledge and phonological awareness (see Sims & Lonigan, 2013). It is also hypothesized that auditory sustained attention might play a differential role on reading (see Aylward & Brager, 2002; Steele et al., 2012). Specifically, it is expected that it will play a more important role in the development of word reading than visual sustained attention. The rationale behind this hypothesis is that students in a classroom environment require good auditory attention so as to be able to attend to the information given by the teacher and hence enhance their learning (for the effects of noise on attention, listening comprehension and academic outcomes see also Shield & Dockrell, 2003; Dockrell & Shield, 2012). Auditory attention in relation to early reading development in young children has not been examined by any previous study to my knowledge (apart from Marzocchi et al., 2009)[9] , hence, the present study attempts to explore any possible relationship.

In terms of selective attention the evidence is very limited, but it has been found to correlate with word reading in students between the ages of 7-12 years (Casco et al., 1998). It has also been found to be a longitudinal unique predictor of word reading (Plaza & Cohen, 2007; but see Shapiro et al., 2013). It has been argued that selective attention might be involved in visual pattern recognition (Posner & Petersen, 1990). Consequently, it is anticipated that selective attention might predict lexical reading (i.e., exception word reading).

Taking into account the evidence from studies on reading difficulties and comorbidity, it is foreseen that children at risk of reading difficulties will exhibit attentional difficulties as well. Specifically, it has been reported that at least older children with reading difficulties perform worse in tasks measuring sustained attention and attentional control (Sireteanu et al., 2006; Bental & Tirosh, 2007; Lima et al., 2011).

The research questions that this thesis aimed to answer are:

1. Is attention a concurrent and/or a longitudinal unique predictor of word reading?
    a. What is the role of sustained attention?
        i. auditory modality
        ii. visual modality
    b. What is the role of selective attention?
    c. What is the role of attentional control?

[9] He found that dyslexics (7-12 years old) performed significantly worse than the controls but the difference was not significant after controlling for working memory

2. Do these sub-components of attention have a specific impact on different pathways of word reading accuracy (i.e., Lexical, sub-lexical word reading)?

3. Do children at risk of reading difficulties exhibit a pattern of attention difficulties? In which sub-components of attention?

4.3 Design

The present study was designed to answer the research questions stated above. It was a longitudinal study in which the participants were tested at two times over a period of 12 months, when they were at the Spring term of Reception Year and again at the Spring term of Year 1. Both their early literacy and attention skills were tested at Time 1 and Time 2, so as to be able to examine which are the concurrent and/or longitudinal predictors of word reading.

In order to measure the different sub-components of attention, cognitive measures that have been shown by previous research to load onto the specific sub-components were employed. Table 4.1 summarizes the literacy and language tests used at Time 1 and 2; and Table 4.2 summarizes the attentional tasks. The Diagnostic Test of Word Reading Processes (DTWRP) was used as an additional measure of accuracy in word reading at Time 2, as it has been recently standardized (2012) in the U.K. and it provides separate scores for lexical and sub-lexical word reading (regular, exception and nonword reading).

Regression analysis was used so as to examine whether any of the sub-components of attention is a concurrent and/or longitudinal predictor of lexical and/or sub-lexical word reading.

In order to examine the attentional profiles of children at risk of reading difficulties, a sub-group (at risk) was identified at Time 2 (standard score below 90 in the DTWRP) and their performance on the attention measures was compared to the standardised scores of the rest of the participants (control group).

Table 4.1: Literacy and Language tests employed in this thesis

	Time 1 and Time 2	Time 2 only	Test used
Outcome variable	Early word reading accuracy	Regular, exception and nonword reading accuracy	• Early word reading subtest from YARC (T1 & T2) • DTWRP (T2)
Predictor variables	Letter sound Knowledge		Letter-sound knowledge extended subtest from YARC
	Phonological awareness		Sound Isolation and deletion subtests from YARC
	Rapid Naming		RAN of Objects subtest from CTOPP
Control Variables	Receptive Vocabulary	Recalling sentences	• BPVS (T1 & T2) • Recalling sentences subtest from CELF4 (T2)

Table 4.2: Attention measures employed in this thesis

	Time 1 and Time 2	**Time 2 only**
Selective attention	Flanker (Breckenridge, 2012)	
	Visual Search task (Wilding, 2010)	
Sustained attention	Visual CPT (Steele, 2013)	
	Auditory CPT (Gooch, 2013)	
Attentional Control	HTKS (behavioural inhibition)	
	Day-Night (inhibition control)	
	Dual Visual Search (shifting; Wilding, 2010)	
Behavioural rating of attention		SWAN rating scale

4.4 Methods

4.4.1 Participants

Eighty-three children participated in this study (M= 58.42 months, SD= 4.016 months; range= 52-65 months, 45 girls and 38 boys). This sample is representative of the range of literacy skills you would expect at this age, with the group average for early literacy skills and verbal abilities falling within the 45th and 55th percentile (for details see Chapter 4: Preliminary analysis Part 2) Participants were recruited through one infant school from Greater London. The ethnicity of the sample was predominantly White British; however, it included a high proportion of children with EAL (34.9% in comparison to 18.1% at national level in 2013). They also have a low socio-economical background (FSM 39% in comparison to 19.2% at national level, 2013). The percentage of the children with SEN from the sample used was not higher than expected (6 out of 83 students; i.e., 7.2%).

These six participants were identified from the school at follow-up (time 2) as having SEN and/or other medical conditions and were excluded from the analysis. Hence, the number of participants included in the analysis, at Time 1, is 77 (57% girls, 43% boys) with a mean age of 58.62 months (SD = 4.02). Due to attrition at Time 2, 74 children were tested (M=70.67 months, SD= 4.07 months, range=64-77; 41 female, 33 male).

The children with EAL were not excluded from the analyses since they did not differ as a group in their verbal language skills (vocabulary knowledge) when compared to the native English speaking children in the class. Namely, independent samples t-test showed that they did not have significant differences in language skills (M_{EAL}= 47.74, SD=12.06; M_{ENG}=45.12, SD=10.72; $t(70) = .92$, $p > .05$); the effect size was small .11). Their word reading performance was also not significantly different (M_{EAL}= 5.22, SD=5.35; M_{ENG}=4.29, SD=4.32; $t(70) = .78$, $p > .05$); the effect size was also small .09.

An independent-samples t-test was also conducted to compare attentional skills in the two groups. There was no significant difference in the scores at any of the attention measures, apart from commission errors in the auditory continuous performance (M_{EAL}= 3.36, SD= 4.12; M_{ENG}= 7, SD= 6.75; $t(67) = -2.32$, $p > .05$); the effect size was large .30).

4.4.2 Materials and Procedure

For the administration of the computerized tests a touch screen Toshiba laptop was used for the Visual search tasks (Visearch; Wilding, 2001) and a Dell laptop for the rest. The tests were administered in four sessions each lasting for approximately 15 minutes. During the first session, the participants were administered the Early Reading subtests of YARC (letter knowledge, early word reading, sound deletion and sound isolation). After all students were tested, they were administered the BPVS II and the Day-Night task. In the third session, they completed the CPT, Dual target Visual Search, HTKS and Flanker and in the last one the ACPT, RAN from CTOPP and Visual Search tasks. Details of each task follow..

Continuous Performance test (CPT)

This task was used so as to measure the children's ability to sustain their visual attention over a prolonged period of time. The test was developed in DMDX using Steele's et al. (2013) paradigm. The stimuli used were presented in 100 trials consisting of animal pictures (20 targets, 80 distractors; the target was a picture of a dog and the distractors pictures of various other animals). Each stimulus was presented for 250ms in duration with an interstimulus interval of 1250ms. Participants were instructed to place their index finger below the space bar and press it each time they saw the picture of a dog (target). There were 5 practice trials to ensure that children had understood what they had to do. They were reminded to keep their finger on the correct position if needed throughout the test but they were not given feedback as this could influence their performance. Overall task duration was approximately 5 minutes. Reaction Times for correct responses, Omission Errors (missed targets) and Commission Errors (false alarms) were recorded.

Auditory Continuous Performance test (ACPT)

This task was designed to measure sustained auditory attention using animal sounds for stimuli. Gooch's paradigm (Gooch, Hulme, Nash & Snowling, 2014) was used. A farm house picture was presented during the whole test. There were 20 targets (dog bark) and 140 distractors (other animal sounds: duck, cow, pig, frog). Each auditory stimulus was presented for 500ms and the inter-stimulus interval was 1500ms. All of the participants had 6 practice trials. The children were instructed to push the left mouse button when they heard the dog bark and ignore the other animal sounds. Task duration was approximately 5 minutes. Omission Errors, Commission Errors and Reaction Times for correct responses were recorded as in the visual CPT.

Flanker

The flanker paradigm by Breckenridge (2012) was used so as to measure the children's ability to orient their attention and ignore distractors. The stimuli used were pictures of same coloured fish and mice. All stimuli were displayed on a computer screen and the target was the fish. All trials began with a central fixation dot. The participants were instructed to respond by touching the right or left side of the table according to the direction that the fish was looking. There were four groups of trials, the first and fourth were congruent conditions and the third and fourth incongruent. All of the participants completed familiarization and practice trials. The duration of the test was approximately 2 minutes. Completion time for each trial was measured with a timer. Mean completion time was measured for the congruent and incongruent conditions separately. The score was computed by dividing the completion time of the incongruent condition by the completion time of the congruent, so as to ensure that variance was not affected by general processing speed.

Visual search

The single target condition of the Wilding Visual Search task (Visearch; Wilding et al., 2001) was used to assess the participants' selective attention. In this task, participants were seated in front of a touch screen laptop showing a display of black “holes” on a green background with a river and some trees. In the single-target search condition, participants were instructed to tap with a pen as quickly as they could on the black holes until they found the king of the monsters. The king always appeared on the twentieth target touched. All the participants completed a practice trial. Mean time per hit, false alarms and mean distance per hit were measured. The duration of the test was approximately 1 minute.

Dual Visual Search

The dual target condition of the Wilding Visual Search task (Visearch; Wilding et al., 2001) was used to assess the participants’ ability to switch their visual attention. For the administration of the task a touch screen Toshiba laptop was used. Participants were seated in front of the laptop showing a display of black and brown holes on a green background with a river and trees. They were instructed to tap with a pen as quickly as they could on black and brown holes alternatively in order to find the king of the monsters. Thus they had to switch their visual attention between two targets. There were 15 of each type of target (i.e., total 30 targets). The task ended if the king was not found after 50 clicks or after the participant had clicked on all targets (the king always appeared when all targets were clicked). Mean time per hit, false alarms and mean distance per hit were measured and they were recorded automatically by the program. The duration of the test was approximately 1.5 minutes.

Day-Night Task

The paradigm of Simpson & Rigg (2005) was used to assess the ability to inhibit a conventional verbal response to the picture displayed. The children were tested on a day-night inhibitory condition. The participants were instructed to say "moon" to a picture of the sun and "sun to the picture of the "moon". They had 8 seconds in order to give their response. Reaction time and number of errors were recorded.

Head Toes Knees Shoulders (HTKS)

McClelland et al.'s (2008) paradigm of HTKS was used as a behavioural measure of non-verbal inhibition control. The child is instructed to do the opposite of the verbal instructions he/she gets. Specifically, in the first part, they are instructed to touch their head when the instructions are "touch your toes" and to touch their toes when the instructions are "touch your head". In the second part in addition to the head and toes, the participants are instructed to touch their shoulders when the instruction is "touch your knees" and vice versa. The child is given up to 3 practice trials and 10 test trials for each part.

SWAN rating scale of inattention (Swanson et al., 2001)

The SWAN rating scale for teachers is a questionnaire with 18 items (9 for inattention and 9 for impulsivity)[10]. The highest score indicates attentional difficulties and/or impulsivity. A zero or negative score indicates that the child's attentional behaviour is within or better than the average compared to other

[10] Examples of items in SWAN measuring inattention: 'Engage in tasks that require sustained mental effort', 'Ignore extraneous stimuli'; Examples of items in SWAN measuring hyperactivity: 'Sit still (control movement of hands/ feet or control squirming)', 'Stay seated (when required by class rules/social conventions)'.

children at the same age. This measure was used only at time 2 for the case studies (see Chapter 8).

<u>Foundations for literacy skills</u>

Letter sound Knowledge

Children were administered the extended version of the YARC Letter Sound Knowledge subtest on a one-to-one basis, where they were shown flash cards depicting 26 lower case letters and 6 digraphs and instructed to say the sound that they make. If the child said the name of the letter, they were prompted once to say the sound. The overall score recorded was the number correct out of a maximum of 32. Cronbach's alpha as provided by the manual is .98.

Early word Reading

In the YARC early word reading subtest the children had to read aloud a card with a mixed list of 15 regular and 15 exception words graded in difficulty, starting with regular CVC and high frequency words and moving on exception and multisyllabic words. After 10 consecutive errors the test was discontinued. This is an untimed test and the score is the total number of words read aloud accurately with a maximum score of 30. Cronbach's alpha as provided by the manual is .98.

Phoneme awareness skills

Sound Isolation

In the YARC Sound Isolation subtest the child hears 6 nonsense words and has to identify the initial sound. Then he/she hears 6 different nonsense words and has to identify the final sound. There were 3 practice trials for the initials sounds and 3 for the final sounds. The score from a maximum of 12 correct is recorded. Cronbach's alpha as provided by the manual is .88.

Sound Deletion

The child hears and sees the picture of a word and is instructed to repeat it by taking away a sound. The task begins with composite words and child is required to take away the first and then the second part of the word. For example, they hear the word ‘seesaw’ and they are asked to say it again without saying ‘saw’. Then they are presented with words and are asked to repeat them, without saying the last sound (e.g., say the word ‘sheep’ without saying ‘p’). This was followed by words starting with a digraph (e.g. say ‘cloud’ without saying ‘c’). The last step was to repeat words without saying sounds that were in the middle of the word (e.g. say ‘jumper’ without saying ‘p’). Cronbach’s alpha as provided by the manual is .93.

The Phoneme awareness composite was calculated (in line with the manual’s instructions) by adding the scores of the sound deletion and sound isolation tasks in order to reduce the number of the variables.

Rapid Automatized Naming of Colours and Objects (CTOPP)

In the rapid automatized naming of colours and objects the students see two pages of coloured squares or objects (4 rows of 9 items per page) and are instructed to say the name of the colours/objects on each row from left to right, as quickly as they can, without making errors. The score is the total time to name all of the stimuli on the card. The test is discontinued if the participant makes more than 4 errors on either page.

British Picture Vocabulary Scale II (BPVS-II)

In the BPVS II the participants were told a word and were instructed to select a picture that represents the meaning of this word. For each word they were shown 4 pictures, only one of which was correct. This task is intended to measure the child’s receptive vocabulary. There is no verbal response, reading or writing involved. Cronbach’s alpha as provided by the manual is .93.

Additional measures employed at Time 2 only

Diagnostic Test of Word Reading Processes (DTWRP)

The DTWRP comprises of 3 sets of words (30 regular words, 30 exception and 30 nonwords). The participant is required to read aloud each set of words on separate cards and the test is discontinued after 5 consecutive errors. This test also provides information on whether the reading difficulties of a child are due to phonological and/or lexical-semantic difficulties. The duration of the test was approximately 10 minutes. Cronbach's alpha as provided by the manual is .97 for regular word reading, .96 for nonword reading and .97 for exception word reading.

Recalling Sentences (CELF4)

The Recalling Sentences subtest measures the participants' ability to listen to spoken sentences of increasing length and complexity and repeat them verbatim. The ability to imitate sentences is one of the core language skills. For each correct sentence, the participant was given 3 points; for 1 error they were given 2 points; for 2-3 errors, 1 point and for 4 or more errors 0 points. The test was discontinued after 4 consecutive 0 points. The duration of the test was approximately 15 minutes. Cronbach's alpha as provided by the manual is .86.

4.5 Ethical Considerations, Recruitment and Inclusion criteria

The research was approved by the Institute of Education Research Ethics Committee. Information letters regarding the research were sent to several schools in Greater London. Out of the three schools which were interested in participating only one finally agreed to take part. Only typically developing children were included in the study. The parents were sent an information letter and a consent form (see appendix 7). All the participants and their parents were informed about their right to withdraw from the study at any point with no negative consequences. The data collected for this research project were kept confidential and all participants were identified by a code in order to maintain their anonymity. The data were stored securely.

4.6 Preliminary analysis

4.6.1 Part 1: Developmental Changes in Literacy, Language and Attention from Reception to Year 1

4.6.1.1 Introduction

This section presents the results of a preliminary analysis in regards to the growth of each skill from Reception to Year 1. It aims at examining whether there was a significant development in the skills measured (i.e., literacy, language, attention). It is expected that there will be a significant growth in all the literacy measures as the participants when re-assessed had received 12 months of additional literacy instruction. Based on the literature reviewed regarding the sub-components of attention, it is also expected that there will be some growth in the attentional measures. However, this analysis is more exploratory as the age range used in this study is limited in comparison to previous studies (see Breckenridge et al., 2012; Manly et al., 2001; Steele et al., 2013) reporting significant developmental changes over time (see chapter 2).

This section sets the context of this thesis (which explores which variables may influence the growth of literacy skills) as it will provide the first set of information which is essential for the present study. Namely, it will reveal whether there was this significant change over time in literacy, which will be attempted to be explained in subsequent chapters.

4.6.1.2 Results

In order to examine whether the developmental changes from Time 1 to Time 2 were statistically significant, a repeated measures general linear model analysis (ANOVA) was conducted separately for each measure.

As expected, there was a significant increase in letter sound knowledge, $F(1,73)=429.20$, $p<.001$; phonological awareness, $F(1,73)=303.46$, $p<.001$; and word reading accuracy as measured by the Early Word reading subtest from Reception to Year 1, $F(1,73)=470.07$, $p<.001$. The effect sizes (partial eta-square) were large for all the variables: LSK $\eta_p^2=.85$, PA $\eta_p^2=.81$, and EWR

η_p^2=.87, indicating that performance in the emergent literacy measures was greatly affected by chronological age.

The same pattern was valid for language skills (vocabulary) as measured by BPVS, $F(1,73)=103.38$, $p<.001$. The effect size (partial eta-square) was large, η_p^2=.59.

There was a statistically significant development in all the variables of the Visual and Auditory Continuous Performance tasks. In particular, Reaction Time in the VCPT was significantly reduced, $F(1,69)= 5.04$, $p<.05$ and had a small effect size,η_p^2=.07. Visual Sustained attention as measured by the omission errors also improved, $F(1,69)= 16.53$, $p<.001$ with a medium effect size, η_p^2=.19; and there was a significant decrease in the commission errors, $F(1,66)= 11.03$, $p<.001$ with a medium effect size, η_p^2=.14.

There was also a significant development in the Reaction Time of the Auditory CPT,$F(1,65)= 12.42$, $p<.001$ with a medium effect size, η_p^2=.16 and in the omission errors of the ACPT, $F(1,65)= 60.66$, $p<.001$ with a large effect size, η_p^2=.48. There was also a decrease in the number of commission errors, $F(1,66)= 10.62$, $p<.001$ with a medium effect size, η_p^2= .14.

There was no significant development in visual selective attention as measured by the Flanker task from Time 1 to Time 2, $F(1,73)= .04$, $p=.84$ (η_p^2=.00). However, it is worth noting that there were 14 participants at time 1 whose raw score in the Flanker was below 1. Namely, they completed the incongruent condition in a shorter time than the control condition. When these participants were treated as outliers and removed from the analysis, it was found that the developmental change from time 1 to time 2 became statistically significant, F(1,62)= 5.06, $p<.05$and had a small effect size, η_p^2=.07.

There was a significant improvement in the performance in inhibition control tasks both verbal and non-verbal. In particular, the mean Reaction time in the Day-Night task reduced in Time 2, $F(1,72)= 9.64$, $p<.01$ and had a moderate effect size, η_p^2=.12. The improvement in the HTKS task was greater, $F(1,72)= 47.73$, $p<.001$ and had a large effect size, η_p^2=.40.

Visual selective attention as measured by the Visual Search task had a significant improvement. False alarms were reduced in Time 2 and the reduction was statistically significant, $F(1,70)= 54.29$, $p<.05$ with a small effect size, $\eta_p^2=.05$. Time per hit also improved, $F(1,70)= 11.53$, $p<.001$ with a medium effect size, $\eta_p^2=.14$.

There was a large significant difference in the performance on the switching of attention task (Dual Visual Search task) as well. False alarms were significantly reduced, $F(1,70)= 44.45$, $p<.001$ with a large effect size, $\eta_p^2=.39$. Time per Hit also decreased, $F(1,70)= 65.25$, $p<.001$ with a large effect size, $\eta_p^2=.48$.

To sum up, there was a significant and positive developmental change in performance across all the measures of early literacy, language and attention apart from selective attention as measured by the Flanker, where there was no change in scores.

4.6.1.3 Interim Discussion

The findings indicate that there is a vast significant growth in letter-sound knowledge, phonological awareness and word reading accuracy from Reception to Year 1. There was also a significant growth in receptive vocabulary but this was smaller compared to the early literacy skills. These results were expected as the children received an additional year of formal literacy instruction.

The results regarding the development of inhibition control are in line with previous studies that have showed that there is a significant change in self-regulation and shifting skills in preschoolers from 3 to 4 years old (Jones, Rothbart & Posner, 2003). The effect sizes of the differences in the HTKS and the Dual Visual Search task indicate that these skills continue to develop rapidly in children from $4^{1/2}$ to $5^{1/2}$ years old. The change in the Day-Night task was significant but smaller compared to the two other attentional control tasks. This might be explained in light of Jones et al. (2003) study in which it was reported that physical self-regulation is more developed than verbal self-regulation in preschoolers.

The lack of significant change in the performance on the Flanker task might indicate that selective attention as measured by this task does not develop greatly within a period of 12 months for the specific age group or that the task is not sensitive to the developmental change over this period. However, Breckenridge, Braddick and Atkinson (2013) showed that there is a significant development in the performance on this Flanker paradigm for the ages between 3-$4^{1/2}$ and $4^{1/2}$-6 years old. However, the age bands that they used were broader compared to the present study.

Breckenridge (2007) in her PhD thesis reported that there was a significant improvement in performance in the Flanker task between 4 to 5 years old children. A subsequent examination of the present results showed that at time 1 16% of the sample not only did they perform at ceiling but their scores showed that they were slower in the control condition, which is the opposite to expectations. Breckenridge (2007) reported that only 6% of her sample performed at ceiling and that a raw score of .99 or less falls above the 95^{th} percentile, which is in line with the results of the present thesis at time 2 (6.8% of the participant at time 2 performed at ceiling).

A possible explanation of the results of this thesis might be relevant to the order that the incongruent and control sets of trials were presented (an issue which was noticed by Breckenridge in her pilot study, but presumably was addressed in the final version of the task). The test was beginning and ending with a control trial (i.e., control-incongruent-incongruent-control). This means that performance on the first set might be influenced by limited practice and/or stress and on the last set by fatigue. Nonetheless, it should be noted that all participants completed practice trials and none appeared to be visibly stressed during the administration of any test.

When the analysis was repeated by excluding the participants above the 95^{th} percentile, then the results were comparable to those reported by Breckenridge (2007, 2013). Namely, there was a significant developmental change for time 1 to time 2 ($F(1,62)= 5.06$, $p<.05$).

The findings regarding the development of sustained attention are in line with previous research, comparing the performance of 5-6 to 8-9 years old children, suggesting that there is a significant growth in all the indices of the CPTs (reaction time, omission and commission errors) (Betts, Mckay , Maruff & Anderson, 2006). The present study showed that there is significant development within 1 year also for children aged $4^{1/2}$-$5^{1/2}$ years old. This finding is further supported by Steele et al.'s (2013) findings using 3-6 years old children. Specifically they found that performance in a CPT task improved with age. The same pattern of results was also reported both by the present and Steele et al.'s (2013) study regarding the visual search task. There was significant growth both in accuracy and reaction time.

4.6.2 Part 2: Predictors of lexical and sub-lexical word reading accuracy.

4.6.2.1 Introduction

The aim of this section is to present the results of the second part of the preliminary analysis using the literacy and language measures only at both times. This analysis does not attempt to answer the research questions of this thesis, but to examine whether strong evidence from previous research can be replicated with this sample. Hence, the research question of this study is whether letter-sound knowledge, phoneme awareness and RAN are predictors of word reading accuracy. This will assist in the discussion and interpretation of the results regarding the sub-components of attention.

There is a strong body of evidence demonstrating that letter knowledge, phonological awareness and rapid naming are strong predictors of early decoding skills (accuracy and fluency), concurrently and longitudinally, for children learning to read in English and other alphabetic orthographies (Schatchneider et al., 2004; Lervag, Braten and Hulme, 2009; Caravolas et al., 2012). Poor oral language skills (e.g., vocabulary) have also been shown to hinder reading development (Bishop & Snowling, 2004), particularly text processing and reading comprehension (Carroll, 1993; Protopapas et al., 2007).

To begin with, phoneme awareness has been reported to be a very strong correlate of later word reading skills (Melby-Lervag, Lyster & Hulme, 2012) and intervention studies have provided evidence regarding its causal role in reading acquisition (Ball & Blachman, 1991; Swanson, 1999).

In addition letter knowledge has been found to be a strong longitudinal predictor of word reading alongside phoneme awareness (Muter, Hulme, Snowling & Stevenson, 2004; Hulme, Bowyer-Crane, Carroll, Duff & Snowling, 2012) and mediates the relationship between phonological awareness and reading (Blaiklock, 2004). Rapid naming has been shown to be a reliable concurrent and longitudinal predictor of word reading across orthographies even after controlling for phonological awareness (van de Bos, 1998; Wagner Torgesen & Rashotte, 1994; Simpson & Everatt, 2005; Moll et al., 2014).

Finally, it has been found that children at risk of dyslexia and language difficulties are more possible to have later reading difficulties (Gallagher, Frith & Snowling, 2000; Gooch, Hulme, Nash & Snowling, 2014) and it has been suggested that vocabulary is a predictor of word reading above and beyond decoding skills (Nation & Snowling, 2004).

4.6.2.2 Results

4.6.2.2.1 Results Time 1 (Reception Year)

The following table presents the descriptives of the literacy and language measures. It should be noted that in RAN of colours, there were 23 data points missing due to the fact that some of the children made too many errors or did not know the colours. According to the test protocol, a raw score could not be recorded for these cases. Due to the high number of missing data in the RAN of colours, this task was not included in the analysis (correlations and regression). In RAN of Objects there was less data missing (n=14).

Table 4.3: Descriptives of literacy measures (without outliers) at Time 1

	Mean	**SD**	**Range**	**SS**[11]	**SD SS**	**Sk.**	**Kurt.**
LSK	16.14	6.96	2-29	103.64	11.90	.02	.03
EWR	4.43	4.58	0-15	104.51	14.89	.42	-.94
PA	7.76	6.17	0-20	102.70	15.46	.47	-1.08
R.V.	45.43	11.28	21-68	96.12	11.24	-.03	-.24
RANC.	122.39	28.32	75-200	9.04	1.76	.17	-.60
RANO.	120.22	27.58	64-185	9.75	2.19	.39	-.18

Note: n=77. LSK= Letter-sound knowledge (max. 32); EWR= Early word reading (max. 30); PA= phonological awareness composite score (max. 24); R.V. = Receptive vocabulary; RAN C.= Rapid naming of colours (in secs); RAN O. = Rapid naming of objects (in secs)

Table 4.3summarizes the mean raw and standard scores, range, skewness and kurtosis in early word reading, letter-sound knowledge, phonological awareness, rapid naming and vocabulary. Letter sound knowledge standard

[11]Standard scores for LSK, EWR, PA and R.V. have a population mean of 100; Standard scores for RAN have a population mean of 10.

scores have a normal distribution and the mean standard score is 103.64 (SD = 11.90) suggesting the sample scored within the normal range for their age.

The early word reading test consisted of regular and exception word reading accuracy. Only 14 participants were able to read more than 1 exception word. Both distributions were positively skewed. For this reason, instead of using two separate variables for early word reading (regular and exception words), the total of both was used. The distribution for the total scores remained positively skewed but was insignificant (skewness = .42; kurtosis = -.94). The mean of the SS is 104.54 (SD= 14.89). It should be noted that 20 of the participants scored 0, so there was a high percentage of floor effect, which might mask any possible correlations if they are not strong.

Receptive vocabulary distribution was normal and the overall group mean standard score fell within the average range 96.12 (SD=11.24).The distribution of the SS in RAN of colours was normal. The same pattern was exhibited in the RAN of objects. The distribution for the completion times was also normal.

Inter-correlations at Time 1

In the following tables the Pearson bivariate correlations are reported. Parametric correlations were conducted for all the variables even if their distribution was not normal as according to the Central Limit Theorem (Lumley, Diehr, Emerson & Chen, 2002), we can assume normality for samples that are large enough (i.e., *n*>40).

Table 4.4: Correlations among Time 1 literacy variables

	LSK	EWR	PA	RV	RAN O.
LSK	1				
EWR	.82**	1			
PA	.73**	.78**	1		
R.V.	.33**	.39**	.62**	1	
RANO	-.29*	-.25*	-.24	-.28*	1

Note: n=77. LSK= Letter-sound knowledge (max. 32); EWR= Early word reading (max. 30); PA= phonological awareness composite score (max. 24); R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects (in secs)

$^{**}p<.01$, $^{*}p<.05$

As expected, there are moderate to high correlations between most of the Time 1 literacy variables. The only correlations that did not reach significance were between phonological awareness and RAN of objects. This might be due to the missing data in the RAN task (n=63).

A regression analysis followed so as to examine the amount of variance explained in Early word reading by the other variables.

Table 4.5: Stepwise Regression for Predictors of Early word reading in Reception Year

Model	B	SE B	Beta
Step 1			
(Constant)	-2.30	2.29	
R.V.	.15	.05	.37**
Step 2			
(Constant)	-2.30	2.50	
R.V.	-.02	.03	-.05
LSK	.36	.07	.56***
PA	.29	.09	.39***
RAN O.	-.00	.01	-.02

Note: LSK= Letter-sound knowledge (max. 32); EWR= Early word reading (max. 30); PA= phonological awareness composite score (max. 24); R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects (in secs); N=63. R^2= .14 for Step 1, ΔR^2= .61 for Step 2 (p<.001). ***p<.001, **p<.01

It was found that the only concurrent predictors of Early word reading in Reception Year were letter-sound knowledge and phonological awareness, explaining 60.9% of the variance. Receptive vocabulary and rapid naming of objects did not account for any additional variance.

Results at Time 2 (Year 1)

The same analysis as in Time 1 was repeated in Time 2. Table 3.6 summarizes the descriptives of the literacy and language measures. Overall, the participants scored within the normal range for their age in all the measures.

Table 4.6 Descriptives of literacy and language measures at Time 2

	Mean	SD	Range	SS	SD SS	Skew.	Kurt.
LSK	30.17	2.04	25-32	111.10	11.00	-1.25	.78
EWR	17.98	8.11	4-30	105.91	11.91	.06	-1.14
DTWRP	23.89	15.58	2-55	101.17	12.11	.65	-.98
PA	16.59	4.04	8-23	105.74	11.03	-.41	-.65
R. W.	11.19	7.33	0-25	5.80	1.91	.58	-1.16
N. W.	6.23	1.94	2-10	5.01	.92	-.00	-.45
E. W	6.39	6.81	0-20	4.72	2.71	.06	-.14
R.S.	30.68	11.55	4-60	10	SD	.50	.38
R.V.	56.16	9.85	36-76	97.22	8.67	.33	-.58
RAN C.	101.50	24.37	55-175	9	SD	.42	.69
RAN O.	107.05	24.61	55-152	8	SD	-.22	-.42

Note: n=74. LSK= Letter-sound knowledge (max. 32); EWR= Early word reading (max. 30); DTWRP= Diagnostic Test of Word Reading Processes composite score (max. 90); PA= phonological awareness composite score (max. 24); R.W.= Regular word reading (max. 30); N.W.= Nonword reading (max. 30); E.W.= Exception word reading (max. 30); R.S.= Recalling sentences; R.V. = Receptive vocabulary; RAN C.= Rapid naming of colours (in secs); RAN O.= Rapid naming of objects (in secs).

The distribution of the following variables, according to the Shapiro-Wilk test, was normal: RAN Objects and Colours, Receptive vocabulary, nonword reading and recalling sentences. In the RAN objects there were 4 participants who were not able to complete the task, as they found it too challenging. There were also data missing from 10 cases in RAN colours for the same reason. As the number of participants who found the RAN colours too difficult was quite high, it was decided to use only RAN objects in all subsequent analyses. The mean performance on the measures was within the normal range. A simple correlation analysis followed (Table 3.7).

Table 4.7: Inter-correlations between literacy and language measures at Time 2 (Year 1)

		1	2	3	4	5	6	7	8	9	10
1	**DTWRP**	1									
2	**N.W.**	.80**	1								
3	**E.W.**	.97**	.70**	1							
4	**R.W**	.98**	.78**	.93**	1						
5	**LSK**	.59**	.62**	.53**	.60**	1					
6	**EWR**	.91**	.78**	.90**	.92**	.73**	1				
7	**PA**	.68**	.61**	.64**	.67**	.62**	.72**	1			
8	**RAN O**	-.38**	-.20	-.39**	-.38**	-.35**	-.36**	-.29*	1		
9	**R.V.**	.45**	.40**	.43**	.45**	.31**	.48**	.49**	-.11	1	
10	**R.S.**	.43**	.40**	.40**	.43**	.31**	.43**	.50**	-.22	.54**	1

Note: LSK= Letter-sound knowledge (max. 32); EWR= Early word reading (max. 30); DTWRP= Diagnostic Test of Word Reading Processes composite score (max. 90); PA= phonological awareness composite score (max. 24); R.W.= Regular word reading (max. 30); N.W.= Nonword reading (max. 30); E.W.= Exception word reading (max. 30); R.S.= Recalling sentences; R.V. = Receptive vocabulary; RAN O.= Rapid naming of objects (in secs).
p<.01**, p<.05*

Each of the word reading measures correlated strongly with each other. Nonword reading had comparatively the weakest correlations with the rest of the reading accuracy measures (*r*=.70** exception word reading; *r*=.78** regular and early word reading). Also, Letter-sound knowledge, phonological awareness, Rapid naming of Objects and language skills (both receptive vocabulary and recalling sentences) had moderate to strong correlations with all word reading tasks. The two language measures had also a significant strong positive correlation.

The following tables present the results of the regression analyses for the predictors of early word reading, regular word reading, exception word reading and nonword reading separately.

Table 4.8: Stepwise Regression analysis for Predictors of early word reading in Year 1

Model	**B**	**SE B**	**Beta**
Step 1			
(Constant)	-2.59	4.94	
R.V	.29	.10	.36**
R. S.	.18	.09	.21
Step 2			
(Constant)	-52.08	11.70	
R.V.	.13	.07	.17
R.S.	.02	.06	.03
LSK	1.78	.38	.43***
PA	.67	.21	.33**
RAN O.	-.03	.03	-.09

Note: N=70. R^2= .25 for Step 1, ΔR^2= .41 for Step 2 (p<.001). ***p<.001, **p<.01;
LSK= Letter-sound knowledge; PA = phonological awareness; R.S.= Recalling sentences; R.V. = Receptive vocabulary; RAN O.= Rapid naming of objects

After controlling for language skills (i.e., receptive vocabulary and recalling sentences), the only concurrent predictors of early word reading in Year 1 were letter-sound knowledge and phonological awareness, explaining 40.7% of the variance.

However, it was observed that the amount of variance the language measures accounted for was relatively high (i.e., 25%). For this reason, the analysis was repeated removing the recalling sentences task. In the second analysis, receptive vocabulary appeared to be an additional significant predictor (p=.036), explaining approximately 21% of the variance. Letter-sound knowledge and phonological awareness explained 44%.

Table 4.9: Stepwise Regression analysis for Predictors of regular word reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	-6.21	4.54	
R.V.	.23	.09	.31*
R. S.	.16	.08	.24
Step 2			
(Constant)	-29.53	12.52	
R.V.	.11	.08	.14
R.S.	.04	.07	.07
LSK	.92	.41	.24*
PA	.66	.22	.36**
RAN O.	-.05	.03	-.16

Note: N= 70. R^2= .24 for Step 1, ΔR^2= .29 for Step 2 (p<.001). ***p<.001, **p<.01
LSK= Letter-sound knowledge; PA = phonological awareness; R.S.= Recalling sentences; R.V. = Receptive vocabulary; RAN O.= Rapid naming of objects

Regular word reading in Year 1 was concurrently predicted by letter-sound knowledge and phonological awareness, explaining 29.1% of the variance (49% in total with language measures). There were no significant changes when the analysis was repeated excluding the recalling sentences measures.

Table 4.10: Stepwise Regression analysis for Predictors of exception word reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	-8.99	4.54	
R.V.	.20	.09	.29*
R.S.	.14	.08	.23
Step 2			
(Constant)	-23.41	12.39	
R.V.	.09	.08	.13
R.S.	.03	.07	.05
LSK	.62	.41	.17
PA	.66	.22	.38**
RAN O.	-.05	.03	$-.19^{+}$

Note: N= 69. R^2= .21 for Step 1, ΔR^2= .27 for Step 2 (p<.01). **p<.01, *p<.05, $^{+}$p=.053; LSK = Letter-sound knowledge; PA = phonological awareness; R.S.= Recalling sentences; R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects

Exception word reading in Year 1 was concurrently predicted by phonological awareness and rapid naming of objects, which accounted for 27% of the variance (44% in total with language measures). There were no significant changes when recalling sentences was excluded from the analysis.

Table 4.11: Stepwise Regression analysis for Predictors of nonword reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	2.22	1.21	
R.V.	.05	.02	.27*
R.S.	.04	.02	.22
Step 2			
(Constant)	-9.61	3.49	
R.V.	.02	.02	.11
R.S.	.02	.02	.10
LSK	.39	.11	.40***
PA	.12	.06	.26*
RAN O.	.00	.01	.05

Note: N= 69. R^2= .19 for Step 1, ΔR^2= .26 for Step 2 (p<.001). ***p<.001, *p<.05; LSK = Letter-sound knowledge; PA = phonological awareness; R.S.= Recalling sentences; R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects

Longitudinal Results

Table 4.12 summarizes the results of the bivariate correlations between early word reading, letter-sound knowledge, phonological awareness, rapid naming of objects and vocabulary in Reception Year (Time 1) with early word reading, regular, exception and nonword reading in Year 1 (Time 2).

Table 4.12: Correlations between Early Word Reading, Foundation literacy skills and language in Reception to Year 1

	EWR T2	R.W. T2	E.W. T2	N.W. T2
EWR T1	.78**	.75**	.77**	.64**
LSK T1	.79**	.74**	.74**	.63**
PA T1	.70**	.65**	.63**	.60**
RAN O. T1	-.42**	-.44**	-.45**	-.32**
R.V. T1	.37**	.33**	.33**	.28*

Note: LSK= Letter-sound knowledge (max. 32); EWR= Early word reading (max. 30); PA= phonological awareness composite score (max. 24); R.W. = Regular word reading (max. 30); N.W. = Nonword reading (max. 30); E.W. = Exception word reading (max. 30); R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects (in secs). ** p<.01, * p<.05

Early Word Reading mean score in Reception had high correlations with the same subtest in Year 1, as well as with the subtests of Regular, Exception and nonword Reading. Letter sound knowledge and phonological awareness in Reception had also strong correlations with lexical and sub lexical word reading skills one year later. Rapid Naming of Objects and Receptive vocabulary in Reception had a weak to moderate relationship to all the word reading measures employed in Year 1.

Table 4.13: Stepwise Regression analysis for Longitudinal Predictors of Early word reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	12.27	.95	
EWR T1	1.35	.15	.77***
Step 2			
(Constant)	9.99	2.84	
EWR T1	1.30	.15	.74***
R.V. T1	.05	.06	.08
Step 3			
(Constant)	14.13	4.63	
EWR T1	.48	.24	$.27^{+}$
R.V. T1	.00	.07	.01
LSK T1	.55	.15	.49***
PA T1	.07	.18	.05
RAN O T1.	-.06	.02	-.21**

Note: N= 69. R^2= .59 for Step 1, ΔR^2= .01 for Step 2 (p= *ns*), ΔR^2= .14 for Step 3 (p<.001). ***p<.001, **p<.01, +p=.056;

EWR T1 = Early word reading at Time 1; LSK T1 = Letter-sound knowledge at Time 1; PA T1= phonological awareness at Time 1; R.V. T1 = Receptive vocabulary at Time 1; RAN O. T1 = Rapid naming of objects at Time 1

The regression revealed that 59% of the variance in Early word reading in Year 1 was explained by Early word reading in Reception. Letter-sound knowledge and rapid naming were also significant longitudinal predictors, accounting for an additional 14% of the variance.

Table 4.14: Stepwise Regression analysis for Longitudinal Predictors of regular word reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	2.61	3.93	
R.V. T1	.19	.08	.29*
Step 2			
(Constant)	10.36	5.02	
R.V. T1	-.03	.07	-.04
LSK T1	.55	.13	.53***
PA T1	.25	.18	.22
RAN O. T1	-.07	.02	-.26**

Note: N= 60. R^2= .08 for Step 1, ΔR^2= .54 for Step 2 (p<.001). ***p<.001, **p<.01; LSK = Letter-sound knowledge; PA = phonological awareness; R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects

Regular word reading was longitudinally predicted by letter-sound knowledge and rapid naming, even after controlling for language skills and explained 54% of the variance.

Table 4.15: Stepwise Regression analysis for Longitudinal Predictors of exception word reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	-1.36	3.93	
R.V. T1	.17	.08	.29*
Step 2			
(Constant)	5.80	4.68	
R.V. T1	-.02	.07	-.03
LSK T1	.54	.12	.56***
PA T1	.17	.16	.16
RAN O. T1	-.07	.02	-.27**

Note: N= 60. R^2= .09 for Step 1, ΔR^2= .54 for Step 2 (p<.05). ***p<.001, **p<.01, *p<.05; LSK = Letter-sound knowledge; PA = phonological awareness; R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects

The results for exception word reading were similar to the Regular word reading. Namely, the only significant longitudinal predictors were letter-sound knowledge and rapid naming, accounting for 54% of the variance.

Table 4.16: Stepwise Regression analysis for Longitudinal Predictors of nonword reading in Year 1

Model	B	SE B	Beta
Step 1			
(Constant)	3.92	1.04	
R.V. T1	.05	.02	.29*
Step 2			
(Constant)	6.08	1.58	
R.V. T1	-.02	.02	-.09
LSK T1	.07	.04	.26
PA T1	.14	.05	.46*
RAN O. T1	-.01	.01	-.16

Note: N= 60. R^2= .09 for Step 1, ΔR^2= .39 for Step 2 (p<.05). *p<.05;
LSK = Letter-sound knowledge; PA = phonological awareness; R.V. = Receptive vocabulary; RAN O. = Rapid naming of objects

The pattern of the results for nonword reading appeared to be very different to those of regular and exception word reading. It was found that the only longitudinal predictor of nonword reading was phonological awareness, explaining 38.8% of the variance. Language, letter-sound knowledge and rapid naming in Reception were not significant predictors.

4.6.2.3 Interim Discussion

Performance in word reading, its precursors (letter-sound knowledge, phonological awareness and rapid naming) and language was within the average range for this age group. As expected, there were high inter-correlations between letter-sound knowledge, phonological awareness and word reading accuracy at both times (Reception Year and Year 1). However, rapid naming of objects had only weak correlations with letter-sound knowledge and word reading accuracy and its correlation with phonological awareness did not reach significance in Reception. This finding is similar to previous studies which have reported a weak correlation between RAN and PA (i.e., Clarke, Hulme & Snowling, 2005). However, in Year 1, RAN's correlations with letter-sound knowledge, phonological awareness and early word reading increased and its correlation with PA reached significance. Vocabulary had a strong correlation with phonological awareness and a moderate correlation with letter-sound knowledge and word reading at both times.

The regression analysis revealed that the only significant concurrent predictors of word reading accuracy in Reception year were letter-sound knowledge and phonological awareness (sound isolation and sound deletion composite score), explaining approximately 61% of the variance, even after controlling for the effects of vocabulary. Rapid naming of objects was not a significant predictor. This finding is in consonance with Wimmer et al.'s (2000) suggestion that rapid naming deficits hinder word reading fluency rather than accuracy. Nonetheless, other studies report contradictory results; it has been found that rapid naming (including naming of objects) predicts word reading accuracy above and beyond age and letter knowledge (Simpson & Everatt, 2005). The inconsistency of the results (between Wimmer's and Simpson & Everatt's studies) might be explained by the fact that the later study did not include phonological awareness in the control variables.

Vocabulary was not a concurrent predictor of word reading, even though a large number of former studies have shown that language skills influence word reading accuracy outcomes (e.g., Nation & Snowling, 2004). This might be due to the fact that only receptive vocabulary was measured in this study and not language in general. This limitation is addressed in the study conducted at Time 2 (for details see Chapter 3: Methodology).

It should be noted that the results reported might have been affected by floor effects observed in the Early Word Reading (EWR) subtest (i.e., word reading accuracy). Approximately, 26% of the participants scored 0 and an additional 13% scored only 1 out of 30. Consequently, one of the reasons why RAN and vocabulary appear not to be significant predictors of reading accuracy might be the fact that floor effects on EWR weaken the possible predictive value of the other variables. Again, this limitation is addressed at Time 2, as the participants were older and there were no floor effects.

In addition, 72% of the participants were not able to read any of the exception words in the EWR test. This means that the results mainly refer to pre or partial alphabetic phase. Both RAN and vocabulary have been suggested to be more important in lexical word reading (for RAN see Logan, Schatschneider& Wagner, 2011; for vocabulary see Nation & Snowling, 2004; Ricketts, Nation & Bishop, 2007).

The results of the regression analysis at Time 2 (Year 1) revealed the same pattern in terms of predictors of Early word reading. Namely, its only concurrent predictors were letter-sound knowledge and phonological awareness but not Rapid naming. However, the variance explained was less (41%) compared to Time 1. This might indicate that as reading develops, there are more variables that start influencing its growth and letter knowledge along phonological awareness might not be sufficient skills in becoming a skilled reading.

At Time 2, Regular and nonword reading were concurrently predicted only by letter-sound knowledge and phonological awareness, explaining 29% and 26% of the variance, respectively. However, exception word reading (i.e., lexical word reading accuracy) was predicted by phonological awareness and marginally by RAN ($p=.057$), explaining a total of 26.8% of the variance. Letter-sound knowledge and language skills were not significant predictors of exception word reading.

The findings regarding regular and nonword reading might be explained by the fact that there were data missing from 14 cases (16.8% of the whole sample) in the RAN of objects task, as some participants found this task very challenging to complete; hence the number of the sample was significantly reduced. Another possible explanation of this finding, which is strengthened by the results regarding exception word reading (i.e., the fact that RAN was a significant predictor) could be that as previous research has reported RAN is a more reliable predictor of word fluency and not decoding (for review see Wolf & Bowers, 1999).

Finally, the longitudinal analysis showed that Early word reading in Year 1 was predicted by performance in LSK and Rapid naming in Reception Year, even after controlling for autoregressor effects and vocabulary. Early word reading at Time 1 explained 59% of the variance and LSK and RAN an additional 14%. Regular and exception word reading were longitudinally predicted by LSK and rapid naming (54% of the variance explained for each); however, it was not possible to control for the effects of the autoregressor as the DTWRP was not employed in Reception Year. Nonword reading at Time 2 (i.e., sub-lexical word reading) was predicted only by letter-sound knowledge at Time 1. As already discussed, these results are in consonance with previous studies which have showed that RAN is more important in lexical word reading (i.e., Logan, Schatschneider & Wagner, 2011).

Overall, the results of the preliminary analysis are in line with a large body of research reporting that the most reliable predictors of word reading are letter-sound knowledge, phonological awareness and rapid naming (Caravolas et al., 2013). However, it should be noted that there are different patterns of predictors depending on whether lexical or sub-lexical word reading is explored.

4.7 Conclusions

The findings of the preliminary analysis (Part 1: Developmental changes and Part 2: Predictors of lexical and sub-lexical reading accuracy) set the context of this thesis and will inform the discussion on subsequent chapters. As discussed the main research question of this thesis is whether different sub-components of attention have a unique impact of the development of lexical and sub-lexical reading in typically developing and ‘at risk’ of RD children. The analysis of the developmental changes revealed that the attention measures (apart from the Flanker) used were sensitive enough so as to pinpoint the changes due to development. However, it also shed light on methodological issues regarding the purity of the tasks and the sensitivity of the Flanker task. The second part of the preliminary analysis revealed that as expected there were differential effects of well-established predictors on the two strategies/pathways of reading, lexical and sub-lexical word reading. This finding guided the approach used when investigating the role of attention on reading.

Chapter 5: Sustained attention skills as predictors of variation in children's emerging literacy skills

5.1 Introduction

The aim of this study was to examine whether visual and/or auditory sustained attention as measured by cognitive experimental tasks (i.e., Continuous Performance tasks) are unique concurrent and/or longitudinal predictors of emerging word reading accuracy above and beyond other known cognitive-linguistic predictors of reading.

As outlined in Chapter 3, research with adults has shown that attention is not a unitary construct; instead it comprises three sub-components which are interacting but separate (Posner & Petersen, 1990; Petersen & Posner, 2012). These sub-components are sustained attention, selective attention and attentional control and there is some research evidence suggesting them to be separable from the age of 4 ½ years old (Breckenridge et al., 2012). The focus of the current chapter is on sustained attention. There have been very few studies examining at the role of sustained attention in emerging literacy skills and the evidence is inconsistent (i.e., Steele et al., 2012; Sims & Lonigan, 2013).

Hence, despite the recognition that reading difficulties are highly comorbid with attentional difficulties and the theories that try to explain reading development through an attentional perspective (Bosse et al.,2007; Facoetti et al. 2009), the question of whether attention is a unique predictor of word reading remains unanswered. In particular, there is a lack of studies in the literature integrating the well-established cognitive-linguistic precursors of reading and attention in young children.

The current study aims to examine whether or not sustained attention skills contribute unique variance in children's early literacy outcomes, after the contribution of phoneme awareness (PA), letter-sound knowledge and Rapid Automatized Naming (RAN) has been accounted for in the analyses.

5.1.1. Literature review

Sustained attention is our ability to maintain our focus over a period of time. In a classroom environment and while learning children have to employ both their auditory attention (e.g., to listen to instructions) and visual attention (e.g., to attend to the letters of a word and its morphology during visual word recognition). Auditory sustained attention has also been found to be associated with language difficulties in children with specific language impairment (SLI), when compared to typically developing children (for a metanalysis see Ebert & Kohnert, 2011).

There is a limited number of studies researching the influence of sustained visual attention in reading development, and even fewer on the role of auditory sustained attention and reading development or its difficulties. Sims and Lonigan (2013) reported that visual sustained attention was a unique predictor of concurrent letter knowledge, phonological awareness (blending and elision) and vocabulary in American English preschoolers. However, in contrast, Davidse et al., (2011) reported that sustained attention was not a unique predictor of letter knowledge nor vocabulary in Dutch, after controlling for environmental factors, intelligence and short term memory. In addition, a study which examined the longitudinal predictive power of visual sustained attention on word reading reported that it is not an independent predictor in the beginning of literacy instruction (Steele et al., 2013). The above studies did not include any measures of auditory attention in their study.

It has also been found that children with reading difficulties (Lima et al., 2013[12]) and also those with primary language impairment (see meta-analysis by Ehbert & Kohnert, 2011) have poor visual sustained attention. However, Marzocchi et al. (2009) proposed that the poor performance on visual sustained attention tasks (as measured by TEA-Ch) for a group of children with dyslexia (Italian, 9 years old) compared to that of an age matched control group, was due to an impairment in their working memory, and the poor performance on the auditory task reflected slow speed of processing. It should be noted that the sustained

[12] Sustained attention was measured through a CPT in a sample of 10 year old Brazilian children.

attention tasks[13] used had working memory and/or inhibition control demands and this might have been the reason why the influence of sustained attention was masked. Also, the auditory task might have not been sensitive enough so as to measure sustained attention as there were only 60 stimuli in total, whereas in other paradigms there are more than 100 stimuli (i.e., the duration of the task is longer and hence the need to sustain attention is higher).

The inconsistencies of the results reported by each study are probably due to the differences in language (Italian, Brazilian and English) as well as differences in the tasks used to measure literacy outcomes or in the criteria used to identify children with dyslexia. For example, in the Marzocchi et al. study Italian dyslexic students were identified as having a deficit in either fluency or accuracy; Sims & Lonigan used a measure of print knowledge including both letters and words in Brazilian; Steele et al. employed a task testing letter name or sound knowledge and a phoneme matching task in English.

As already mentioned, there is also evidence regarding the role of sustained attention on reading through studies focusing on Specific Language Impairment (see Ebert & Kohnert, 2011). For example, Finneran et al. (2009) examined the visual sustained attention skills of 4-6 years old children with SLI in comparison to typically developing children. The group with SLI performed significantly worse in terms of accuracy compared to the TD group (however, there was no difference in their reaction times). Moreover, Spaulding et al. (2009) found that children with SLI also performed worse than typically developing children on an auditory sustained attention task. This implies that children with SLI have attentional difficulties. This is relevant to the present study as SLI has been linked to reading difficulties (e.g. see Bishop & Snowling, 2004).

To conclude, there are only two studies to my knowledge reporting a significant relationship between sustained attention and literacy skills (Lima et al., 2013; Sims & Lonigan, 2013). Both of these studies have been conducted in Brazil and used different measures of literacy and/or attention. Hence, there are some indications regarding the role of sustained attention on reading but the evidence is inconclusive.

[13] The measures used for sustained attention were the Score!, Walk Don't Walk and Sky Search subtests from TEA-Ch (Manly, 2001) and an ACPT (Di Nuovo, 2000).

In the following sections the design, hypothesis and method of the study is presented. The results are organized in separate subsections for each time point (i.e. results from Time 1, Time 2 and longitudinal results) followed by a discussion.

5.1.2 Design and Hypothesis

Taking into account the existing literature, it is expected that visual sustained attention will be a concurrent predictor of word decoding (nonword reading) as well as of letter sound knowledge and phonological awareness (see Sims & Lonigan, 2013). In addition, the role of auditory sustained attention will be explored as has not been studied before in relation to literacy for this age group. We hypothesized that auditory sustained attention might be a longitudinal predictor of word reading accuracy and/or its precursors, as it has been reported that it is linked with specific language impairment, which in turn is linked with reading difficulties. It is also predicted to be a stronger predictor of these skills compared to visual sustained attention as it represents better the skills that children have to use in the classroom in order to learn (i.e., listening to verbal instructions).

5.1.3 Method

5.1.3.1 Participants

For a description of the sample see Chapter 4. In brief, 83 children participated in this study (M=58.42 months, SD= 4.016 months; range= 52-65 months, 45 girls and 38 boys). Participants were recruited through one infant school from Greater London. The ethnicity of the sample was predominantly White British.

Six participants were excluded from the analysis as they were identified from the school as having SEN and/or other medical conditions. Hence, the number of participants included in the analysis, at Time 1, is 77 (57% girls, 43% boys) with a mean age of 58.62 months (SD = 4.02).

At time 2, 74 children were tested (M=70.67 months, SD= 4.07 months, range=64-77; 41 female, 33 male). However, due to missing data from several measures, in each regression analysis the exact number of cases is reported (see Results section).

5.1.3.2 Materials and Procedure

In order to measure sustained attention two Continuous Performance Tasks were used (a visual and an auditory) following the paradigms of Steele et al. (2013) and Gooch et al. (2014).

Literacy and language skills in Reception Year were measured using the Early word reading, letter-sound knowledge and phoneme awareness subtests from YARC. Receptive Vocabulary was measured by the British Picture Vocabulary Scale II and RAN of objects was assessed by the corresponding subtest of CTOPP.

The same measures of literacy, vocabulary and sustained attention were used as in Study 1. In addition, at Time 2 the Diagnostic Test of Word Reading Processes (DTWRP) and the Recalling Sentences subtest from the CELF4 were used. For details see Chapter 4.For a detailed description of the materials and procedure see Chapter 4.

5.2 Study 1: Sustained attention and children's concurrent emerging literacy skills

5.2.1 Results

The normality of the distribution was checked through the shape of histograms, the skewness and kurtosis and the Shapiro-Wilk normality test. In order to improve the shape of the distribution, the outliers (+- 2sd from mean) were replaced by a value equal to the next highest non-outlying score plus one unit of measurement (Winzorisation; Tabachnik & Fidell, 2001).

5.2.1.1 Descriptives

Table 5.1 summarises the descriptives in the two sustained attention measures (visual CPT and auditory CPT).

Table 5.1: Descriptives for the group mean scores on the visual and auditory Continuous Performance Tasks (VCPT and ACPT) at Time 1

	Mean	SD	Range	Skew.	Kurt.
VCPT Rt	748.60	102.95	543.42- 965.00	.31	-.46
VCPT O.	4.53	2.95	0-11	.37	-.58
VCPT C.	3.75	4.10	0-16	1.35	1.24
ACPT Rt	1076.14	135.96	801.21-1478.30	.26	.11
ACPT O.	7.30	4.37	0 - 17	.08	-1.03
ACPT C.	5.73	6.05	0 - 35	1.46	1.54

Note: VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O. = Visual Continuous Performance task Omission Errors; VCPT C. = Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors.

All the variables had acceptable, close to normal distribution.

5.2.1.2 Correlations

Table 5.2: Correlations between ACPT, VCPT and the literacy variables at Time 1

	VCPT Rt	VCPT Om	VCPT Com	ACPT Rt	ACPT Om	ACPT Com
LSK	-.04	-.21	-.01	-.07	-.29*	-.04
EWR	-.06	-.23*	-.01	-.10	-.24*	-.02
PA	-.18	-.31**	-.12	-.15	-34**	-.02
RV	-.28*	-.40**	-.09	-.14	-.21	-.02
RAN O	.23	.34**	-.01	.37**	.33*	.20

Note: LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RV= Receptive Vocabulary (BPVS); RAN O= Rapid naming of Objects; VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O. = Visual Continuous Performance task Omission Errors; VCPT C. = Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors.**p<.01, *p<.05

There was a weak but significant correlation between the average VCPT RTs and receptive vocabulary. Omission errors in the Visual Continuous Performance task had moderate significant correlations with almost all the predictors of early literacy (apart from Letter Sound knowledge), early word reading and with receptive vocabulary. On the other hand, reaction time in the auditory CPT did not correlate at all with most of the literacy measures (apart from RAN of Objects) nor with receptive vocabulary.

Omission errors in the auditory CPT had low to moderate correlations with letter-sound knowledge, phoneme awareness, Early word reading and RAN of objects.

5.2.1.3 Stepwise regression analyses

Regression analysis was used in order to examine the predictive power of the variables measured in regards to various outcome measures (i.e., word reading accuracy, phoneme awareness and letter-sound knowledge). The main aim of this analysis was to investigate whether sustained attention was a unique predictor of word reading accuracy after controlling for the established cognitive-linguistic predictors of reading (i.e., letter-sound knowledge, phoneme awareness, RAN and verbal abilities). A secondary aim was to investigate whether sustained attention might have an indirect impact on word reading accuracy through its possible influence on phoneme awareness and/or letter-sound knowledge.

Table 5.3 is a summary of the regression with Omission Errors of the Auditory Continuous Performance task as an additional predictor of Early Word Reading. It is shown that ACPT Omission Errors is not a unique concurrent predictor of EWR. Only Letter-Sound Knowledge and phoneme awareness were significant predictors, accounting for 60% of the variance in Early Word reading.

Table 5.3: Stepwise regression summary with ACPT Omission errors as a predictor of early word reading at Time 1 after controlling for vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-2.67	2.41	
RV	.15	.05	.39**
Step 2			
(Constant)	-3.38	2.79	
RV	-.01	.03	-.01
LSK	.36	.07	.55***
PA	.27	.10	.37**
RAN O.	.00	.01	.01
Step 3			
(Constant)	-3.55	2.82	
RV	-.01	.03	-.02
LSK	.35	.07	.55***
PA	.29	.10	.39**
RAN O.	-.00	.01	-.00
ACPT O.	.05	.08	.05

Note: N= 60. R^2= .15 for Step 1, ΔR^2= .60 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*) ***p<.001, **p<.01; LSK= letter-sound knowledge; PA= phoneme awareness; RV = Receptive Vocabulary; RAN O = Rapid naming of Objects; ACPT O.= Auditory Continuous Performance task Omission Errors

Similar results were obtained for the Visual Continuous Performance task Omission Errors (see Table 5.4 below). Letter-sound knowledge and phoneme awareness were significant predictors of word reading accuracy, but RAN and visual sustained attention did not reach significance.

Table 5.4: Stepwise regression summary with VCPT Omission errors as a predictor of early word reading at Time 1

Model	B	SE B	Beta
Step 1			
(Constant)	-2.128	2.301	
RV	.14	.48	.37**
Step 2			
(Constant)	-2.35	2.79	
RV	-.01	.03	-.01
LSK	.36	.07	.55***
PA	.27	.10	.37**
RAN O.	-.00	.01	.01
Step 3			
(Constant)	-2.47	2.55	
RV	-.01	.03	-.04
LSK	.36	.06	.57***
PA	.27	.08	.37**
RAN O.	-.00	.01	-.02
VCPT Om.	.02	.11	.01

Note: N=62. R^2= .13 for Step 1, ΔR^2= .61 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*) ***p<.001, **p<.01; LSK= letter-sound knowledge; PA= phoneme awareness; RV = Receptive Vocabulary; RAN O = Rapid naming of Objects; VCPT O.= Visual Continuous Performance task Omission Errors

In sum, visual and auditory sustained attention do not appear to be independent concurrent predictors of word reading accuracy in the early stages of literacy instruction (i.e., Reception Year).

Omission Errors of the Auditory CPT (see Tables 5.5 and 5.6) did not predict phoneme awareness nor letter-sound knowledge, after controlling for language skills and letter-sound knowledge, and phoneme awareness, respectively.

Table 5.5: Stepwise regression analysis with ACPT omission errors as a predictor of phoneme awareness at Time 1

Model	B	SE B	Beta
Step 1			
(Constant)	-7.68	2.40	
RV	.34	.05	.63***
Step 2			
(Constant)	-11.44	1.62	
RV	.23	.03	.43***
LSK	.55	.06	.62***
Step 2			
(Constant)	-10.04	1.96	
RV	.23	.04	.41***
LSK	.54	.06	.60***
ACPT Om.	-.12	.09	-.08

Note: N=76.R^2= .40 for Step 1, ΔR^2= .35 for Step 2 (p<.001),ΔR^2= .01 for Step 3 (*ns*) ***p<.001; LSK= letter-sound knowledge; RV = Receptive Vocabulary; ACPT O.= Auditory Continuous Performance task Omission Errors

Table 5.6: Stepwise regression analysis with auditory sustained attention as a predictor of letter-sound knowledge after controlling for language and PA at Time 1

Model	B	SE B	Beta
Step 1			
(Constant)	6.79	3.29	
RV	.20	.07	.33**
Step 2			
(Constant)	14.76	2.31	
RV	-.16	.06	-.25*
PA	1.04	.11	.92**
Step 3			
(Constant)	15.22	2.61	
RV	-.16	.06	-.25*
PA	1.03	.11	.91***
ACPT Om.	-.05	.13	-.03

Note: N=76.R^2= .11 for Step 1, ΔR^2= .51 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*) ***p<.001, **p<.01, *p<.05; PA= phoneme awareness; RV = Receptive Vocabulary; ACPT O.= Auditory Continuous Performance task Omission Errors

Taking into account, that omission errors in the visual CPT correlated with phoneme awareness, a regression analysis with phoneme awareness as the outcome variable and VCPT omission errors as the predictor was conducted (Table 5.7). It was found that VCPT omission errors did not predict phoneme awareness after controlling for letter-sound knowledge and vocabulary.

Table 5.7: Stepwise regression analysis examining visual sustained attention as a predictor of PA after controlling for language and LSK at Time 1

Model	**B**	**SE B**	**Beta**
Step 1			
(Constant)	-7.62	2.32	
RV	.34	.05	.62***
Step 2			
(Constant)	-11.29	1.70	
RV	.23	.04	.43***
LSK	.52	.06	.59***
Step 3			
(Constant)	-11.07	2.23	
RV	.23	.04	.43***
LSK	.52	.06	.59***
VCPT Om.	-.02	.15	-.01

Note: N= 76. R^2= .39 for Step 1, ΔR^2= .03 for Step 2 (*ns*), ΔR^2= .01 for Step 3 (*ns*) ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; RV = Receptive Vocabulary; VCPT O.= Visual Continuous Performance task Omission Errors

5.3 Study 2: Sustained attention as a predictor of early literacy outcomes in Year 1

5.3.1 Results

The same procedure regarding the outliers, as in Study 1 (Time 1), was followed.

5.3.1.1 Descriptives

The sample at Time 2 performed within the average range for their age in the literacy and language tests (Table 5.8).

Table 5.8: Descriptives of visual and auditory Continuous Performance Tasks at Time 2

	Mean	**SD**	**Range**	**Skew.**	**Kurt.**
VCPT RT	720.01	92.07	533-905	.11	-.47
VCPT O.	3.09	2.31	0-8	.39	-59
VCPT C.	2.39	2.14	0-7	.94	-12
ACPT RT	1014.05	115.96	786.75-1248	.12	-.76
ACPT O.	3.72	3.60	0-11	.95	-.40
ACPT C.	3.90	2.51	0-9	.28	-.71

Note: VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O. = Visual Continuous Performance task Omission Errors; VCPT C. = Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O. = Auditory Continuous Performance task Omission Errors; ACPT C. = Auditory Continuous Performance task Commission Errors.

The distribution of the CPT variables was close to normal.

5.3.1.2 Correlations

The following table summarizes the results of the parametric bivariate correlation analysis between the word reading, language and attention tasks.

Table 5.9:Bivariate correlations between literacy, language measures and CPTs at Time 2

	VCPTRt.	VCPT O.	VCPTC.	ACPTRt.	ACPTO.	ACPTC.
DTWRP	.04	.00	-.16	-.05	-.24*	-.12
N.W.	-.04	-.02	-.14	.00	-.36**	-.05
E.W.	.09	.06	-.15	-.07	-.20	-.13
R.W.	.00	-.05	-.16	-.05	-.23*	-.12
LSK	-.11	-.11	-.17	-.04	-.19	-.12
EWR	-.03	-.08	-.21	-.09	-.23*	-.13
PA	-.07	-.27*	-.22	-.03	-.32**	-.03
RAN O.	.07	.09	.16	-.04	-.05	.18
RV	-.04	-.10	-.20	-.00	-.05	-.02
RS	.09	.00	-.15	-.21	-.27*	.03

Note: DTWRP= Composite score of Diagnostic Test of Word Reading Processes; N.W. = nonword reading accuracy (DTWRP subtest); E.W. = exception word reading accuracy (DTWRP subtest); R.W. = regular word reading accuracy (DTWRP subtest); LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest). $^{**}p<.01$, $^{*}p<.05$

Omission Errors of the Auditory CPT had weak to moderate negative correlations with all word reading measures (apart from exception word reading). It also correlated with Phoneme awareness and recalling Sentences. The highest correlations were with nonword reading and phoneme awareness.

In addition, omission errors of the Visual CPT had a weak correlation with phoneme awareness. However, none of the other CPTs' variables had a significant correlation with either word reading, early literacy foundation skills or language skills.

5.3.1.3 Stepwise Regression analyses

The following tables present the results of a series of regression analyses. The dependent variables of each regression were raw accuracy scores for the Early word reading, Regular, Exception and Nonword Reading. In the first step of the regression the measures of language skills were entered, followed by letter-sound knowledge, phoneme awareness and RAN of objects. The aim of these analyses was to examine whether the auditory or visual omission errors were unique predictors and could explain additional variance in word reading accuracy (both decoding and lexical reading), after controlling for language and the established cognitive-linguistic predictors of reading. Due to constraints on the number of variables that can be entered into the model, given the sample size, a composite score of language measures was used (Receptive Vocabulary& Recalling Sentences).

Table 5.10 summarizes the findings of the regression analysis with Early Word reading in Year 1 as an outcome variable and auditory sustained attention as the predictor, after controlling for language skills, letter-sound knowledge, phoneme awareness and RAN.

Table 5.10:Stepwise regression analysis for Auditory Sustained attention as a predictor of Early word reading after controlling for language, LSK, PA and RAN (Year 1)

Model	B	SE B	Beta
Step 1			
(Constant)	-.60	4.09	
Language	.21	.05	.37**
Step 2			
(Constant)	-52.49	11.78	
Language	.08	.04	.18*
LSK	1.83	.38	.45***
PA	.64	.21	.32**
RAN O.	-.02	.03	-.07
Step 3			
(Constant)	-51.95	12.01	
Language	.08	.04	.18+
LSK	1.83	.39	.45***
PA	.63	.22	.31**
RAN O.	-.02	.03	-.07
ACPT O.	-.05	.18	-.02

Note: N=68. R^2= .25 for Step 1, ΔR^2= .40 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, ** p<.01, *p<.05, ^{+}p=.053; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O = Rapid naming of Objects; ACPT O.= Auditory Continuous Performance task Omission Errors

It was found that visual sustained attention in Year 1 is not a unique concurrent predictor of Early word reading. The only statistically significant predictors were letter-sound knowledge, phoneme awareness and marginally language, explaining in total approximately 63% of the variance.

Table 5.11 summarizes the results of the regression analysis exploring the relationship between Regular word reading accuracy and auditory sustained attention.

Table 5.11: Stepwise regression analysis for Auditory Sustained attention as a predictor of regular word reading after controlling for language, LSK, PA and RAN (Year 1)

Model	B	SE B	Beta
Step 1			
(Constant)	-5.34	3.753	
Language	.19	.042	.49***
Step 2			
(Constant)	-29.86	12.58	
Language	.07	.04	.19
LSK	.95	.41	.25*
PA	.65	.23	.35**
RAN O.	-.04	.03	-.15
Step 3			
(Constant)	-29.14	12.83	
Language	.07	.04	.19
LSK	.95	.41	.25*
PA	.63	.23	.34**
RAN O.	-.05	.03	-.15
ACPT O.	-.07	.19	-.03

Note: N= 68. R^2= .24 for Step 1, ΔR^2= .27 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ****p*<.001, ** *p*<.01, **p*<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O = Rapid naming of Objects; ACPT O.= Auditory Continuous Performance task Omission Errors

It was found that the only significant predictors were letter-sound knowledge and phoneme awareness, accounting for 49% of the variance. Omission errors in the auditory CPT (i.e., auditory sustained attention) did not reach significance as a predictor of regular word reading.

Table 5.12 shows the results of the regression analysis using nonword reading as the outcome and auditory sustained attention as the predictor. Again, it was found that auditory sustained attention was not a unique concurrent predictor of nonword reading after controlling for language, letter-sound knowledge, phoneme awareness and RAN. Nonword reading was predicted only but letter-sound knowledge explaining approximately 42% of the variance.

Table 5.12:Stepwise regression analysis for Auditory Sustained attention as a predictor of nonword reading after controlling for language, LSK, PA and RAN (Year 1)

Model	B	SE B	Beta
Step 1			
(Constant)	-2.37	.99	
Language	.04	.01	.45***
Step 2			
(Constant)	-10.25	3.44	
Language	.02	.01	.21
LSK	.40	.11	.42***
PA	.11	.06	.23
RAN O.	.01	.01	.08
Step 3			
(Constant)	-9.41	3.44	
Language	.02	.01	.20
LSK	.40	.11	.42***
PA	.09	.06	.19
RAN O.	.00	.01	.06
ACPT O.	-.08	.05	-.15

Note: N= 68. R^2= .20 for Step 1, ΔR^2= .26 for Step 2 (p<.001),ΔR^2= .02 for Step 3 (*ns*). ***p<.001; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O = Rapid naming of Objects; ACPT O.= Auditory Continuous Performance task Omission Errors

Based on the finding that sustained attention (both visual and auditory) correlated with phoneme awareness in Year 1, a regression analysis with phoneme awareness as an outcome and attention as predictor was conducted.

Table 5.13 summarizes the results regarding PA and visual sustained attention. It was found that this modality of sustained attention uniquely predicted phoneme awareness above and beyond the effects of letter-sound knowledge and language skills. It accounted for 3.8% of additional variance.

Table 5.13: Stepwise regression analyses for Visual CPT Omission Errors as a predictor of Phoneme awareness, after controlling for language and LSK (Year 1)

Model	B	SE B	Beta
Step 1			
(Constant)	5.96	1.89	
Language skills	.12	.02	.57***
Step 2			
(Constant)	-19.54	5.02	
Language skills	.08	.02	.39***
LSK	.95	.18	.48***
Step 3			
(Constant)	-17.14	4.95	
Language skills	.08	.02	.39***
LSK	.91	.17	.46***
VCPT Om.	-.35	.14	-.20*

Note: N= 71. R^2= .32 for Step 1, ΔR^2= .20 for Step 2 (p<.001),ΔR^2= .04 for Step 3 (p<.05).***p<.001, *p<.05; LSK= letter-sound knowledge; VCPT O.= Visual Continuous Performance task Omission Errors

The following scatter plot shows the relationship between phoneme awareness and VCPT omission errors in Year 1. It was found that their linear relationship was very weak (R^2 *Linear*=.07; i.e., 7% of variance explained).

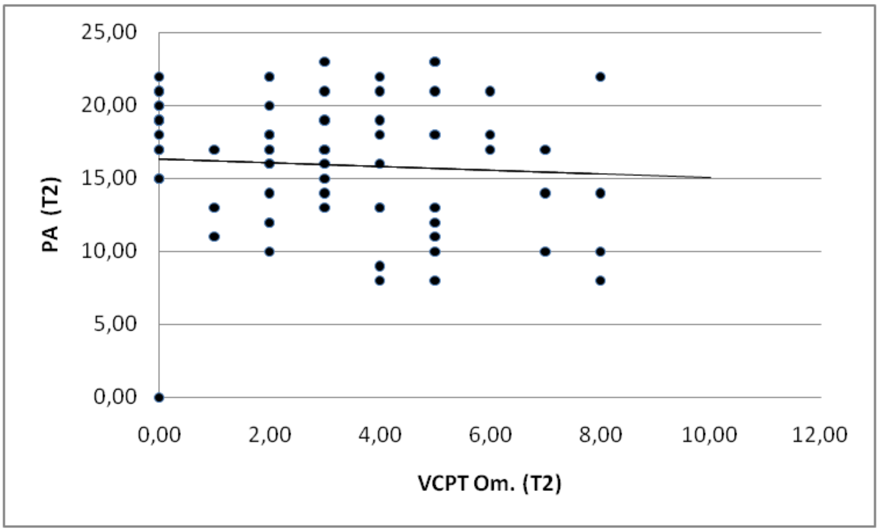

Figure 5: Scatter plot illustrating the relationship between CPT Omission errors and phoneme awareness in Year 1.

Table 5.14 summarizes the results of the regression analysis using auditory sustained attention as a predictor. It was shown that phoneme awareness was not predicted by auditory sustained attention after controlling for language and letter-sound knowledge.

Table 5.14: Stepwise regression analysis for ACPT Omission Errors as a predictor of Phoneme awareness after controlling for language and LSK (Year 1)

Model	B	SE B	Beta
Step 1			
(Constant)	5.79	1.84	
Language skills	.12	.02	.58***
Step 2			
(Constant)	-18.90	4.90	
Language skills	.09	.02	.41***
LSK	.92	.17	.47***
Step 3			
(Constant)	-16.49	4.98	
Language skills	.08	.02	.39***
LSK	.88	.17	.45***
ACPT Om.	-.18	.09	-.16

Note: N=72. R^2= .34 for Step 1, ΔR^2= .19 for Step 2 (p<.001),ΔR^2= .02 for Step 3 (*ns*). ***p<.001; LSK= letter-sound knowledge; ACPT O.= Auditory Continuous Performance task Omission Errors

Taking into account the argument that RAN might tap on attentional processes (Stringer, Toplak & Stanovich, 2004), the analyses were repeated removing the RAN from the regression. Only significant results are reported here (Table 5.15).

Table 5.15: Stepwise regression analysis with ACPT omission errors as a predictors of nonword reading controlling for language, LSK and PA but not RAN at Time 2

Model	B	SE B	Beta
Step 1			
(Constant)	2.04	.95	
Language skills	.05	.01	.47***
Step 2			
(Constant)	-8.78	2.70	
Language skills	.02	.01	.17
LSK	.38	.10	.40***
PA	.12	.06	.26*
Step 3			
(Constant)	-7.93	2.67	
Language skills	.02	.01	.17
LSK	.38	.10	.40***
PA	.10	.06	.20
ACPT Om.	-.10	.05	-.19*

Note: R^2= .22 for Step 1, ΔR^2= .27 for Step 2 (p<.001),ΔR^2= .03 for Step 3 (p<.05). ***p<.001; LSK= letter-sound knowledge; PA= phoneme awareness; ACPT O.= Auditory Continuous Performance task Omission Errors

It was revealed that auditory sustained attention became a significant predictor of nonword reading above and beyond language skills, letter-sound knowledge and phoneme awareness, explaining 3.2% of the variance (p=.04). However, auditory sustained attention remained a non-significant predictor of exception, regular and early word reading.

In order to further examine the robustness of this finding, the scatterplot of the variables was examined.

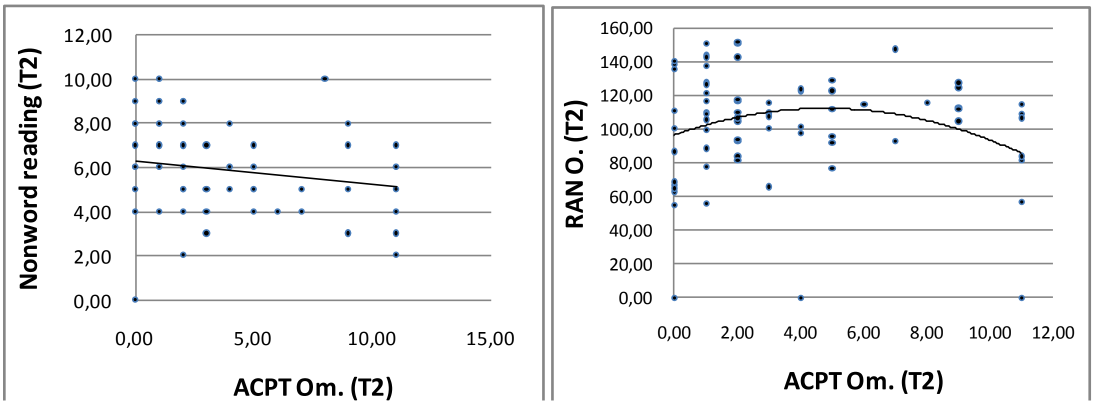

Figure 6: Scatter plots illustrating the relationship between ACPT Omission errors and RAN (A), nonword reading (B)

It was shown that the linear relationship between RAN and ACPT was very weak. However, there appears to be a weak quadratic relationship (R^2 *Quadratic*=.04). Namely, very short completion time and very long completion time in the RAN appears to relate with better performance in the ACPT (i.e., fewer omission errors) and it explains 4% of the variance. It was also shown that nonword reading had a linear relationship with ACPT omission errors (R^2 *Linear*=.13; 13% of variance explained).

5.4 Study 3: Longitudinal Results

5.4.3 Results

5.4.3.1 Correlations

In the following table (Table 5.16), the bivariate correlation between the variables of the Continuous Performance tasks in Reception Year and the reading measures in Year 1 are presented.

Table 5.16: Correlations between Attention measures in Reception and Word Reading in Year 1

	EWR T2	R.W. T2	E.W. T2	N.W. T2
VCPT Rt T1	-.05	-.02	.05	-.14
VCPT O. T1	-.27*	-.26*	-.21	-.29*
VCPT C. T1	-.11	-.10	-.14	-.17
ACPT Rt T1	-.08	-.14	-.08	-.14
ACPT O. T1	-.38**	-.30*	-.31**	-.39**
ACPT C. T1	-.08	-.09	-.14	-.01

Note: EWR T2= early word reading (YARC subtest) at time 2; R.W.= regular word reading accuracy (DTWRP subtest); E.W.= exception word reading accuracy (DTWRP subtest); N.W.= nonword reading accuracy (DTWRP subtest); VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O.= Visual Continuous Performance task Omission Errors; VCPT C.= Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors. $^{**}p<.01$, $^{*}p<.05$

Auditory sustained attention (as indexed by the omission errors in ACPT) had moderate negative correlations with all the word reading tests, namely, more errors in the CPT task were related with lower performance in the reading tasks. Visual sustained attention had a weak negative correlation with sub-lexical reading/decoding (regular and nonword reading) but not lexical word reading (exception words).

Finally, Table 5.17 shows the results of the correlation analysis between the CPT variables in Reception Year and letter-sound knowledge, phoneme awareness, RAN of objects, and language skills (vocabulary and recalling sentences).

Table 5.17: Correlations between attention measures in Reception and foundation literacy and language skills in Year 1

	LSK T2	**PA T2**	**RAN O. T2**	**R.V. T2**	**R.S. T2**
VCPT Rt T1	-.12	-.13	.13	-.12	-.04
VCPT O. T1	-.26*	-.42**	.19	-.24*	-.18
VCPT C. T1	.02	-.07	-.11	-.03	-.07
ACPT Rt T1	-.14	-.17	.25*	.07	.03
ACPT O. T1	-.24*	-.33**	.25*	-.12	-.28*
ACPT C. T1	-.03	-.03	.18	.03	-.08

Note: LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest); VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O.= Visual Continuous Performance task Omission Errors; VCPT C.= Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors.. ***p*<.01, **p*<.05

Visual sustained attention was strongly correlated with phoneme awareness and weakly with vocabulary. Auditory sustained attention was moderately correlated with phoneme awareness and weakly with letter-sound knowledge, RAN and recalling sentences. Reaction time in the auditory task had also a weak correlation with RAN.

5.4.3.2 Regression analysis

Taking into account the results of the correlation analysis, a regression analysis followed. Due to the high number of variables and the limited sample, a composite score for the literacy skills was used (i.e., composite score of letter-sound knowledge and phoneme awareness).

Tables 5.18 and 5.19 present the results of the regression analysis in which Early word reading in Year 1 was the outcome measure and visual (Table 5.18) and auditory (Table 5.19) sustained attention were the predictors. Early word reading (autoregressor), vocabulary, literacy skills and RAN of objects in Reception were the control variables.

Table 5.18: Stepwise regression analysis with VCPT omission errors at T1as predictor of Early word reading at T2, controlling for autoregressor, receptive vocabulary, literacy (LSK & PA) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	11.97	.95	
EWR1	1.38	.14	.78***
Step 2			
(Constant)	9.66	2.80	
EWR1	1.34	.15	.76***
RV	.05	.06	.08
Step 3			
(Constant)	18.15	4.01	
EWR1	.54	.25	.30*
RV	-.05	.06	-.07
Literacy	.33	.10	.52***
RAN O.	-.07	.02	-.23**
Step 4			
(Constant)	17.99	4.15	
EWR1	.54	.25	.30
RV	-.05	.06	-.07
Literacy	.33	.10	.52***
RAN O	-.07	.02	-.23**
VCPT O	.04	.22	.01

Note: N=60. R^2= .61 for Step 1, ΔR^2= .00 for Step 2 (*ns*),ΔR^2= .11 for Step 3 (p<.001), ΔR^2= .03 for Step 4 (*ns*). ***p<.001, **p<.01, *p<.05; EWR1 = Early word reading at Time 1; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; VCPT O.= Visual Continuous Performance task Omission Errors

Table 5.19: Stepwise regression analysis with ACPT omission errors at T1 as predictor of Early word reading at T2, controlling for autoregressor, receptive vocabulary, literacy (LSK & PA) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	11.79	.99	
EWR1	1.36	.15	.78***
Step 2			
(Constant)	8.97	2.97	
EWR1	1.30	.16	.74***
RV	.07	.06	.09
Step 3			
(Constant)	17.50	4.33	
EWR1	.51	.26	.29$^+$
RV	-.04	.06	-.06
Literacy	.34	.10	.53***
RAN O	-.07	.02	-.23**
Step 4			
(Constant)	18.29	4.44	
EWR1	.53	.26	.30*
RV	-.04	.06	-.06
Literacy	.32	.10	.50**
RAN O	-.06	.02	-.21*
ACPT O	-.13	.15	-.07

Note: N= 55*.* R^2= .61 for Step 1, ΔR^2= .01 for Step 2 (*ns*),ΔR^2= .12 for Step 3 (p<.001), ΔR^2= .00 for Step 4 (*ns*). ***p<.001, **p<.01, *p<.05, ^+p=.056; EWR1 = Early word reading at Time 1; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; ACPT O.= Auditory Continuous Performance task Omission Errors

Early word reading (as measured by the YARC) in Year 1 was longitudinally predicted by Early word reading, literacy skills and RAN in Reception Year, explaining approximately 73% of the variance. Visual and auditory sustained attention were not unique longitudinal predictors of early word reading.

Tables 5.20 and 5.21 present the longitudinal predictors of regular word reading. The results were the very similar with the results regarding early word reading. Namely, none of the modalities of sustained attention was a significant predictor; and regular word reading was longitudinally predicted by literacy and RAN in Reception Year, which accounted for approximately 64% of the variance.

Table 5.20: Stepwise regression analysis with VCPT omission errors at T1 as predictor of Regular word reading at T2, controlling for receptive vocabulary, literacy (LSK & PA) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	2.29	3.94	
RV	.20	.08	.30*
Step 2			
(Constant)	12.56	4.21	
RV	-.06	.06	-.10
Literacy	.43	.05	.73***
RAN O	-.07	.02	-.27**
Step 3			
(Constant)	10.88	4.36	
RV	-.04	.06	-.06
Literacy	.44	.05	.74***
RAN O	-.08	.02	-.30***
VCPT O	.33	.24	.12

Note: N= 59. R^2= .09 for Step 1, ΔR^2= .55 for Step 2 (p<.001), ΔR^2= .01 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; VCPT O.= Visual Continuous Performance task Omission Errors

Table 5.21: Stepwise regression analysis with ACPT omission errors at T1 as predictor of Regular word reading at T2, controlling for receptive vocabulary, literacy (LSK & PA) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	.71	4.03	
RV	.22	.08	.35*
Step 2			
(Constant)	10.22	4.50	
RV	-.04	.06	-.06
Literacy	.42	.06	.73***
RAN O	-.06	.02	-.24**
Step 3			
(Constant)	9.77	4.62	
RV	-.03	.06	-.05
Literacy	.43	.06	.74***
RAN O	-.07	.02	-.25**
ACPT O	.08	.16	.05

Note: *N*= 54. R^2= .12 for Step 1, ΔR^2= .62 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; ACPT O.= Auditory Continuous Performance task Omission Errors

In Table 5.22, the results of the regression with Exception word reading as the dependent variable are presented. The only longitudinal predictors were literacy skills and RAN, accounting for 63% of the variance. Auditory sustained attention was not a significant predictor, after controlling for vocabulary, literacy and RAN.

Table 5.22: Stepwise regression analysis with ACPT omission errors at T1 as predictor of Exception word reading at T2, controlling for receptive vocabulary, literacy (LSK & PA) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-2.75	3.74	
RV	.19	.08	.33*
Step 2			
(Constant)	7.39	4.22	
RV	-.04	.06	-.07
Literacy	.38	.05	.71***
RAN O	-.07	.02	-.28**
Step 3			
(Constant)	7.14	4.35	
RV	-.04	.06	-.07
Literacy	.38	.05	.71***
RAN O	-.07	.02	-.29**
ACPT O	.04	.15	.03

Note: N= 54. R^2= .11 for Step 1, ΔR^2= .62 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; ACPT O.= Auditory Continuous Performance task Omission Errors

Tables 5.23 and 5.24 summarize the results of the regression with nonword reading as the outcome measure. Nonword reading (sub-lexical reading) in Year 1 was predicted only by literacy skills (composite score of letter-sound knowledge and phoneme awareness) in Reception. Auditory and visual sustained attention were not longitudinal predictors of nonword reading, even when the analysis was repeated without the RAN variable (see Appendix 1: Tables 1 & 2).

Table 5.23: Stepwise regression analysis with VCPT omission errors at T1 as predictor of Nonword reading at T2, controlling for receptive vocabulary, literacy (LSK & PA) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	3.92	1.05	
RV	.05	.02	.29*
Step 2			
(Constant)	5.43	1.37	
RV	-.01	.02	-.04
Literacy	.10	.02	.65***
RAN O	-.01	.01	-.15
Step 3			
(Constant)	5.76	1.43	
RV	-.01	.02	-.07
Literacy	.10	.02	.64***
RAN O	-.01	.01	-.13
VCPT O.	-.06	.08	-.09

Note: N= 59. R^2= .19 for Step 1, ΔR^2= .38 for Step 2 (p<.001),ΔR^2= .01 for Step 3 (*ns*). ***p<.001, *p<.05; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; VCPT O.= Visual Continuous Performance task Omission Errors

Table 5.24: Stepwise regression examining the predictive value of ACPT Omission errors at time 1 on Nonword Reading at time 2 after controlling for language, literacy (PA and LSK) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	3.34	1.09	
RV	.06	.02	.36**
Step 2			
(Constant)	4.48	1.41	
RV	.00	.02	.02
Literacy	.10	.02	.67***
RAN O.	-.01	.01	-.11
Step 3			
(Constant)	4.79	1.44	
RV	.00	.02	.11
Literacy	.10	.02	.64***
RAN O.	-.01	.01	-.08
ACPT O.	-.05	.05	-.12

Note: N= 54. R^2= .13 for Step 1, ΔR^2= .32 for Step 2 ($p<.001$),ΔR^2= .01 for Step 3 (*ns*). ***p<.001, **p<.01; RV= Receptive Vocabulary (BPVS); RAN O: Rapid Automatized Naming of objects; ACPT O.= Auditory Continuous Performance task Omission Errors

The dependent variable in the following regression analysis (Table 5.25 and 5.26) was phoneme awareness in Year 1 and the control variables were vocabulary and emerging literacy skills (letter-sound knowledge and phoneme awareness) in Reception Year. The aim was to examine whether auditory and/or visual sustained attention were unique longitudinal predictors of PA.

Table 5.25: Stepwise regression examining the predictive value of VCPT Omission errors at time 1 on phoneme awareness at time 2 after controlling for language, literacy (PA and LSK) and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	8.50	1.72	
RV	.18	.04	.50***
Step 2			
(Constant)	8.58	1.34	
RV	.07	.03	.18*
Literacy	.21	.03	.63***
Step 3			
(Constant)	11.23	1.67	
RV	.04	.03	.11
Literacy	.20	.03	.61***
VCPT O.	-.29	.12	-.21*

Note: N= 73. R^2= .25 for Step 1, ΔR^2= .30 for Step 2 (p<.001),ΔR^2= .04 for Step 3 (p<.05). ***p<.001, *p<.05; RV = Receptive Vocabulary (BPVS); VCPT O.= Visual Continuous Performance task Omission Errors

The following scatter plot (Figure 7) shows the relationship between PA in Year 1 and VCPT omission errors in Reception. It appears that there is a linear relationship between the two variables (R^2 *Linear*= .17; i.e., 17% of variance explained).

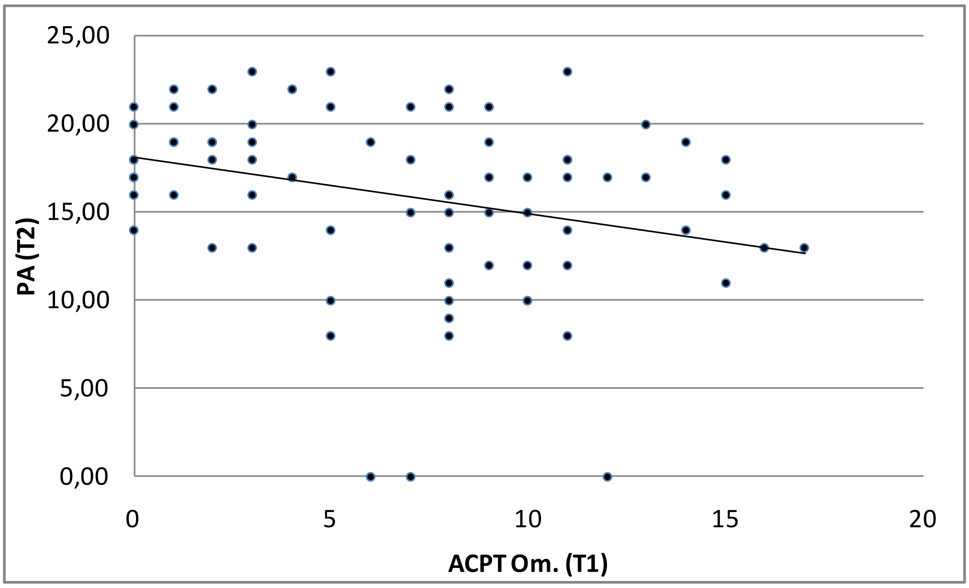

Figure 7: Plot of raw score in PA at Year 1 against raw score in ACPT omission errors at Reception Year

Phoneme awareness in Year 1 was longitudinally predicted by visual sustained attention (Table 5.26) in Reception, even after controlling for emerging literacy and language skills in Reception, and it accounted for 3.7% of the variance. Auditory sustained attention (Table 5.27) was not a longitudinal predictor of phoneme awareness.

Table 5.26: Stepwise regression examining the predictive value of ACPT Omission errors at time 1 on phoneme awareness at time 2 after controlling for language and literacy (PA and LSK)

Model	B	SE B	Beta
Step 1			
(Constant)	7.89	1.79	
RV	.19	.04	.52***
Step 2			
(Constant)	8.05	1.32	
RV	.07	.03	.19*
Literacy	.22	.03	.66***
Step 3			
(Constant)	8.88	1.58	
RV	.07	.03	.19*
Literacy	.21	.03	.64***
ACPT O.	-.08	.08	-.08

Note: N= 68. R^2= .27 for Step 1, ΔR^2= .33 for Step 2 (p<.001),ΔR^2= .01 for Step 3 (*ns*). ***p<.001, *p<.05; RV = Receptive Vocabulary (BPVS); ACPT O.= Auditory Continuous Performance task Omission Errors

The same analysis was repeated using letter-sound knowledge as the dependent variable.

Table 5.27: Stepwise regression examining the predictive value of VCPT Omission errors at time 1 on letter-sound knowledge at time 2 after controlling for language and literacy (PA and LSK)

Model	B	SE B	Beta
Step 1			
(Constant)	28.62	.98	
RV	.03	.02	.19
Step 2			
(Constant)	28.67	.77	
RV	-.03	.02	.-16
Literacy	.12	.02	.71***
Step 3			
(Constant)	29.70	.98	
RV	-.04	.02	-.22*
Literacy	.11	.02	.70***
VCPT O.	-.11	.07	-.16

Note: N= 73. R^2= .04 for Step 1, ΔR^2= .38 for Step 2 (p<.001),ΔR^2= .02 for Step 3 (*ns*). ***p<.001, *p<.05; RV= Receptive Vocabulary (BPVS); VCPT O.= Visual Continuous Performance task Omission Errors

Table 5.28: Stepwise regression examining the predictive value of ACPT Omission errors at time 1 on letter-sound knowledge at time 2 after controlling for language and literacy (PA and LSK)

Model	B	SE B	Beta
Step 1			
(Constant)	28.30	1.02	
RV	.04	.02	.21
Step 2			
(Constant)	28.38	.79	
RV	-.03	.02	-.14
Literacy	.12	.02	.72***
Step 3			
(Constant)	28.59	.95	
RV	-.03	.02	-.14
Literacy	.12	.02	.71***
ACPT Om.	-.02	.05	-.04

Note: N= 68. R^2= .04 for Step 1, ΔR^2= .42 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001; RV= Receptive Vocabulary (BPVS); VCPT O.= Visual Continuous Performance task Omission Errors

Omission errors in both modalities of the CPTs (Tables 5.27 and 5.28) did not account for any additional variance in letter sound knowledge in Year 1 above and beyond the variance explained by letter sound knowledge and phoneme awareness in Reception Year.

5.5 Interim Discussion

This study aimed to investigate the predictive value of sustained attention in regards to word reading accuracy and its precursors at the beginning of literacy instruction. The hypothesis was that, as explained in Chapters 2 and 3, both modalities of sustained attention will play a role (direct or indirect) in reading acquisition. Specifically, it was expected that visual sustained attention would affect reading development indirectly through its impact on letter-sound knowledge and phonological awareness (see Sims & Lonigan, 2013). Moreover, it was expected that auditory sustained attention would have a more direct and significant impact on reading development (see Aywald & Brager, 2002; Steele et al. 2012). This hypothesis derived from the fact that auditory attention is crucial when trying to follow instructions and hence learn in the classroom environment.

It should be noted that the nature of this study was also exploratory as there is very limited research on this sub-component of attention (i.e., sustained attention) and reading accuracy at the beginning of literacy instruction.

Word reading accuracy and sustained attention in Reception Year

The performance of the participants in the sustained attention measures was in the expected range for this age group. In particular, the mean scores of the VCPT omission errors are comparable with a previous study which has used a similar paradigm for the same age group (e.g. Steele et al., 2013).

The current study replicated others (Steele et al., 2013, Marzocchi et al., 2009) in finding that visual sustained attention is not a unique predictor of word reading, after controlling for the effects of other variables (e.g., phoneme awareness). However, in the sample of the current study the variance was small, compared to Steele et al.'s study (standard deviation of 2.9 compared to the 5.02 reported in Steele's study). A smaller variance can weaken the strength of the correlation between the variables (Goodwin & Leech, 2006). Hence, the predictive value of visual sustained attention might have been masked due to the limited variance exhibited in this sample.

In terms of the precursors of reading in Reception, i.e., letter-sound knowledge and phoneme awareness, it was found that they were not concurrently predicted by sustained attention. Letter-sound knowledge was predicted by phoneme awareness and vocabulary, explaining 61% of the variance; and phoneme awareness by letter-sound knowledge and vocabulary, explaining 74% of the variance. This finding is contradictory to other studies (see Sims & Lonigan, 2013), in which it was reported that sustained attention was uniquely associated with emergent literacy skills. The difference in the results can be explained by the fact that Sims and Lonigan when exploring the predictive value of sustained attention on letter knowledge did not control for the effects of phoneme awareness and vice versa.

When the data of the present study were analyzed again without controlling for PA or LSK the results found were still not in line with Sims & Lonigan. Namely, visual sustained attention continued to be a non-significant predictor of phoneme awareness and letter-sound knowledge. However, auditory sustained attention was a significant predictor and it accounted for 4.7% of the variance in PA and 5.2% in LSK, when controlling for vocabulary only (see Appendix 2: Tables 3 & 4).

To conclude, it was found that at the beginning of formal literacy instruction, when students are at Reception Year (age 4-5 years old), sustained attention is not a significant factor in the acquisition of reading, after controlling for the established cognitive linguistic predictors of reading. One of the limitations of this study was the fact that in Reception Year there were floor effects in the word reading accuracy task, which might have affected the results, however, these floor effects were expected due to the age of this group.

Sustained attention and word reading in Year 1

Finally, nonword reading was concurrently predicted by letter-sound knowledge and auditory sustained attention; however, it should be highlighted that the latter was significant only after RAN was removed from the regression analysis.

Auditory sustained attention explained variance in decoding (nonword reading), even after controlling for letter-sound knowledge and phoneme awareness. It should be noted that auditory sustained attention was not a significant predictor of decoding when the effects of RAN were factored out, which might be an indication that both tasks tap onto common cognitive skills (i.e., executive function skills and/or speed of processing). It was also shown through a scatter plot that the two variables had a quadratic relationship, implying that very rapid and very slow responses in RAN are linked to less omission errors in the ACPT. Namely, the participants who needed more time to complete the RAN task as well as the participants who completed it very quickly in comparison to their peers were missing less targets in the ACPT task. The amount of variance in word reading explained by auditory sustained attention was small compared to that explained by the control variables, however it was significant.

The fact that auditory sustained attention was a predictor of word reading only in Year 1 and not Reception might have two explanations. The first is in regards to the floor effects and the task used in the Reception, namely the Early word reading task. It should be noted that this task included both regular and exception words and the score used for the analysis was the composite score for both types of words. Taking into account the results from Time 2, where auditory attention predicted sub-lexical reading and visual attention predicted lexical reading, it could be argued that the use of a composite score, including both regular and exception words, might have ‘hidden’ the differential effects of the two modalities of sustained attention on the two pathways of reading.

The second possible explanation fits well with Davidse et al.’s (2011) suggestion that attention skills (sustained attention and inhibition) might play an important role only at later stages of reading development. In particular, it was proposed that visual sustained attention might influence more complex reading tasks than letter knowledge. If that was the case, it would be expected for visual sustained attention to be at least a concurrent predictor of word reading accuracy in older children. Hence, there is need for further research which would follow children longitudinally over a longer period.

Sustained attention as a longitudinal predictor of word reading and its precursors

Visual sustained attention in preschoolers does not appear to be a longitudinal predictor of word reading after 1 year. This finding is commensurate with Steele et al.'s (2012) results. As already discussed, in their study they used the same visual CPT task and found that it was not a longitudinal predictor of single word reading. However, they highlighted the need for research on the role of auditory sustained attention on word reading and its precursors, which has been addressed in the present study. Similarly to visual sustained attention, the auditory modality was a not a unique longitudinal predictor of word reading accuracy, after controlling for letter-sound knowledge, phoneme awareness and RAN.

One of the novel findings of this study was that phoneme awareness in Year 1 was longitudinally predicted by visual sustained attention (but not auditory) in Reception, even after controlling for letter-sound knowledge, phoneme awareness (autoregressor) and vocabulary (see pg., 145). This implies that visual sustained attention might have an indirect impact on word reading skills through its impact on the development of phoneme awareness. There has been one study (Yang, Yang & Kang, 2014) which has examined the role of sustained attention in children (mean age: 67.5 months) and it was reported that there was no correlation between the two skills. However, their sample was very different as they used only bilingual children. It is apparent that the evidence is very limited and there is need for further research on both modalities of sustained attention and literacy skills.

One possible interpretation of the finding of a longitudinal effect of visual sustained attention on PA could be in line with the view that development of language requires the child to attend to verbal stimuli so that their phonological skills develop (starting with the ability to identify larger units and moving to phonemes). Difficulties in sustaining their attention to the verbal stimuli might result in poor phonological skills (including phoneme awareness). Hulme and Snowling (2009) specifically wrote that 'auditory localization and attention are general prerequisites for this process' (i.e., the process of language learning;

pg. 137). However, according to this view it would have been expected that auditory sustained attention would also be a predictor of PA, which was not found in the current study.To conclude, the current study attempted to bridge the gap in the literature regarding the relationship between auditory and visual sustained attention and lexical and sub-lexical word reading. It was shown that visual sustained attention was a concurrent and longitudinal predictor of phoneme awareness. Auditory sustained attention was a concurrent predictor of nonwordreading (i.e., decoding) and phoneme awareness. At time 1, it also predicted letter-sound knowledge. These findings are novel, as there is no study to my knowledge which has explored the effects of both modalities of sustained attention on the different pathways of word reading and its precursors in young children. The findings are further discussed in the General discussion chapter (pg. 249).

Chapter 6: Exploring the relationship between selective attention and word reading

6.1 Introduction

The aim of this chapter is to explore the role of selective attention as a concurrent and/or longitudinal predictor of lexical and sub-lexical word reading. As discussed in previous chapters, there is unequivocal evidence regarding the predictors of word reading (i.e., letter-sound knowledge, phoneme awareness and RAN); nonetheless, there are studies that have demonstrated also a positive relationship between attention and reading. The chapter is organized in the following way: literature review, hypothesis, method, results for each timepoint and discussion.

6.1.1 Literature review

There is some limited evidence regarding the impact of visual selective attention on word reading development. Selective attention is defined as the ability to orient our attention in order to minimize the influence of irrelevant stimuli (Posner & Petersen, 1990).

A former study with findings in support of the relationship between selective attention and reading was conducted by Casco et al. (1998) who hypothesized that low performance in tasks involving visual selective attention is related to low performance in reading. They argued that visual selective attention and reading abilities develop in parallel and hence it is likely that a relationship between visual selective attention and reading performance exists because similar visual operations are involved in these two tasks.

Their participants were 590 children, from Italy, 11 to 12 years old. They employed a visual search task in which uppercase letters were used as stimuli. Groups with different levels of selective efficiency in the visual attention task were tested for reading accuracy and fluency.

They found that the efficiency in visual selective attention is related to reading efficiency. Performance in a visual attention task (letter cancellation task) was related to reading performance. Good and poor searchers differed mainly in visual errors; hence, there is an indication that there is a relationship between selective attention and reading. They concluded that at least in part, some poor searcher's reading problems depend on a visual difficulty, which also affects performance in visual attention tasks. They also noted that poor searchers present a visual selective attention difficulty that makes the whole word segregation process required to perform the lexical search task difficult. One of the limitations of this study is that they did not control for the influence of phonological skills, thus undermining the specific role of selective attentional skills in reading acquisition. It should be highlighted that the above mentioned studies used older children and consequently any attentional difficulties might be the result of their pre-existing reading difficulties.

There are only two studies to my knowledge studying selective attention and reading in young children and their findings are contradicting. Plaza and Cohen (2007; France) found that visual selective attention skills at the end of preschool predicted word reading (as measured by word discrimination) a year later, even after controlling for Syllable inversion, Phoneme Identification, Naming speed and Digit span. They argued that selective attention plays an important role at the beginning of reading development. Specifically, visual selective attention skills, like serial scanning and analysis of visual stimuli are needed in order to learn to read. It was argued that selective attention was one of the foundation literacy skills.

On the other hand, in a more recent study, Shapiro, Carroll and Solity (2013) using a similar visual search task in a group of 4-5 year old children (approximately 1 year younger that Plaza & Cohen's participants) found, through structural equation modeling, that visual selective attention was not a unique predictor of either word (regular and exception) and nonword reading. Their interpretation contradicts Plaza and Cohen's argument regarding the role of selective attention in the early stages of reading acquisition. In particular, they proposed that selective attention might start playing an important role in reading when children become more fluent.

The two studies discussed have used different measures of reading (i.e., word discrimination vs word reading accuracy) and samples in terms of language (French vs English) and age (5-6 and 4-5 years old). Also, the variables that they controlled for in their analysis are different; Shapiro et al. (2013) assessed the participant's letter-sound knowledge and rhyme awareness, whereas Plaza and Cohen (2007) employed a syllable inversion task. It is very possible that the results reported are contradictory due to those factors.

In conclusion, very few studies have studied selective attention as a predictor of early word reading, and of those which have, their findings are contradictory. Hence, the present chapter attempts to build upon the above mentioned studies and address their limitations by including a thorough set of precursors of reading as control variables.

6.1.2 Design and Hypothesis

The analyses reported in this chapter aim to explore the role of selective attention as an independent concurrent and/or longitudinal predictor of lexical word reading and/or sub-lexical word reading. The hypothesis is that visual selective attention might be a predictor of whole word processing but not nonword reading (see Casco et al., 1998, 2004; Shapiro et al., 2013). However, since the existing evidence about selective attention is extremely limited the main aim is to explore rather than confirm or reject a specific hypothesis.

6.1.3 Method

6.1.3.1 Participants

Seventy seven preschoolers (Spring term of Reception Year) were followed longitudinally up to the Spring term of Year 1. Due to attrition 74 of the participants were re-tested at Time 2 (mean age of 70.67 months). More details regarding the characteristics of the sample can be found in Chapter 4.

6.1.3.2 Materials and Procedure

The tests of precursors of reading, word reading accuracy and selective attention used are described in Chapter 4. In brief, for the assessment of visual selective attention a Visual search task (Visearch; Wilding, 2001) and the Flanker task (Breckenridge, 2012) were employed. Word reading was measured using the Early word reading subtest from YARC (Reception Year and Year 1). Measures of letter-sound knowledge, phoneme awareness, RAN and language (receptive vocabulary) were also used.

However, an additional measure of word reading accuracy (Diagnostic Test of Word Reading Processes) was employed, as it includes 3 subtests for regular, exception and nonword reading. Moreover, the recalling sentences subtest from CELF4 was used as an additional measure of language. Selective attention was measured with the Visual Search and the Flanker task.

6.2. Study 1: Visual selective attention and children's concurrent emerging literacy skills

6.2.1 Results

6.2.1.1 Descriptives

Mean scores, standard deviations, range as well as skewness and kurtosis are reported in Table 6.1.

Table 6.1: Descriptives of Visual Search Task at Time 1

	Mean	**SD**	**Range**	**Skew.**	**Kurt.**
Flanker	1.07	0.11	.74-1.37	0.64	0.54
VSFA	6.16	5.25	0 – 27	1.83	4.48
VSDpH	3.19	0.71	1.96 - 5.97	1.36	3.11
VSTpH	2.03	0.64	1.13 - 5.06	1.16	5.36

Note: VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit. Means and standard deviations for raw scores are shown. Flanker score was computed by dividing total completion time in the incongruent condition by time in the control condition. A lower score indicated better performance. Distance per Hit was calculated by dividing the total distance 'travelled' by the number of hits and Time per Hit was the total completion time divided by hit.

6.2.1.2 Correlations

Bivariate correlations between selective attention and the literacy and language measures are summarized in Table 6.2. Due to the fact that none of the selective attention measures correlated significantly with word reading, further analysis (i.e., regression) was not conducted. It appears that selective attention does not have an impact on word reading in preschoolers, which is in line with Shapiro's et al.'s findings.

Table 6.2: Correlations between literacy and Visual Search and Flanker at Time 1

	VSFA	VSTpH	VSDpH	Flanker
LSK	-.05	.14	-.07	.07
EWR	-.14	-.05	-.14	.10
PA	-.15	-.03	-.06	.14
RV	-.18	-.11	-.05	.11
RAN O	.26*	.14	.04	.04

Note: LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit;**p*<.05

Responses on the visual selective attention measure did not correlate with any of the literacy and language measures in Reception Year. There was only a weak correlation between the False Alarms of the visual search task and RAN of objects. Due to the lack of a correlation between the selective attention tasks and the outcome measures, a regression analysis was not conducted.

6.3 Study 2: Visual selective attention as a concurrent predictor of early literacy outcomes in Year 1 (time 2)

6.3.1 Results

6.3.1.1 Descriptives

The normality of the distribution was checked through the shape of histograms, the skewness and kurtosis and the Shapiro-Wilk normality test. In order to improve the shape of the distribution, the outliers (+/- 2SD from mean) were replaced by a value equal to the next highest non-outlying score plus one unit of measurement (Winzorisation; Tabachnik & Fidell, 2001).

The following tables summarize the descriptives of the selective attention tasks (Table 6.3) and the bivariate correlations (Table 6.4) between selective attention and literacy and language measures.

Table 6.3: Descriptives of Flanker and Visual Search Task (Year 1)

	Mean	**SD**	**Range**	**Skew.**	**Kurt.**
Flanker	1.08	0.09	.71 – 1.37	.19	4.96
VSFA	5.00	3.35	0 – 13	.68	-.26
VSTpH	1.70	.52	.95 – 3.01	1.06	.56
VSDpH	2.69	.51	1 -3.01	-1.73	2.34

Note: VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit. Means and standard deviations for raw scores are shown. Flanker score was computed by dividing total completion time in the incongruent condition by time in the control condition. A lower score indicated better performance. Distance per Hit was calculated by dividing the total distance 'travelled' by the number of hits and Time per Hit was the total completion time divided by hit.

6.3.1.2 Correlations

Table 6.4 below summarizes the results of the preliminary bivariate correlations analysis at time 2. It reveals that the Flanker task had a moderate correlation with exception and regular word reading as well as the composite score of the

DTWRP (r=-.30, p<.01 for all variables). Also, Time per Hit of the Visual Search task correlated weakly with the same word reading measures(r=-.28, p<.05 for DTWRP composite and exception word reading; and r=-.27, p<.05 for regular word reading).

Table 6.4: Bivariate correlations between literacy, language measures, Flanker and Visual Search in Year 1 (Time 2)

	Flanker	VSFA	VSTpH	VSDpH
DTWRP	-.30**	-.11	-.28*	.12
N.W.	-.23	.03	-.20	.20
E.W.	-.30**	-.13	-.28*	.07
R.W	-.30**	-.12	-.27*	.13
LSK	-.01	.01	.02	.01
EWR	-.22	-.04	-.22	.04
PA	-.16	-.14	-.02	-.08
RAN O.	.21	-.02	.01	-.01
RV	.05	-.21	-.13	-.02
RS	-.01	-.00	-.15	.10

Note: DTWRP= Composite score of Diagnostic Test of Word Reading Processes; N.W. = nonword reading accuracy (DTWRP subtest); E.W. = exception word reading accuracy (DTWRP subtest); R.W. = regular word reading accuracy (DTWRP subtest); LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest); VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit. ***p*<.01, **p*<.05

6.3.1.3 Regression analysis

Based on the results of the correlation analysis, a series of regression analyses followed to examine whether visual selective attention could explain additional variance in word reading accuracy beyond that explained by the precursors of reading. The outcome variables were regular and exception word reading. The independent variables were letter-sound knowledge, phoneme awareness, RAN, language (composite score of receptive vocabulary and recalling sentences) and the variables of selective attention.

Table 6.5: Stepwise regression analysis examining the predictive value of Flanker on Regular word Reading at time 2

Model	B	SE B	Beta
Step 1			
(Constant)	-5.03	3.76	
Language T2	.19	.04	.48***
Step 2			
(Constant)	-29.04	12.41	
Language T2	.07	.04	.18
LSK T2	.93	.41	.25*
PA T2	.67	.22	.36**
RAN O. T2	-.05	.03	-.16
Step 3			
(Constant)	-13.13	13.18	
Language T2	.09	.04	.22*
LSK T2	1.06	.39	.28**
PA T2	.53	.22	.29*
RAN O. T2	-.03	.03	-.11
Flanker T2	-18.87	6.90	-.24**

Note: N= 69. R^2= .23 for Step 1, ΔR^2= .29 for Step 2 (p<.001),ΔR^2= .05 for Step 3 (p<.01). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects

Performance on the Flanker task in Year 1 (Table 6.5) concurrently and uniquely predicted a significant amount of variance in regular word reading (5%), even after controlling for language and the precursors of word reading. Phoneme awareness and letter-sound knowledge were also significant predictors, accounting for 29% of the variance in regular word reading in Year 1.

Since it has been suggested that the Flanker task also taps inhibition control skills (Fan, McCandliss, Fossella, Flombaum & Posner, 2005), the regression was repeated controlling for inhibition (as measured by the HTKS and Day-Night task (in two separate regressions). It was found that performance on

Flanker remained a significant predictor even after the influence of inhibition control (HTKS and Day-Night) was controlled for (see Appendix 3: Tables 5 & 6).

Table 6.6: Stepwise regression analysis examining the predictive value of visual search time per hit on Regular word Reading at time 2

Model	B	SE B	Beta
Step 1			
(Constant)	-5.19	3.71	
Language T2	.19	.04	.49***
Step 2			
(Constant)	-30.46	12.53	
Language T2	.07	.04	.19
LSK T2	.92	.41	.25*
PA T2	.67	.22	.37**
RAN O. T2	-.04	.03	-.11
Step 3			
(Constant)	-23.11	11.93	
Language T2	.05	.04	.14
LSK T2	.95	.38	.25*
PA T2	.69	.21	.38**
RAN O. T2	-.04	.03	-.12
VSTpH T2	-3.65	1.15	-.27**

Note: N= 67. R^2= .24 for Step 1, ΔR^2= .27 for Step 2 (p<.001), ΔR^2= .07 for Step 3 (p<.01). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; VSTpH= Visual Search Time per Hit

Regular word reading was also predicted by time per hit in the visual search task, accounting for 7% of the variance in regular word reading in Year 1 (Table 6.6).

The relationship between performance on the Flanker task, Visual search time per hit and Regular word reading was also explored through scatter plots

(Figure 8). Figure 8 indicates that the linear relationship between these two attention measures and regular word reading was weak (R^2 *Linear*= .09 and .08 respectively; i.e., 9% and 8% of variance explained).

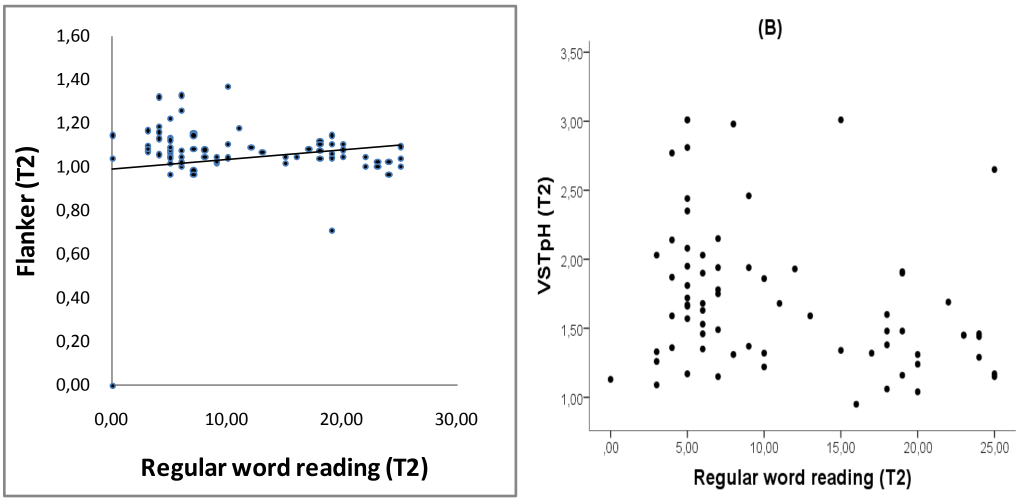

Figure 8: Plot of raw score in regular word reading against raw score in Flanker (A) and Visual Search Time per Hit (B) in Year 1; Note: lower scores indicate better performance in the Flanker task.

Table 6.7: Stepwise regression analysis examining the predictive value of Flanker on Exception word reading at time 2

Model	B	SE B	Beta
Step 1			
(Constant)	-8.00	3.61	
Language T2	.17	.04	.45***
Step 2			
(Constant)	-22.96	12.28	
Language T2	.06	.04	.16
LSK T2	.63	.40	.18
PA T2	.66	.22	.38*
RAN O. T2	-.05	.03	-.19
Step 3			
(Constant)	-8.71	13.18	
Language T2	.07	.04	.19
LSK T2	.75	.39	.21
PA T2	.54	.22	.31*
RAN O. T2	-.04	.03	-.14
Flanker T2	-16.9	6.90	-.22*

Note: N= 69. R^2= .21 for Step 1, ΔR^2= .27 for Step 2 (p<.001), ΔR^2= .05 for Step 3 (p<.01). ***p<.001, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects

Performance on the Flanker task was also a unique concurrent predictor of exception word reading in Year 1 (Table 6.7), even after controlling for language skills, phoneme awareness, letter sound knowledge and RAN, accounting for 5% of the variance.

Table 6.8: Stepwise regression analysis examining the predictive value of visual search time per hit on Exception word Reading at time 2

Model	B	SE B	Beta
Step 1			
(Constant)	-8.04	3.56	
Language T2	.17	.04	.46***
Step 2			
(Constant)	-22.48	12.31	
Language T2	.06	.04	.16
LSK T2	.60	.40	.17
PA T2	.66	.22	.39**
RAN O. T2	-.05	.03	-.17
Step 3			
(Constant)	-15.68	11.83	
Language T2	.04	.04	.11
LSK T2	.62	.38	.18
PA T2	.68	.21	.40**
RAN O. T2	-.05	.03	-.17
VSTpH T2	-3.38	1.14	-.26**

Note: N= 67. R^2= .21 for Step 1, ΔR^2= .26 for Step 2 (p<.001),ΔR^2= .07 for Step 3 (p<.01). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; VSTpH= Visual Search Time per Hit

It was also found that 6.7% of unique variance was explained by time per hit on the visual search task (Table 6.8).

The relationships between Flanker, visual search time per hit and exception word reading were also examined through scatter plots (Figure 9). They both had weak linear relationships with exception word reading (R^2 *Linear*=.09 and .08 respectively).

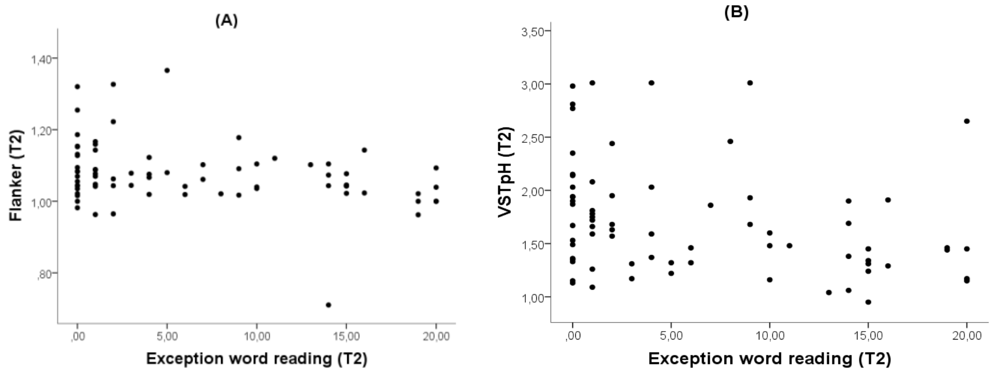

Figure 9: Scatter plots illustrating the relationship between exception word reading and Flanker (A), visual search time per hit (B); Note: lower score in Flanker indicates better performance.

6.4 Study 3: Visual selective attention as a longitudinal predictor of lexical and sub-lexical word reading accuracy

5.4.1 Results

5.4.1.1 Correlations

The following tables summarize the bivariate correlations between performance on selective attention in Reception Year, performance on reading tests in Year 1 (Table 6.9) and performance on measures of the precursors of word reading as well as language skills (Table 6.10). It was revealed that none of the selective attention variables in Reception had a statistically significant correlation with lexical and sub-lexical word reading in Year 1.

Table 6.9: Correlations between Attention measures in Reception and Word Reading in Year 1

	EWR T2	**R.W.**	**E.W.**	**N.W.**
Flanker	.05	-.05	-.05	.05
VSFA	-.17	-.21	-.20	-.04
VSDpH	.03	-.06	-.06	-.02
VSTpH	.08	.12	.06	.14

Note: EWR= Early word reading (YARC subtest); R.W. = regular word reading accuracy (DTWRP subtest); E.W. = exception word reading accuracy (DTWRP subtest); N.W. = nonword reading accuracy (DTWRP subtest); VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit.

Table 6.10: Correlations between attention measures in Reception and foundation literacy and language skills in Year 1

	LSK	PA	RAN O.	RV	RS
Flanker	.11	.06	-.02	.05	.19
VSFA	-.12	-.21	.23	-.29*	-.12
VSDpH	.01	-.12	.17	-.06	-.23*
VSTpH	.18	-.07	.11	-.03	-.13

Note: LSK= letter-sound knowledge; PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest); LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; *p<.05

There was only a weak correlation between receptive vocabulary and false alarms in the visual search task, and recalling sentences and visual search distance per hit (Table 6.10).

The correlation between the above mentioned variables was further investigated through plots of raw score in visual search false alarms and raw score in receptive vocabulary (Figure 10A), and visual search distance per hit against recalling sentences (Figure 10B). It was found that the linear relationships between those measures were weak (R^2 *linear*= .08 and .05 respectively).

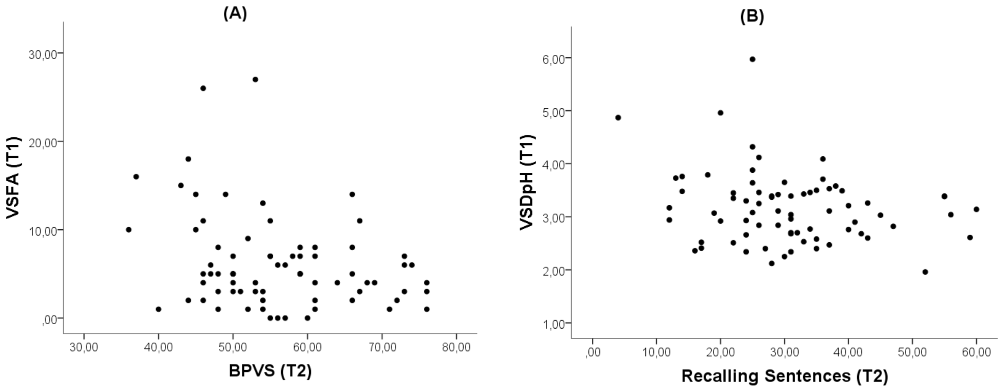

Figure 10: Scatter plots illustrating the relationship between visual search false alarms in Time 1 and receptive vocabulary in Time 2 (A), visual search distance per hit and recalling sentences (B)

Due to the lack of significant correlations between selective attention in Reception and word reading skills in Year, a regression analysis was not conducted.

6.5 Interim Discussion

Visual selective attention as measured by both Flanker and Visual search appears to be a unique concurrent predictor of regular and exception word reading, above and beyond language skills, letter-sound knowledge, phoneme awareness and RAN. The Flanker task explained 5% and the visual search 7% of the variance in regular and exception word reading. However, visual selection attention measured by both tasks was not associated with variation in nonword reading in this sample.

Selective attention as measured by a Flanker task did not correlate with early word reading or its precursors in Time 1. However, in Time 2, it correlated moderately with the Regular and Exception word reading subtests of the DTWRP. An interesting finding is that it was also a unique concurrent predictor at time 2 of both regular and exception word reading, even after controlling for language skills (receptive vocabulary and recalling sentences composite score), letter-sound knowledge, phoneme awareness and RAN. The variance explained was much less compared to the language skills and the other predictors of word reading (5% compared to 49% and 47% for Regular and Exception word reading respectively), however it was statistically significant.

In order to measure selective attention a second task was also used. That was a visual search task and the variables measured were reaction time, false alarms and distance per hit. At Time 1, the only correlation of selective attention (Visual Search False Alarms) was with the RAN of Objects. However, in Time 2, the results had the same pattern as those for the Flanker task. Namely, selective attention (Time per Hit) correlated with Regular and Exception word reading and it was a concurrent unique predictor of both, even after controlling for language, letter-sound knowledge, phoneme awareness and RAN. The variance explained was again small compared to the percentage explained by language and the precursors of reading (48% and 47% for Regular and Exception word reading), as it was only approximately 7%.

In contrast to the previous results discussed, where auditory and visual sustained attention (Chapter 5) seemed to have an impact on decoding and its precursors, the current results suggest selective attention appears to be involved in whole word processing/lexical word reading. This is supported from the results of this study in three ways. Firstly, selective attention does not correlate with skills that are necessary for decoding (i.e., letter-sound knowledge and phoneme awareness) or with nonword reading (which can be achieved only through phonological decoding) but only with lexical word reading. Secondly, it starts to have a significant correlation with word reading accuracy (regular and exception) only in Year 1 and not Reception. In accordance with Ehri’s (1995) model of reading and based on the performance of the participants on the word reading measures (i.e., there were no floor effects in exception word reading at Time 2), it is suggested that selective attention becomes important when the children start becoming more fluent readers and rely more on their lexical knowledge.

These results are further validated through the regression analysis, in which it was shown that at Year 1, selective attention predicts concurrently whole word processing (regular and exception words) above and beyond language and foundation literacy skills. Some preliminary evidence regarding the role of selective attention on reading were provided by Casco et al. (1998) and Plaza and Cohen (2007). Their results are in line with the results of the present study as they reported that performance on a visual search task is linked to word reading in terms of fluency and accuracy.

Similar results to the present study regarding the concurrent relationship between selective attention and reading at Time 1 (Reception Year; but not at Time 2) were also reported by Shapiro, Carroll and Solity (2013) with 4-5 years old children. They found that performance in a non-linguistic visual search task had no direct influence on early word reading in preschool children. They concluded that this might be due to the fact that selective attention becomes more important in more fluent readers. They specifically suggested that scanning and "maintaining an optimal viewing position may be more relevant when reading longer words or when decoding words more efficiently" (pg. 292). Their suggestion is further supported by the results of the present study.

In addition, the difference in the results of the Casco et al. (1998), Plaza and Cohen (2007) and Shapiro et al. (2013) studies might reflect the difference in the orthographies between the languages (Italian, French and English, respectively). It could be expected that selective attention starts predicting variation in reading at an earlier stage in Italian and French than in English, since children learn to decode words later in more inconsistent orthographies.

On the other hand, Goswami (2015) in a review paper on theories of developmental dyslexia suggested that the poor performance in visual attention tasks might result from the effects of reduced reading experience. The data of this thesis fit this view as there was no evidence of a longitudinal relationship between selective attention at Time 1 and word reading at Time 2. Other researchers (e.g., McBride-Chang et al., 2005, 2011) have suggested a bidirectional association of visual skills (as measured by several paradigms tapping on selective attention skills) and word reading.

Finally, it is worth noting that the expectation was that the two measures of selective attention (Flanker and Visual Search) would be highly correlated since they are proposed to measure the same sub-component of attention. However, it should be noted that Flanker did not have any significant correlations with any of the Visual search task variables. It might be the case that the Flanker task apart from visual selective attention taps also on inhibition control skills, as the participants, apart from orienting their attention to the target ignoring the distractors, they also had to give a response which was not the pre-potent response. This is due to the fact that the distractors were more that the target and they were indicating towards the opposite direction. For this reason, when examining the role of Flanker performance on word reading, the regression was repeated controlling for inhibition control. The results indicated that Flanker continued to be a predictor above and beyond the cognitive-linguistic predictors of reading and inhibition control. On the other hand, the visual search task might have involved motor skills as well as selective attention, as the participants were required to tap with a pen on targets presented on a touch-screen.

To conclude, the evidence from this study suggests selective attention is an important predictor of variation in early lexical word reading acquisition, as measured by both selective attention tasks (Flanker and visual search). This finding is novel as this is the first study including measures of both lexical and sub-lexical word reading and looking at attention from a developmental perspective on this age group. Consequently, further longitudinal research is required in order to be able to understand the relationship between the two. The interpretation of the results is included in the General Discussion chapter (pg., 252).

Chapter 7: The predictive role of Attentional control (inhibition and shifting) in emerging literacy

7.1 Introduction

Attentional control is divided in different sub-functions: inhibition, shifting and dividing attention. Miyake et al. (2000) defined attentional control as the ability to update our working memory, inhibition control and shifting of attention. Developmental researchers usually employ the broad term executive functions when referring to inhibition control, shifting and working memory. Hence, there is a variability in the way these terms are used. In the current paper, the term attentional control will be used so as to make a distinction between working memory in general and attentional processes (i.e., inhibition and shifting).

7.1.1 Literature review

Executive functioning (including attentional control) has been found to have an impact on academic outcomes such as reading comprehension (Daneman & Carpenter, 1980; Gathercole & Pickering, 2000). In addition, children with reading difficulties have been shown to also exhibit deficits in executive functioning (de Jong, 1998; Swanson & Sachse-Lee, 2001).

Inhibition control has been found to correlate and/or be a predictor of word reading. In particular, it has been reported that inhibition control (as measured by the HTKS) was a concurrent predictor of vocabulary and word reading skills of first grade children (Connor et al. 2010). It was suggested that children who have good attentional skills are enabled to take advantage of instructional activities more effectively. In the same vein, Burrage et al. (2008) reported positive correlations between word decoding and the HTKS scores in preschoolers. Ponitz et al. (2009) found that inhibition (HTKS task) was also a longitudinal (over a period of 5 months) predictor of real word reading accuracy and letter knowledge in preschoolers (Ponitz et al., 2009). They suggested that this pattern of results is observed as the skills needed in order to perform well in the HTKS (inhibition control, working memory and attentional focus) also enhance academic performance. Finally, Wanless et al. (2011) measured inhibition control using the same HTKS paradigm in a group of 4-6 years old children and reported significant correlations between HTKS and early literacy and vocabulary scores, even after age, gender, parent education and teacher ratings of behavioural regulation had been controlled for. They interpreted their results by proposing that good inhibition control enables children to follow classroom rules and instructions as well as to pay attention and remember rules. In that way they are better able to access the learning environment and enhance their learning. Blair and Razza (2007) also reported that inhibition control (peg tapping test) in kindergarten concurrently predicted phonemic awareness and letter knowledge.

One of the limitations of the above studies is the fact that they did include measures of speed of processing which might explain the predictive power of the HTKS (Ponitz et al., 2009). The above studies also have not controlled for other predictors of word reading like phoneme awareness, letter knowledge and RAN.

Steele et al. (2013) in their study with 3-6 year old children found that executive attention (as measured by a spatial conflict task and commission errors in a visual CPT) was a concurrent predictor of letter knowledge and vocabulary. Nonetheless, it was not a longitudinal predictor of word reading accuracy. They suggested that their results might be due to floor effects in emerging literacy skills. In line with this finding was Davidse et al.'s (2011) study in which it was reported that inhibition control, as measured by a peg tapping paradigm, was not a concurrent predictor of emerging literacy, even though it had strong correlations with letter knowledge and vocabulary.

The evidence regarding shifting of attention is more limited. Welsh et al. (2010) using a composite score of inhibition and shifting of attention (i.e., attention control) found, through path analysis, that attentional control in the beginning of prekindergarten predicted longitudinally emerging literacy skills at the end of prekindergarten. In addition, attentional control at the end of prekindergarten uniquely predicted word reading in kindergarten, even after controlling for the growth in emergent literacy skills. Their interpretation was the same as in Wanless et al. (2011), namely attentional control enables children to follow rules and pay attention, hence promoting their learning. Similar results have been reported by van der Sluis et al. (2004, 2007), who found that shifting of attention explained a unique variance in word reading in 10-11 years old students.

However, May, Rinehart, Wilding and Cornish (2013) using an older sample (mean age: 12 years old) found that shifting of attention (Dual Visual Search task) was not a unique predictor of word reading after controlling for age and short-term memory.

Their finding converges with Kieffer, Vukovic and Berry's (2013) study with 4th graders, in which it was found (using path analysis) that shifting of attention (WCST) and inhibition control (Stroop paradigm) had a direct influence on reading comprehension but not on word reading accuracy. Similar results were also reported with preschoolers were shifting of attention (set shifting paradigm) was reported to not predict emerging literacy skills in kindergarten (Blair & Razza, 2007).

To conclude, there seems to be consistent evidence regarding the role of inhibition control, as measured by the HTKS task, as a concurrent and longitudinal predictor of word reading. Nonetheless, the evidence is contradicting when other measures of inhibition control are used (i.e., Davidse et al., 2011; Steele et al., 2013). The results regarding shifting are contradicting with some studies reporting a significant relationship with word reading and others finding there this relationship is not significant after controlling for other factors (e.g., van der Sluis et al., 2007; but see May et al., 2013).

7.1.2 Design and Hypothesis

One of the aims of this paper is to examine the role of inhibition on word reading using two different measures (HTKS and Day-Night). The hypothesis is that inhibition control will be a unique concurrent and longitudinal predictor of word reading. Another aim is to explore whether inhibition plays a different role in lexical and sub-lexical word reading. It is anticipated that it will affect more sub-lexical word reading as the evidence indicates a strong correlation with letter knowledge and phoneme awareness (Bental & Tirosh, 2007; Altmeier, Abbott &Berninger, 2008). In terms of shifting of attention, it is expected to predict sub-lexical word reading in Time 1 and lose its predictive power at Time 2, when some children are becoming more fluent readers. This is based on the findings of the previous research discussed in which it was found that in later stages of reading development, shifting did not have a significant effect on word reading (e.g., Kieffer et al., 2013).

7.1.3 Method

7.1.3.1 Participants

Seventy seven children between 4-5 years old (Spring term of Reception Year) were tested. At Time 2, 74 children (instead of 77 at Time 1; due to attrition) were tested (M=70.67 months, SD= 4.07 months, range=64-77; 41 female, 33 male). More details regarding the characteristics of the sample can be found in Chapter 4.

7.1.3.2 Materials and Procedure

The tests of precursors of reading as well as word reading accuracy used are described in Chapter 4. In addition to those, two computerized tests of shifting the Day-Night task (Diamond et al., 2002) and the Dual Visual Search task (Visearch; Wilding, 2001) were employed. Inhibition control was measured using the HTKS task (McClelland et al., 2008). Another measure of inhibition was the commission errors of the visual and auditory Continuous performance tasks. The Diagnostic Test of Word Reading processes (DTWRP) and the recalling sentences subtest from CELF4 were employed at Time 2. .For more details, see Chapter 5.

7.2 Study 1: Attentional Control and children's concurrent emerging literacy skills.

7.2.1 Results

7.2.1.1 Descriptives

The normality of the distribution was checked through the shape of histograms, the skewness and kurtosis and the Shapiro-Wilk normality test. In order to improve the shape of the distribution, the outliers (+- 2sd from mean) were replaced by a value equal to the next highest non-outlying score plus one unit of measurement (Winzorisation, Tabachnik and Fidell, 2001).

Table 7.1: Descriptives of Dual Visual Search Task, Day-Night and HTKS at T1

	Mean	SD	Range	Skew.	Kurt.
DVSFA	16.62	10.81	0 - 37	0.24	-1.14
DVSDpH[1]	5.71	1.29	2.35 – 10.25	0.58	1.75
DVSTpH[2]	3.44	1.71	1.58 – 7.72	1.27	1.62
Day-Night Rt	1.84	0.49	1.04 – 3.02	0.37	-0.66
HTKS	24.84	10.24	3 – 40	-0.63	-0.53

Note: DVSFA= Dual Visual Search False Alarms; DVSDpH= Dual Visual Search Distance per Hit; DVSTpH= Dual Visual Search Time per Hit. [1]*total distance travelled/number of hits*
[2]*total time/number of hits*

Table 7.1 summarizes the descriptives of the attentional control tasks. The shapes of distribution for all the variables was close to normal. Mean scores for the HTKS are comparable to other studies using preschoolers in various countries (i.e., Ponitz et al.2009, Wanless et al. 2011). The Day-Night mean reaction times are also similar to studies using similar paradigms with typically developed young children (i.e., Diamond et al., 2002; Simpson & Riggs, 2005).

7.2.3.2 Correlations

The following tables summarize the results of the simple bivariate correlations analysis. Results regarding the commission errors of the CPT tasks are described in Chapter 5. In brief, commission errors did not correlate with any of the literacy measures and for this reason they are omitted from the analysis in this chapter.

Table 7.2: Bivariate correlations between literacy and Day-Night and HTKS at Time 1

	Day-Night Rt	**HTKS**
LSK	-.06	.39**
EWR	-.15	.45**
PA	-.21	.55***
RV	-.23*	.54**
RAN O	.23	-.27*

Note: LSK= letter-sound knowledge (YARC subtest); EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RV= receptive vocabulary (BPVS); RAN O. = rapid naming of objects (CTOPP subtest); Day-Night Rt = Day-Night Reaction time; HTKS = Head Toes Knees Shoulders task;****p*<.001, ***p*<.01, **p*<.05

Table 7.2 summarizes the results of the correlation analysis for the literacy, language and inhibition control measures. Inhibition control as measured by the Day-Night task had a weak correlation only with receptive vocabulary. On the other hand, inhibition control as measured by the HTKS task had moderate to strong correlations with all the measures of literacy and language and a weak correlation with RAN.

Table 7.3: Correlations between literacy and Dual Visual Search at Time 1

	DVSFA	**DVSTpH**	**DVSDpH**
LSK	-.08	.07	.01
EWR	-.22*	-.28*	-.10
PA	-.27*	-.25*	-.04
RV	-.32**	-.34**	-.26*
RAN O	.27*	.44**	.17

Note: DVSFA= Dual Visual Search False Alarms; DVSDpH= Dual Visual Search Distance per Hit; DVSTpH= Dual Visual Search Time per Hit; LSK= letter-sound knowledge; EWR= Early word reading; PA= phoneme awareness; RV= receptive vocabulary; RAN O. = rapid naming of objects ***p*<.01, **p*<.05

Table 7.3. shows the correlations between literacy, language and shifting of attention. The mean number of False alarms in the dual visual search task was significantly and negatively correlated with all the predictors of reading (apart from letter-sound knowledge) and receptive vocabulary. Time per Hit was also correlated with all Early word reading, vocabulary and RAN of Objects, whereas, Distance per Hit correlated only with receptive vocabulary.

7.2.3.3 Regression

Tables 7.4-7.6 summarize the results of the regression analyses with early word reading in Reception Year as the outcome measure. It was found that none of the attentional control measures was a unique significant predictor of early word reading, after controlling for language, letter-sound knowledge, phoneme awareness and RAN.

Table 7.4: Stepwise regression analysis predicting T1 Early word reading from individual differences in HTKS after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-2.30	2.29	
RV	.15	.04	.37**
Step 2			
(Constant)	-2.29	2.49	
RV	-.02	.03	-.05
LSK	.35	.06	.55***
PA	.28	.08	.39*
RAN O.	-.00	.01	-.01
Step 3			
(Constant)	-2.60	2.57	
RV	-.02	.03	-.06
LSK	.35	.06	.55***
PA	.28	.08	.38*
RAN O.	-.00	.01	-.01
HTKS	.02	.03	.04

Note: N= 63.R^2= .14 for Step 1, ΔR^2= .60 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; EWR= Early word reading; PA= phoneme awareness; RV= receptive vocabulary; RAN O. = rapid naming of objects; HTKS = Head Toes Knees Shoulders task

Table 7.5: Stepwise regression analysis predicting T1 Early word reading from individual differences in DVS False Alarms after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-2.30	2.29	
RV	.15	.04	.37**
Step 2			
(Constant)	-2.29	2.49	
RV	-.02	.03	-.05
LSK	.35	.06	.55***
PA	.28	.08	.39***
RAN O.	-.00	.01	-.01
Step 3			
(Constant)	-3.18	2.60	
RV	-.01	.03	-.03
LSK	.38	.06	.59***
PA	.27	.08	.37**
RAN O.	-.00	.01	-.02
DVSFA	.03	.03	.08

Note: N= 63. R^2= .14 for Step 1, ΔR^2= .60 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01; LSK= letter-sound knowledge; PA= phoneme awareness; RV = receptive vocabulary; RAN O. = rapid naming of objects; DVSFA = Dual Visual Search False Alarms

Table 7.6: Stepwise regression analysis predicting T1 Early word reading from individual differences in DVS time per hit after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-2.30	2.29	
RV	.15	.04	.37**
Step 2			
(Constant)	-2.29	2.49	
RV	-.02	.03	-.05
LSK	.35	.06	.55***
PA	.28	.08	.39***
RAN O.	-.00	.01	-.01
Step 3			
(Constant)	-1.89	2.61	
RV	-.02	.03	-.05
LSK	.35	.06	.55***
PA	.28	.08	.39***
RAN O.	.00	.01	-.00
DVSTpH	-.16	.29	-.04

Note: N= 63.R^2= .14 for Step 1, ΔR^2= .60 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV = receptive vocabulary; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O. = rapid naming of objects; DVTpH = Dual Visual Search Time per Hit

The same results were obtained when RAN and vocabulary were removed from the regression. Namely, none of the attentional control measures became a significant predictor of early word reading, even when language and RAN were not controlled for.

Due to the fact that there were many correlations between the attention measures and the predictors of literacy, regression analyses using letter-sound knowledge and phoneme awareness as dependent variables and attention measures as predictors were conducted. The aim was to explore whether attention has an indirect impact on Early word reading through its effect on the established cognitive predictors of word reading after partialling out the effects of the control variables.

Table 7.7: Stepwise regression analysis predicting T1 phoneme awareness from individual differences in HTKS after controlling for receptive vocabulary and LSK

Model	B	SE B	Beta
Step 1			
(Constant)	-7.73	2.32	
RV	.34	.05	.62***
Step 2			
(Constant)	-11.39	1.69	
RV	.24	.04	.43***
LSK	.52	.06	.59***
Step 3			
(Constant)	-11.39	1.97	
RV	.20	.04	.37***
LSK	.49	.06	.55***
HTKS	.08	.05	.14

Note: N= 63. R^2= .39 for Step 1, ΔR^2= .31 for Step 2 (p<.001),ΔR^2= .01 for Step 3 (*ns*). ***p<.001; RV = receptive vocabulary; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O. = rapid naming of objects; HTKS = Head Toes Knees Shoulders task

The results (Table 7.7) indicate that HTKS does not predict phoneme awareness, after controlling for language skills and letter-sound knowledge. Due to the fact that HTKS had a strong language element (i.e., children had to follow verbal instructions) and its high correlation with vocabulary, the analysis was repeated excluding receptive vocabulary (i.e., BPVS). It was found that HTKS became a significant predictor of phoneme awareness (p=.00), above and beyond the influence of letter-sound knowledge, explaining 8.7% of the variance.

Table 7.8 summarizes the results of the analysis examining HTKS as a concurrent predictor of letter-sound knowledge.

Table 7.8: Stepwise regression analysis predicting T1 letter-sound knowledge from individual differences in HTKS after controlling for receptive vocabulary and PA

Model	B	SE B	Beta
Step 1			
(Constant)	7.03	3.15	
RV	.20	.07	.32**
Step 2			
(Constant)	14.51	2.40	
RV	-.13	.06	-.21*
PA	.97	.11	.86***
Step 3			
(Constant)	14.29	2.46	
RV	-.14	.06	-.22*
PA	.95	.12	.84***
HTKS	.03	.07	.04

Note: *N*= 63. R^2= .11 for Step 1, ΔR^2= .45 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001

Moreover, HTKS did not predict letter-sound knowledge after controlling for receptive vocabulary and phoneme awareness. The same result was obtained even when the effect of vocabulary was not factored out.

7.3 Study 2: Attentional control as a predictor of early literacy outcomes in Year 1

7.3.3 Results

7.3.3.1 Descriptives

The following table (Table 7.9) summarizes the descriptives of the attentional control measures in Year 1.

Table 7.9: Descriptives of HTKS, Day Night Task and Dual Visual Search at Time 2

	Mean	SD	Range	Skew.	Kurt.
HTKS	32.26	6.66	4 – 40	-2.16	6.15
Day – Night	1.64	.38	.90 – 2.45	.47	-.54
DVSFA	8.16	6.83	0 – 25	1.08	.56
DVSTpH	2.26	.55	1.48 – 3.63	1.21	.74
DVSDpH	4.86	.78	3.63 – 6.72	.71	-.20

Note: HTKS = Head Toes Knees Shoulders task; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit

The HTKS test had a non-normal distribution. However, according to the Central Limit Theorem, for non-normal data, the distribution of the sample means has an approximate normal distribution. Hence, as long as the sample size is large enough (usually at least 30) and all samples have the same size, a parametric correlation analysis can be conducted.

7.3.3.2 Correlations

HTKS correlated with all the literacy and language measures but not with RAN. Mean reaction time of the Day-Night task did not correlate with any of the early literacy and language measures (Table 7.10).

Table 7.10: Bivariate correlations between literacy, language measures, HTKS and Day Night at Time 2

	HTKS	Day-Night
DTWRP	.31**	-.03
N.W.	.32**	-.03
E.W.	.29*	-.01
R.W.	.31**	-.05
LSK	.23*	-.20
EWR	.34**	-.06
PA	.45**	-.05
RAN O.	-.15	.16
RV	.41**	-.10
RS	.41**	-.16

Note: DTWRP= Composite score of Diagnostic Test of Word Reading Processes; N.W. = nonword reading accuracy (DTWRP subtest); E.W. = exception word reading accuracy (DTWRP subtest); R.W. = regular word reading accuracy (DTWRP subtest); LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest); HTKS = Head Toes Knees Shoulders task; ***p*<.01, **p*<.05

Table 7.11 summarizes the results of the bivariate parametric correlation analysis. False Alarms of the Dual Visual Search task correlated with the composite score of the DTWRP, with regular word reading and early word reading as well as with phoneme awareness and receptive vocabulary. Time per Hit correlated mildly with exception and regular word reading as well as the composite DTWRP score. It also correlated with Early word Reading and phoneme awareness.

Table 7.11: Bivariate correlations between literacy, language measures and Dual Visual Search at Time 2

	DVSFA	**DVSTpH**	**DVSDpH**
DTWRP	-.23*	-.23*	-.09
N.W.	-.06	-.01	.08
E.W.	-.23	-.24*	-.12
R.W	-.26*	-.26*	-.09
LSK	-.11	-.11	.03
EWR	-.24*	-.25*	-.05
PA	-.37**	-.27*	-.08
RAN O.	.03	.12	.12
RV	-.29*	-.19	-.09
R.S.	-.12	-.21	.12

Note: DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; DTWRP= Composite score of Diagnostic Test of Word Reading Processes; N.W. = nonword reading accuracy (DTWRP subtest); E.W. = exception word reading accuracy (DTWRP subtest); R.W. = regular word reading accuracy (DTWRP subtest); LSK= letter-sound knowledge; EWR= Early word reading (YARC subtest); PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest); ***p*<.01, **p*<.05

7.3.3.3 Regression

The following tables summarize the results of the stepwise regression analysis conducted. The dependent variables were the literacy outcomes as measured by the EWR task (YARC) and the DTWRP. The control variables were language, letter-sound knowledge, phoneme awareness and RAN.

Table 7.12: Stepwise regression analysis predicting T2 Early word reading from individual differences in HTKS after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-.24	4.11	
Language T2	.21	.05	.49***
Step 2			
(Constant)	-51.22	11.66	
Language T2	.07	.04	.17
LSK T2	1.80	.38	.44***
PA T2	.67	.21	.33**
RAN O. T2	-.03	.03	-.08
Step 3			
(Constant)	-52.82	12.38	
Language T2	.07	.04	.16
LSK T2	1.83	.39	.44***
PA T2	.65	.22	.32**
RAN O. T2	-.02	.03	-.08
HTKS T2	.04	.11	.03

Note: N= 69. R^2= .24 for Step 1, ΔR^2= .41 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; HTKS = Head Toes Knees Shoulders task

Inhibition control and shifting (see Tables 7.12, 7.13 & 7.14) were not unique concurrent predictors of Early word Reading after controlling for language and foundation literacy skills in Year 1.

Table 7.13: Stepwise regression analysis predicting T2 Early word reading from individual differences in Dual Visual Search false alarms after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-.30	4.09	
Language T2	.21	.05	.49***
Step 2			
(Constant)	-51.16	11.78	
Language T2	.07	.04	.17
LSK T2	1.78	.38	.43***
PA T2	.67	.21	.34**
RAN O. T2	-.02	.03	-.06
Step 3			
(Constant)	-50.72	11.92	
Language T2	.07	.04	.17
LSK T2	1.80	.39	.44***
PA T2	.65	.22	.32**
RAN O. T2	-.02	.03	-.07
DVSFA T2	-.03	.10	-.03

Note: N= 67.R^2= .24 for Step 1, ΔR^2= .41 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; DVSFA= Dual Visual Search False Alarms

Table 7.14: Stepwise regression analysis predicting T2 Early word reading from individual differences in Dual Visual Search Time per Hit after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-.30	4.10	
Language T2	.21	.05	.49***
Step 2			
(Constant)	-51.16	11.78	
Language T2	.07	.04	.17
LSK T2	1.78	.38	.43***
PA T2	.67	.21	.34**
RAN O. T2	-.02	.03	-.07
Step 3			
(Constant)	-48.64	12.17	
Language T2	.07	.04	.16
LSK T2	1.80	.39	.44***
PA T2	.64	.21	.32**
RAN O. T2	-.02	.03	-.06
DVSTpH T2	-.95	1.11	-.07

Note: N= 67. R^2= .24 for Step 1, ΔR^2= .40 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; DVSTpH= Dual Visual Search Time per Hit

The following tables (Table 7.15-7.17) summarize the results of a series of regression analyses using regular word reading from the DTWRP as an outcome measure. It was found that performance on the attentional control measures did not account for unique variance in regular word reading.

Table 7.15: Stepwise regression analysis predicting T2 Regular word reading from individual differences in HTKS after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-5.03	3.77	
Language T2	.19	.04	.48***
Step 2			
(Constant)	-29.04	12.41	
Language T2	.07	.04	.18
LSK T2	.93	.41	.25*
PA T2	.67	.22	.36**
RAN O. T2	-.05	.03	-.16
Step 3			
(Constant)	-28.70	13.20	
Language T2	.07	.04	.18
LSK T2	.92	.42	.24*
PA T2	.67	.23	.37**
RAN O. T2	-.05	.03	-.16
HTKS T2	-.01	.12	-.01

Note: N= 69. R^2= .23 for Step 1, ΔR^2= .29 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; HTKS = Head Toes Knees Shoulders task

Table 7.16: Stepwise regression analysis predicting T2 regular word reading from individual differences in Dual Visual Search false alarms after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-5.19	3.71	
Language T2	.19	.04	.49***
Step 2			
(Constant)	-30.46	12.53	
Language T2	.07	.04	.19
LSK T2	.92	.41	.25*
PA T2	.67	.22	.37**
RAN O. T2	-.04	.03	-.11
Step 3			
(Constant)	-29.79	12.67	
Language T2	.07	.04	.19
LSK T2	.95	.41	.25*
PA T2	.63	.24	.35**
RAN O. T2	-.04	.03	-.12
DVSFA T2	-.05	.10	-.05

Note: N= 67. R^2= .24 for Step 1, ΔR^2= .27 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; DVSFA= Dual Visual Search False Alarms

Table 7.17: Stepwise regression analysis predicting T2 Regular word reading from individual differences in Dual Visual Search Time per Hit after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-5.19	3.71	
Language T2	.19	.04	.49***
Step 2			
(Constant)	-30.46	12.53	
Language T2	.07	.04	.19
LSK T2	.92	.41	.25*
PA T2	.67	.22	.37**
RAN O. T2	-.04	.03	-.11
Step 3			
(Constant)	-28.09	12.96	
Language T2	.07	.04	.18
LSK T2	.94	.41	.25*
PA T2	.64	.23	.35**
RAN O. T2	-.03	.03	-.11
DVSTpH T2	-.89	1.18	-.07

Note: N= 67. R^2= .24 for Step 1, ΔR^2= .27 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; DVSTpH= Dual Visual Search Time per Hit

Exception word and nonword reading (Tables 7.18-7.20) were also not predicted by inhibition control nor shifting. Phoneme awareness was the only predictor of exception word reading. Nonword reading was predicted by both letter-sound knowledge and phoneme awareness.

Table 7.18: Stepwise regression analysis predicting T2 Exception word reading from individual differences in HTKS after controlling for language, LSK, PA and RAN.

Model	B	SE B	Beta
Step 1			
(Constant)	-8.00	3.61	
Language T2	.17	.04	.45***
Step 2			
(Constant)	-22.96	12.28	
Language T2	.06	.04	.16
LSK T2	.63	.40	.17
PA T2	.66	.22	.38**
RAN O. T2	-.05	.03	-.19⁺
Step 3			
(Constant)	-23.09	13.06	
Language T2	.06	.04	.16
LSK T2	.63	.41	.18
PA T2	.66	.23	.38**
RAN O. T2	-.05	.03	-.18
HTKS T2	.00	.12	.00

Note: N= 69. R^2= .21 for Step 1, ΔR^2= .44 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*).***p<.001, **p<.01, *p<.05, ^{+}p=.056; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; HTKS = Head Toes Knees Shoulders task

Table 7.19:Stepwise regression analysis predicting T2 Exception word reading from individual differences in Dual Visual Search Time Per Hit after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-8.04	3.56	
Language T2	.17	.04	.46***
Step 2			
(Constant)	-22.48	12.31	
Language T2	.06	.04	.16
LSK T2	.60	.40	.17
PA T2	.66	.22	.39**
RAN O. T2	-.05	.03	-.17
Step 3			
(Constant)	-20.56	12.75	
Language T2	.06	.04	.15
LSK T2	.61	.40	.17
PA T2	.64	.22	.38**
RAN O. T2	-.05	.03	-.17
DVSTpH T2	-.72	1.17	-.06

Note: N= 67. R^2= .21 for Step 1, ΔR^2= .26 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; DVSTpH= Dual Visual Search Time per Hit

Table 7.20: Stepwise regression analysis predicting T2 nonword reading from individual differences in HTKS after controlling for language, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	2.47	1.00	
Language T2	.04	.01	.43***
Step 2			
(Constant)	-9.58	3.45	
Language T2	.02	.01	.19
LSK T2	.39	.11	.40***
PA T2	.13	.06	.26*
RAN O. T2	.00	.01	.05
Step 3			
(Constant)	-9.86	3.66	
Language T2	.02	.01	.18
LSK T2	.39	.11	.40***
PA T2	.12	.06	.25
RAN O. T2	.00	.01	.05
HTKS T2	.00	.03	.03

Note: N= 69.R^2= .19 for Step 1, ΔR^2= .26 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, *p<.05; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O= Rapid naming of Objects; HTKS = Head Toes Knees Shoulders task

Due to the high correlations of the HTKS task and phoneme awareness, the predictive power of HTKS on PA skills, above and beyond language and letter-sound knowledge, was examined.

Table 7.21: Stepwise regression analysis predicting T2 phoneme awareness from individual differences in HTKS after controlling for language and LSK

Model	B	SE B	Beta
Step 1			
(Constant)	5.94	1.85	
Language	.12	.02	.57***
Step 2			
(Constant)	-19.22	4.94	
Language T2	.08	.02	.40***
LSK T2	.94	.17	.48***
Step 3			
(Constant)	-20.58	4.84	
Language T2	.07	.02	.31**
LSK T2	.91	.17	.46***
HTKS T2	.12	.06	.20*

Note: N= 73. R^2= .32 for Step 1, ΔR^2= .19 for Step 2 (p<.001),ΔR^2= .03 for Step 3 (p<.05). ***p<.001, **p<.01 *p<.05; LSK= letter-sound knowledge; HTKS = Head Toes Knees Shoulders task

It was found that performance on the HTKS predicted 3.2% of unique variance in phoneme awareness in Year 1, even after controlling for language skills and letter-sound knowledge.

The same analysis was conducted using False alarms in the Dual Visual search task as an independent variable.

Table 7.22: Stepwise regression analysis predicting T2 phoneme awareness from individual differences in Dual Visual search false alarms after controlling for language and LSK

Model	B	SE B	Beta
Step 1			
(Constant)	5.92	1.84	
Language T2	.12	.02	.57***
Step 2			
(Constant)	-19.10	5.04	
Language T2	.08	.02	.40***
LSK T2	.94	.18	.47***
Step 3			
(Constant)	-16.45	4.84	
Language T2	.07	.02	.35***
LSK T2	.92	.17	.46***
DVSFA T2	-.15	.05	-.24**

Note: *N*= 71. R^2= .33 for Step 1, ΔR^2= .19 for Step 2 (*p*<.001), ΔR^2= .06 for Step 3 (*p*<.01). ****p*<.001, ***p*<.01; LSK= letter-sound knowledge; DVSFA= Dual Visual Search False Alarms

It was revealed that false alarms also predicted concurrently performance on the phoneme awareness task, explaining 5.7% of the variance, even after controlling for language and letter-sound knowledge.

The scatter plots (Figure 11) between phoneme awareness and HTKS, and PA and dual visual search false alarms, showed that there was a linear relationship between phoneme awareness and performance on the HTKS task (R^2 *Linear*= .21) and number of false alarms in the Dual visual search task (R^2 *Linear*= .14).

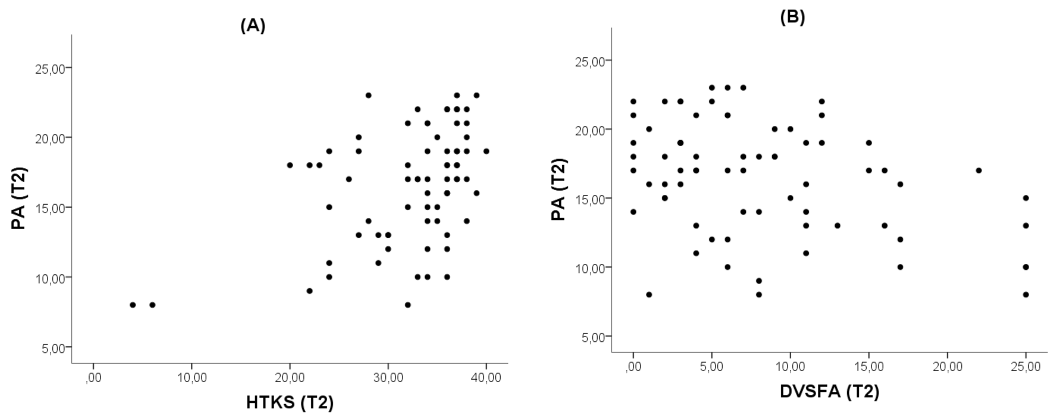

Figure 11: Scatter plots illustrating the relationship between phoneme awareness and HTKS (A), dual visual search false alarms (B) at Time 2.

As shown in the following table, Time per hit was not a significant unique predictor of phoneme awareness, after controlling for language skills and letter-sound knowledge.

Table 7.23: Stepwise regression analysis predicting T2 phoneme awareness from individual differences in Dual Visual search time per hit after controlling for language and LSK

Model	B	SE B	Beta
Step 1			
(Constant)	5.92	1.84	
Language T2	.12	.02	.57***
Step 2			
(Constant)	-19.10	5.04	
Language T2	.08	.02	.40***
LSK T2	.94	.18	.47***
Step 3			
(Constant)	-15.96	5.36	
Language T2	.08	.02	.37***
LSK T2	.93	.18	.48***
DVSTpH T2	-1.00	.63	-.14

Note: *N*= 71. R^2= .33 for Step 1, ΔR^2= .19 for Step 2 (*p*<.001), ΔR^2= .02 for Step 3 (*ns*). ****p*<.001; LSK= letter-sound knowledge; DVSTpH = Dual Visual Search Time per Hit

Finally, the same analysis (Table 7.24) was conducted for letter-sound knowledge and it was found that performance in the HTKS task was not a unique predictor of letter sound knowledge after controlling for language skills and phoneme awareness.

Table 7.24: Stepwise regression analysis predicting T2 letter-sound knowledge from individual differences in HTKS after controlling for language and PA

Model	B	SE B	Beta
Step 1			
(Constant)	26.75	1.06	
	.04	.01	.36**
Language skills T2			
Step 2			
(Constant)	24.91	.96	
Language skills T2	.00	.01	.01
PA T2	.31	.06	.61***
Step 3			
(Constant)	25.22	1.10	
Language skills T2	.00	.01	.03
PA T2	.32	.06	.63***
HTKS T2	-.02	.03	-.07

Note: N= 73. R^2= .13 for Step 1, ΔR^2= .25 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01; PA = phoneme awareness; HTKS = Head Toes Knees Shoulders task

7.4 Study 3: Attentional control as a longitudinal predictor of literacy outcomes.

7.4.1 Results

7.4.1.1 Descriptives

For the descriptives of the tasks used see Chapter 7: Study 1 and Study 2.

7.4.1.2 Correlations

Tables 7.25 and 7.26 show the bivariate correlations between attentional control in Reception and literacy and its predictors in Year 1. Early word reading, regular and exception word reading had strong correlations with HTKS and weak to moderate correlations with shifting. Nonword reading also had a weak correlation with HTKS.

Table 7.25: Correlations between Attention measures in Reception and Word Reading in Year 1

	EWR T2	R.W.	E.W.	N.W.
Day-Night	-.06	-.14	-.11	-.14
HTKS	.40**	.40**	.40**	.30*
DVSFA	-.28*	-.24*	-.28*	-.12
DVSDpH	-.11	-.12	-.15	-.03
DVSTpH	-.27*	-.25*	-.33**	-.12

Note: EWR T2= Early word reading in Time 2 (YARC subtest); R.W. = regular word reading accuracy (DTWRP subtest); E.W. = exception word reading accuracy (DTWRP subtest); N.W. = nonword reading accuracy (DTWRP subtest); HTKS= Head-Toes-Knees-Shoulders; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit. ***p*<.01, **p*<.05

Table 7.26: Correlations between attention measures in Reception and foundation literacy and language skills in Year 1

	LSK	PA	RAN O.	RV	RS
Day-Night	-.00	-.09	.05	-.20	-.25*
HTKS	.19	.43**	-.19	.50**	.42**
DVSFA	-.22	-.29*	.17	-.41**	-.12
DVSDpH	-.06	-.08	.07	-.22	-.03
DVSTpH	-.04	-.22	.27*	-.40**	-.24*

Note: LSK= letter-sound knowledge; PA= phoneme awareness (YARC subtest); RAN O= Rapid naming of Objects; RV= Receptive Vocabulary (BPVS); RS= Recalling sentences (CELF subtest); HTKS= Head-Toes-Knees-Shoulders; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; ** p<.01; * p<.05

Phoneme awareness in Time 2 had a strong correlation with HTKS and a weak correlation with the false alarms of the Dual Visual search task. Receptive vocabulary had strong correlations with HTKS, False alarms and Time per Hit. Recalling sentences had a strong correlation with HTKS and weak correlation with Day-Night and Time per Hit.

7.4.3.3 Regression

In order to examine whether attentional control in Reception was a predictor of word reading in Year 1, a series of regression analyses followed with the outcome measures being early word reading, regular, exception and nonword reading.

Due to the large number of the predictor variables, in the regression analysis a composite score for literacy skills (letter-sound knowledge and phoneme awareness) in Reception was used. For early word reading, the autoregressor effect was controlled for. The following tables summarize the results of the analyses.

Table 7.27: Stepwise regression analysis predicting T2 Early word reading from individual differences in T1 HTKS after controlling for autoregressor, receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	12.26	.95	
EWR1	1.35	.15	.77***
Step 2			
(Constant)	10.00	2.84	
EWR1	1.30	.16	.74***
RV	.05	.06	.08
Step 3			
(Constant)	18.36	4.07	
EWR1	.48	.25	.27
RV	-.05	.06	-.08
Literacy	.35	.10	.54***
RAN O.	-.07	.02	-.23**
Step 4			
(Constant)	19.27	4.20	
EWR1	.50	.25	$.28^{+}$
RV	-.04	.06	-.06
Literacy	.36	.10	.56***
RAN O.	-.07	.02	-.23**
HTKS	-.17	.07	-.08

Note: N= 61. R^2= .59 for Step 1, ΔR^2= .00 for Step 2 (*ns*), ΔR^2= .12 for Step 3 (p<.001), ΔR^2= .00 for Step 4 (*ns*). ***p<.001, **p<.01, *p<.05, ^{+}p= .054; EWR1= Early word reading at time 1; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; HTKS= Head-Toes-Knees-Shoulders

Table 7.28: Stepwise regression analysis predicting T2 Early word reading from individual differences in T1 Dual Visual false alarms after controlling for autoregressor, receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	12.26	.95	
EWR1	1.35	.15	.77***
Step 2			
(Constant)	10.00	2.84	
EWR1	1.30	.16	.74***
RV	.05	.06	.08
Step 3			
(Constant)	18.36	4.07	
EWR1	.48	.25	.27
RV	-.05	.06	-.08
Literacy	.35	.10	.54***
RAN O.	-.07	.02	-.23**
Step 4			
(Constant)	18.54	4.26	
EWR1	.50	.25	.28
RV	-.05	.06	-.08
Literacy	.34	.10	.54***
RAN O.	-.07	.02	-.23**
DVSFA	-.01	.06	-.01

Note: N= 61. R^2= .59 for Step 1, ΔR^2= .00 for Step 2 (*ns*),ΔR^2= .12 for Step 3 (p<.001), ΔR^2= .00 for Step 4 (*ns*). ***p<.001, **p<.01, *p<.05 ; EWR1= Early word reading at time 1; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; DVSFA= Dual Visual Search False Alarms

Table 7.29: Stepwise regression analysis predicting T2 Early word reading from individual differences in T1 Dual Visual search time per hit after controlling for autoregressor, receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	12.26	.95	
EWR1	1.35	.15	.77***
Step 2			
(Constant)	10.00	2.84	
EWR1	1.30	.16	.74***
RV	.05	.06	.08
Step 3			
(Constant)	18.36	4.07	
EWR1	.48	.25	.27
RV	-.05	.06	-.08
Literacy	.35	.10	.54***
RAN O.	-.07	.02	-.23**
Step 4			
(Constant)	17.90	4.27	
EWR1	.48	.25	.28
RV	-.05	.06	-.07
Literacy	.34	.10	.54***
RAN O.	-.07	.02	-.24**
DVSTpH	.22	.55	.03

Note: *N*= 61. R^2= .59 for Step 1, ΔR^2= .00 for Step 2 (*ns*),ΔR^2= .12 for Step 3 (p<.001), ΔR^2= .00 for Step 4 (*ns*). ***p<.001, **p<.01; EWR1= Early word reading at time 1; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; DVSTpH= Dual Visual Search Time per Hit

Inhibition control and shifting (Tables 7.27-7.29) were not unique longitudinal predictors of early word reading, after controlling for the autoregressor effect, vocabulary, literacy skills (i.e., phoneme awareness and letter-sound knowledge) and RAN. It remained non-significant even when vocabulary and RAN were removed from the regression.

The next set of regression analyses examined the predictive value of attentional control on regular word reading.

Table 7.30: Stepwise regression analysis predicting T2 Regular word reading from individual differences in T1 HTKS after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	2.61	3.93	
RV	.19	.08	.29*
Step 2			
(Constant)	12.96	4.32	
RV	-.07	.06	-.10
Literacy	.43	.06	.71***
RAN O.	-.07	.02	-.27**
Step 3			
(Constant)	13.20	4.46	
RV	-.06	.06	-.09
Literacy	.43	.06	.72***
RAN O.	-.07	.02	-.27**
HTKS	-.02	.08	-.03

Note: *N*= 60. R^2= .12 for Step 1, ΔR^2= .52 for Step 2 (*p*<.001), ΔR^2= .00 for Step 3 (*ns*). ****p*<.001, ***p*<.01, **p*<.05; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; HTKS= Head-Toes-Knees-Shoulders

Table 7.31: Stepwise regression analysis predicting T2 Regular word reading from individual differences in T1 Dual Visual search false alarms after controlling for receptive vocabulary, LSK, PA and RAN

Model	**B**	**SE B**	**Beta**
Step 1			
(Constant)	2.61	3.93	
RV	.19	.08	.29*
Step 2			
(Constant)	12.96	4.32	
RV	-.07	.06	-.10
Literacy	.43	.06	.71***
RAN O.	-.07	.02	-.27**
Step 3			
(Constant)	11.86	4.52	
RV	-.06	.06	-.09
Literacy	.44	.06	.74***
RAN O.	-.07	.02	-.28**
DVSFA	.05	.06	.08

Note: N= 60. R^2= .09 for Step 1, ΔR^2= .53 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; DVSFA= Dual Visual Search False Alarms

Table 7.32: Stepwise regression analysis predicting T2 Regular word reading from individual differences in T1 Dual Visual search time per hit after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	2.61	3.93	
RV	.19	.08	.29*
Step 2			
(Constant)	12.96	4.32	
RV	-.07	.06	-.10
Literacy	.43	.06	.71***
RAN O.	-.07	.02	-.27**
Step 3			
(Constant)	11.45	4.59	
RV	-.05	.06	-.08
Literacy	.43	.06	.73***
RAN O.	-.08	.02	-.30**
DVSTpH	.60	.61	.09

Note: N= 60. R^2= .09 for Step 1, ΔR^2= .53 for Step 2 (p<.001),ΔR^2= .01 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; DVSTpH= Dual Visual Search Time per Hit

Regular word reading in Year 1 was not predicted by any of the attentional control variables (inhibition and shifting) after controlling for vocabulary, literacy (phoneme awareness and letter-sound knowledge) and RAN. There was no significant change in the results even when vocabulary and RAN were removed from the regression.

The next dependent variable that was examined was exception word reading (Table 7.33-7.35).

Table 7.33:Stepwise regression analysis predicting T2 Exception word reading from individual differences in T1 HTKS after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-1.36	3.66	
Vocabulary	.18	.08	.29*
Step 2			
(Constant)	9.09	4.06	
Vocabulary	-.06	.06	-.10
Literacy	.39	.05	.70***
RAN O.	-.07	.02	-.29**
Step 3			
(Constant)	9.12	4.19	
Vocabulary	-.06	.06	-.10
Literacy	.39	.06	.70***
RAN O.	-.07	.02	-.29**
HTKS	-.00	.08	-.00

Note: N= 60. R^2= .08 for Step 1, ΔR^2= .53 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RAN O = Rapid naming of Objects; HTKS= Head-Toes-Knees-Shoulders

Table 7.34: Stepwise regression analysis predicting T2 Exception word reading from individual differences in T1 Dual Visual search false alarms after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-1.36	3.66	
RV	.18	.08	.29*
Step 2			
(Constant)	9.09	4.06	
RV	-.06	.06	-.10
Literacy	.39	.05	.70***
RAN O.	-.07	.02	-.29**
Step 3			
(Constant)	8.53	4.26	
RV	-.06	.06	-.10
Literacy	.39	.06	.70***
RAN O.	-.07	.02	-.30**
DVSFA	.03	.06	.04

Note: N= 60. R^2= .08 for Step 1, ΔR^2= .53 for Step 2 (p<.001),ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; DVSFA= Dual Visual Search False Alarms

Table 7.35: Stepwise regression analysis predicting T2 Exception word reading from individual differences in T1 Dual Visual search time per hit after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	-1.36	3.66	
Vocabulary	.18	.08	.29*
Step 2			
(Constant)	9.09	4.06	
Vocabulary	-.06	.06	-.10
Literacy	.39	.05	.70***
RAN O.	-.07	.02	-.29**
Step 3			
(Constant)	9.12	4.35	
Vocabulary	-.06	.06	-.10
Literacy	.39	.05	.70***
RAN O.	-.07	.02	-.29**
DVSFA	-.01	.58	-.00

Note: N= 60. R^2= .08 for Step 1, ΔR^2= .53 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, **p<.01, *p<.05; RAN O= Rapid naming of Objects; DVSFA= Dual Visual Search False Alarms

Similar results as in regular word reading were obtained in the analysis regarding performance in the exception word reading task. Namely, none of the attentional control measures were significant predictors, even when language and RAN skills were not included in the analysis. Finally, the possible effect of attentional control on nonword reading was examined.

Table 7.36: Stepwise regression analysis predicting T2 nonword reading from individual differences in T1 HTKS after controlling for receptive vocabulary, LSK, PA and RAN

Model	B	SE B	Beta
Step 1			
(Constant)	3.92	1.04	
RV	.05	.02	.29*
Step 2			
(Constant)	5.45	1.35	
RV	-.01	.02	-.04
Literacy	.10	.02	.65***
RAN O.	-.01	.01	-.15
Step 3			
(Constant)	5.46	1.40	
RV	-.01	.02	-.04
Literacy	.10	.02	.65***
RAN O.	-.01	.01	-.15
HTKS	-.00	.02	-.01

Note: N= 60. R^2= .09 for Step 1, ΔR^2= .38 for Step 2 (p<.001), ΔR^2= .00 for Step 3 (*ns*). ***p<.001, *p<.05; RV= Receptive Vocabulary; RAN O= Rapid naming of Objects; HTKS= Head-Toes-Knees-Shoulders

In line with the results regarding the other subtests of DTWRP (regular and exception word reading), it was found that nonword reading in Year 1 was not predicted by inhibition nor shifting in Reception.

However, foundation literacy skills in Year 1 had some correlations with attention in Reception. This led to another series of regression analyses in order to check whether performance in attention tests could predict phoneme awareness in Year 1.

Table 7.37: Stepwise regression analysis predicting T2 phoneme awareness from individual differences in T1 HTKS after controlling for receptive vocabulary, LSK and PA

Model	B	SE B	Beta
Step 1			
(Constant)	8.53	1.71	
Vocabulary	.18	.04	.50***
Step 2			
(Constant)	8.64	1.33	
Vocabulary	.07	.03	.18*
Literacy	.21	.03	.63***
Step 3			
(Constant)	8.60	1.35	
Vocabulary	.06	.03	.17
Literacy	.20	.03	.62***
HTKS	.01	.04	.03

Note: *N*= 74. R^2= .25 for Step 1, ΔR^2= .30 for Step 2 ($p<.001$),ΔR^2= .00 for Step 3 (*ns*). ***$p<.001$, *$p<.05$; RAN O= Rapid naming of Objects; HTKS= Head-Toes-Knees-Shoulders

Table 7.38: Stepwise regression analysis predicting T2 phoneme awareness from individual differences in T1 Dual Visual search false alarms after controlling for receptive vocabulary, LSK and PA

Model	B	SE B	Beta
Step 1			
(Constant)	8.53	1.71	
Vocabulary	.18	.04	.50***
Step 2			
(Constant)	8.64	1.33	
Vocabulary	.07	.03	.18*
Literacy	.21	.03	.63***
Step 3			
(Constant)	9.19	1.64	
Vocabulary	.06	.03	.17
Literacy	.20	.03	.62***
DVSFA	-.02	.03	-.05

Note: *N*= 74. R^2= .25 for Step 1, ΔR^2= .30 for Step 2 ($p<.001$), ΔR^2= .00 for Step 3 (*ns*). ***$p<.001$, *$p<.05$; DVSFA= Dual Visual Search False Alarms

It was found that inhibition control and shifting were not longitudinal predictors of phoneme awareness a year later after controlling for phoneme awareness, letter-sound knowledge and language skills in Reception.

7.5 Interim Discussion

At the age of 4-5 years old, performance in on one of the measures of inhibition control (HTKS) had a moderate correlation with word reading accuracy (measured by the subtest of Early word reading from YARC). Similar results were obtained for this sample at the age of 5-6 years. Namely, inhibition control as measured by the HTKS task had a moderate correlation with the Early Word Reading subtest from YARC and with the Regular and Nonword Reading subtests from the DTWRP. It also had a mild correlation with Exception word reading accuracy.

It was found that after controlling for letter-sound knowledge, phoneme awareness and RAN, inhibition control was a non-significant unique predictor of word reading accuracy both in Time 1 and Time 2. Even when the analysis was repeated excluding RAN from the control variables (on the grounds that it might tap on executive functions and thus mask the correlation of HTKS with word reading), the results remained the same.

These results are contradictory to previous studies which have reported that inhibition control(using HTKS task)concurrently predicts early literacy (e.g., Wanless et al., 2012). It is worth noting that Wanless et al. (2012) in their study employed the same measure of inhibition control as in the present study in 3 different countries (U.S.A, China and South Korea) for a similar age group (preschoolers). They also used word reading accuracy tests for each country and they found that inhibition control correlates with word reading even after controlling for age, gender, mother's education and teachers' ratings of behavioural regulation (i.e., inhibition control). However, one of the limitations of this study is that they did not include measures of foundation literacy skills such as letter-sound knowledge and phoneme awareness. Consequently, the difference in the results of Wanless et al (2012) and the present study can be explained through the lack of foundation literacy skills as control variables in the former study.

Nonetheless, it should be noted that HTKS (behavioural inhibition control) had a moderate correlation with phoneme awareness at both Times. The regression analysis controlling for language skills indicated that HTKS predicts concurrently phoneme awareness at Time 2 only, and accounted for 4.6% of the variance, even after the effects of letter-sound knowledge and language skills were controlled for. Moreover, HTKS predicted letter-sound knowledge at Time 1 (but not at Time 2), even after controlling for language and explained 6.6% of the variance. Nonetheless, when phoneme awareness was controlled for, HTKS lost its predictive strength.

In conclusion, inhibition control as measured by a behavioural task appears to have no direct impact on word reading accuracy at the ages of 4-6 years old, above and beyond letter sound knowledge, phoneme awareness and RAN. However, it could have an indirect impact on word reading accuracy as it explains a statistically significant amount of additional variance of phoneme awareness. This might imply that controlling attention effectively enables children to focus their learning better (see Connor et al., 2010). It should be noted that at these ages, in order to help children to read, the skills taught are those of letter sound knowledge and phoneme awareness. It is suggested that inhibition control might play an important role in learning foundation literacy skills.

However, when children master those skills and they start being able to read sight words, then inhibition control ceases being an important factor of word reading development. This is also shown by the fact that the strength of the correlation was reduced from Time 1 to Time 2. Namely, when children were in Reception year (partial alphabetic phase) HTKS and early word reading correlation was .45 ($p<.01$) but in Year 1 (when children move to the full alphabetic phase) r was reduced to .34 ($p<.01$).

The fact that inhibition control might play a role only during the partial alphabetic phase (when children learn letter-sound correspondences, develop their phonological skills and read by decoding words) is supported also by the finding that inhibition control had a stronger correlation with regular and nonword reading than with exception word reading. An additional supporting finding is the reduced amount of variance explained at Time 2 (compared to Time 1), in terms phoneme awareness. However, in order to confirm whether this pattern is valid, there is need for further research that would test the children from the beginning of literacy instruction (Autumn term of Reception/partial alphabetic phase) and follow them at several time points up to Year 2 when they are in the full alphabetic phase.

It is also worth noting, that HTKS is not an absolutely pure measure of inhibition control, as it requires the children to remember a set of instructions (working memory) and sustain their attention as well (McClelland et al., 2014).The association of the HTKS and recalling sentences task could be a reflection of the shared working memory component.

However, it should be noted that the working memory and sustained attention demands were not high as there were only two instructions that they had to remember and the test duration was short (slightly less than 5 minutes).

Inhibition control as measured by the Day-Night task (Reaction Time) did not have any significant correlations with Early word reading, letter-sound knowledge and RAN at Time 1. This result was the same for Time 2, when it was shown that it also does not correlate with regular, exception and nonword reading. It should be noted that this task did not involve any working memory demands. Usually, in Day-Night tasks participants are shown a picture of the sun and they have to respond night and a picture of the moon and they have to respond day. It has been argued that this paradigm requires working memory skills as the opposite of the Sun is not the word Night but the word Moon. For this reason the later version of the task was used.

The two inhibition control tasks (HTKS and Day-Night) were moderately correlated but they did not yield similar results regarding their correlation with word reading accuracy. A possible explanation could be that firstly, there were different variables measured for each task. Namely, HTKS scores reflected correct responses whereas Day-Night scores reflected reaction time. Another factor that might be responsible for the inconsistence results is the fact that in the Day-Night task the children had to give a verbal response after seeing a picture, whereas in the HTKS they were given a verbal instruction and had to respond with an action (i.e., touch their knees etc.).

Shifting of attention was measured through a dual target visual search task during which participants were required to shift their attention between two targets. It was found that False Alarms had weak to moderate correlations with Early word reading, regular word reading and phoneme awareness at Time 2. Time per Hit also correlated with Early word reading, Regular and Exception word reading and phoneme awareness at Time 2. The findings regarding shifting of attention are opposite to the pattern observed in the analysis regarding inhibition control. Namely, shifting appears to not correlate with decoding or the precursors of word reading at the very beginning of literacy development (Reception Year), but it has a relationship with lexical word reading (e.g., exception word reading) at Time 2 (Year 1).

However, the regression analysis revealed that shifting attention was not a unique concurrent nor longitudinal predictor of any of the word reading measures, but it significantly predicted phoneme awareness, at Time 2, concurrently, over and above the effects of language, age and letter-sound knowledge.

The finding regarding the predictive power of shifting on word reading accuracy is in consonance with previous studies reporting that shifting of attention is not a significant predictor of emerging literacy nor word reading accuracy in later stages (Blair & Razza, 2007; May, Rinehart, Wilding & Cornish, 2013; Kieffer, Vukovic & Berry, 2014).

In addition, the finding that shifting predicted uniquely phoneme awareness is in line with Welsh et al.'s (2010) study, who reported that attentional control (inhibition and shifting composite score) predicted concurrently and longitudinally phoneme awareness in preschool.

In summary, the findings of the current study indicate that attentional control is not a predictor of word reading accuracy but it might influence word reading development indirectly through its impact on phoneme awareness. A discussion regarding the interpretation of the results follows in the General discussion chapter (pg. 255)

Chapter 8: The attentional profile of children at risk for reading difficulties

8.1 Introduction

In the results discussed in previous chapters of this thesis (see Chapters 5-7), it has been found that various sub-components of attention have a differential impact on lexical and sub-lexical word reading. In particular, the main findings were that:

- Visual sustained attention predicted concurrently and longitudinally phoneme awareness in Year 1, even after controlling for the auto-regressor, language skills and letter-sound knowledge.
- Auditory sustained attention predicted sub-lexical word reading (nonword reading), even after controlling for language, letter-sound knowledge and phoneme awareness (but not RAN).
- Visual selective attention predicted concurrently regular and exception word reading (lexical word reading) and
- Inhibition control and shifting predicted concurrently phoneme awareness in Year 1, even after controlling for language skills and letter-sound knowledge.

As already discussed in previous chapters, there is extensive evidence regarding the co-occurrence of attentional and reading difficulties. Approximately 15-40% of children with ADHD have been reported to have co-occurring reading difficulties and vice versa (August & Garfinkel, 1990; Willcutt et al., 2005; Germano, Gagliano & Curatolo, 2010). However, there is very limited research on attentional difficulties in preschool and the first year of school, when the foundations of reading are developing (see Gooch, Hulme, Nash & Snowling, 2014). The aim of this study is to explore the attentional profiles of young children (5-6 years old) identified as showing an at risk profile for reading difficulties following their first year of instruction at school.

Children with dyslexia have been found to perform worse on measures of sustained attention (Miranda et al., 2012; Sireteanu et al., 2006) compared to a control group, as well as on cognitive measures of selective attention and inhibition control (Lima et al., 2011; 2013). However, Marzocchi, Ornagni and Barboglio (2009) found that the difference in the attention skills of a group of students (7-12 years old) with dyslexia in comparison to a control group was no longer significant after controlling for working memory and RAN of digits. It was suggested that the inattentive profile of the students with dyslexia was due to difficulties in verbal processing.

Altemeier, Abbott and Berninger (2008) suggested that children with dyslexia may have impaired executive function skills, even when performance on executive function does not predict their literacy outcomes. In their study with a group of students with dyslexia and typically developed control group (approximately 10 years old), it was found that inhibition did predict word reading accuracy in the group with dyslexia in contrast to the control group. However, it predicted rate of word reading in both groups. It was argued that the executive function skills of the children with dyslexia are below the average range and consequently they display less variance rendering the relationship between the two variables weaker. This interpretation is also supported by Berninger et al.'s (2006) findings in a study in which the executive functions (working memory, inhibition and shifting) of children with dyslexia were tested with standardized cognitive measures and it was found that they performed below the average for their age.

Per contra, van der Sluis, de Jong and van der Leij (2004) reported that native Dutch children (11 years old) with a reading fluency deficit had no impairments in their executive functions. They used control tasks for each executive task and they investigated whether the difference in the performance on the executive task versus the control task was significant compared with the control group. They found that the inhibition and shifting demands of the executive functions tasks had the same effect on both the control and the reading disabled group. Nonetheless, it should be highlighted that the control tasks used involved RAN skills. Since they were used as controls, these tasks should have minimum executive attention demands. However, as already discussed (see Chapter 2: RAN), it is unclear on what cognitive processes they tap and it has also been suggested that they might involve executive functions.

Gooch, Hulme, Nash and Snowling (2014) in a recent paper, involving preschoolers with a family risk of dyslexia, suggested that language might influence the relationship between executive functions and literacy. They found that the at risk group without a language impairment performed better in executive functions task than children at risk and with language difficulties but worse than the typically developing group. However, executive functions did not predict early literacy outcomes. It should be noted though that the term 'executive functions' was used to describe performance across a range of attention tasks, including visual selective, auditory sustained attention and inhibition control. Consequently, their results do not refer strictly to attentional control but to the composite score of the above mentioned tasks.

The majority of the studies discussed until now have used similar methods of analysis, at the group level. However, McCloskey (2001) suggested that when examining cognitive deficits and specifically in the case of dyslexia it can be more fruitful to use multiple case studies analysis, as at the group level there is a vast amount of heterogeneity. It is widely accepted that it is important to explain individual differences in reading as it will help in both the diagnosis and development of effective interventions.

Snowling (2008) conducted a series of case studies to investigate additional risk factors for reading difficulties beyond a phonological deficit. The cognitive profiles of two groups of adolescents with a family risk of dyslexia were compared - one group of 28 who were not identified with a reading difficulty when 8 years of age, and another group of 20 who did present a reading difficulty profile at 8 years of age. The family risk group with a reading difficulty showed multiple cognitive deficits (12/20) in contrast to the normal reading group who had a single deficit in either phonological skills, attention or visuospatial skills. Both groups had a high incidence of attentional difficulties (sustained and shifting composite; TEA-Ch). It was suggested that attention deficits appear to reflect comorbid impairments, since they are apparent in both at risk groups irrespective of whether or not they have a reading difficulty. However, it should be noted that in the at risk with literacy impairment group there was a higher percentage of attention difficulties. Namely, 60% of the participants had an attentional difficulty compared to 32% in the at risk with normal reading group. Snowling (2008) proposed that the at risk with literacy difficulties group has more 'diffuse difficulties', whereas the at risk with normal literacy group have selective impairments and 'may be more able to compensate' (pg. 152).

To conclude, the high comorbidity of attention and reading difficulties and the evidence from studies on reading difficulties indicate that attention might be an additional factor influencing reading development above and beyond the phonological deficit. In addition, findings of the present thesis indicate that each sub-component of attention might have a different impact on lexical and sub-lexical word reading.

Hence, the evidence from studies on reading difficulties and attention and the findings of the present thesis reported so far suggest it would be useful to closely examine the attention profiles of children in the current sample who present an at risk profile of reading delay after the first year of literacy instruction at school on the basis of their early literacy results. According to Snowling (2008), it is essential to examine whether the 'pattern of strengths and weaknesses observed at the group level holds across individuals' (pg. 150).

Hence, the aim of this final study is to explore the attentional profiles through Posner and Petersen's (1990) framework of the children showing an at risk profile for reading difficulties after one year of formal literacy instruction.

8.2 Design and Hypothesis

A series of case studies analysis was conducted in order to examine the relationship between the sub-components of attention and word reading accuracy in children identified in the current sample who present a profile of a risk for reading difficulties based on relative weaknesses in their foundation literacy skills compared to other children of the same age.

The first research aim of this study was to examine whether or not children at risk of reading difficulties exhibit a different pattern of developing attention skills relative to typically developing readers of this age.

A second aim was to examine whether any difficulties with sub-components of attention had a differential association with difficulties in lexical reading or sub-lexical reading (decoding).

Taking into account the research on attentional difficulties and reading and the findings described in previous chapters of this thesis (chapters 4-7), the hypotheses were that:

1. The at risk group would have more attentional difficulties than the control group.
2. Those with a phonological deficit would also have sustained attention (visual and auditory) and inhibition control difficulties.
3. Those with a lexical word reading deficit would also have selective attention difficulties.

8.3 Method

8.3.1 Participants

For a description of the full sample used in these analyses see Chapter 4. In brief, 77 students were re-assessed during the Spring term of Year 1.

8.3.2 Materials and Procedure

For the assessment of word reading outcomes, the DTWRP and YARC (Early word reading) were used. The DTWRP also allows us to categorize the participants in phonological recoding deficit, lexical-semantic deficit and mixed deficit groups (see Appendix 4). In brief, by examining the performance of the at risk group on the Exception Word Reading and the Nonword Reading subtests, the subject can be categorized in one of the three different kinds of profile of reading difficulties: phonological dyslexia, surface (or lexical-semantic deficit), or mixed deficit group (weak nonword and exception word reading. Scaled scores were used to identify weaknesses on either reading test. The participant’s phoneme awareness, letter-sound knowledge, RAN and language skills were also assessed.

The profile of the attention skills of this subgroup was examined, using the data from Chapters 4-7 – specifically, using the HTKS and Day-Night task (inhibition control), visual and auditory Continuous performance tasks (sustained attention), visual search and Flanker task (selective attention), and Dual Visual Search task (shifting). Teacher ratings of inattention were also examined for this subgroup from the SWAN questionnaire. For a detailed description of the above mentioned tasks see Chapter 4.

8.4 Results

8.4.1 Descriptives

The individuals for the present study were selected from the main sample of children used for this thesis (for a detailed description see Chapter 4). The criterion used to identify any children presenting a profile of a risk for reading difficulties (RD) in this sample was a Standard score below 90 on the DTWRP (below the 25th percentile) at Time 2 (Year 1). The rationale for this criterion is that it is similar to the value used by researchers studying reading difficulties (e.g., Snowling, Gallagher & Frith, 2003). Eleven out of the 74 participants were identified as being at risk of reading difficulties. The data were preliminary analyzed by examining the descriptive statistics for the at risk group (n=11) relative to the rest of the sample (n=63). Table 8.1 summarizes the mean performance scores of the group across the literacy and language measures at Time 2.

Table 8.1: Descriptives of literacy and language measures of typically developing and at risk of reading difficulties groups (Time 2)

	TD(n=63)					RD(n=11)				
	Mean (raw)	SD	CI 95%		SS	Mean (raw)	SD	CI 95%		SS
			LB	UB				LB	UB	
EWR	19.44	7.75	17.49	21.39	108.84	9.64	4.29	6.75	12.52	89.18
LSK	30.59	1.68	30.58	31	113.58	27.82	2.40	26.20	29.43	96.90
PA	17.09	3.69	16.17	18.02	107.68	13.73	4.96	10.39	17.06	94.63
RAN O.	105.37	23.80	99.21	111.51		117.20	28.20	97.02	137.37	
DTWRP	26.37	15.58	22.41	30.33	104.01	9.90	3.88	7.30	12.52	85.18
R.W.	12.29	7.38	10.41	14.16		5.00	2.28	3.47	6.53	
E.W.	7.45	6.87	5.71	9.19		.45	.93	-.17	1.08	
N.W.	6.54	1.83	6.08	7.01		4.45	1.63	3.35	5.55	
RV.	56.75	9.54	54.34	59.15	98.05	52.81	11.39	45.16	60.47	92.54
RS	31.21	10.35	28.58	33.83		27.72	17.18	16.18	39.27	

Note: TD= Typically developing group; RD= at risk of reading difficulties group; EWR= early word reading (max. 30; YARC subtest); LSK= letter-sound knowledge (max. 32; YARC subtest); PA= phoneme awareness (max. 24; YARC subtest); RAN O.= rapid naming of objects (CTOPP subtest); R.W.= regular word reading (max. 30; DTWRP subtest); E.W.= exception word reading (max. 30; DTWRP subtest); N.W.= nonword reading (max. 30; DTWRP subtest); RV= receptive vocabulary (max. =168; BPVS); RS= recalling sentences (CELF subtest)

An inspection of data in Table 8.1 was revealed that the ‘at risk’ group performed worse across all of the reading and language tasks. However, it is important to note their letter-sound knowledge (LSK) as a group was a relative strength, with a mean score of 27.82 / 32 correct.

8.4.2 Case by Case analysis

A case by case analysis followed in order to identify the participants whose raw scores in the reading and/or language measures fell more than 1 standard deviation below the mean raw of the control group (mean -1SD).

Table 8.2 presents a summary of the deficits exhibited by the participants in the ‘at risk’ of reading difficulties group. It should be noted that based on the DTWRP profiles, all participants presented a lexical-semantic difficulty; apart from cases 20 and 45, who presented a mixed difficulty profile.

Table 8.2: Literacy and language profile of at risk group

Case No.	DTWRP	EWR	LSK	PA	RAN O.	RV	RS	R.W.	E.W	N.W.
06	✓	✓					✓		✓	✓
10	✓				✓				✓	
12	✓		✓		✓					
18	✓	✓	✓	✓	✓				✓	
20	✓									✓
21	✓	✓			✓				✓	
31	✓	✓	✓	✓			✓		✓	✓
32	✓	✓		✓			✓		✓	✓
45	✓	✓	✓	✓		✓	✓	✓	✓	✓
48	✓	✓	✓	✓		✓	✓	✓	✓	✓
55	✓	✓	✓	✓				✓		✓
Total	**11**	**8**	**6**	**6**	**4**	**2**	**5**	**3**	**8**	**7**

Note: DTWRP= Composite score <90 in Diagnostic Test of word Reading Processes; Ticks indicate a deficit; EWR= early word reading; LSK= letter-sound knowledge; PA= phoneme awareness; RAN O.= rapid naming of objects; RV= receptive vocabulary; RS= recalling sentences; R.W.= regular word reading; E.W.= exception word reading; N.W.= nonword reading

Foundation literacy skills and language

The results indicate that, as expected, over 50% of children at risk of reading difficulties performed below the level of performance of that observed for the typically developing word readers, in letter-sound knowledge and phoneme awareness. Four of the 11 (36%) at risk children had difficulties with RAN of objects.

Only 2/11 (18%) children in this subgroup of at risk readers had weaknesses in receptive vocabulary relative to the rest of the sample. Almost half of the “at risk” group (5/11) performed more than 1 standard deviation below the typically developing readers in the recalling sentences sub-test of the CELF.

Word reading strategies

As already mentioned, according to the DTWRP, 9 out of the 11 participants presented a lexical-semantic difficulties profile. An inspection of Table 7.3 revealed only 3 / 11 children had difficulties with regular word reading, whereas 8 children (out of 11) had difficulties in exception word reading, and 7 with nonword reading. Two children have difficulties reading all 3 sets of words and both exception and nonwords (mixed profile); three children (/11) had difficulties on both exception and nonword reading (i.e., 5 / 11 in total with a mixed profile); 3 children (/11) had specific difficulties in exception word reading (surface dyslexia profile); 1 child (/11;) had specific difficulties in nonword reading and another had difficulties reading regular and nonwords- both had good exception word reading for their age in this sample (phonological dyslexic profile), but their level of accuracy reading exception words fell within the range of the typically developing readers in the sample.

Most of these children also had difficulties in reading exception words and nonwords accurately, whereas only 3 of the individuals in this group performed below the typically developing readers in regular word reading accuracy.

To sum up, the majority of the children in the at risk group performed 1 standard deviation below the mean score of their peers in at least 1 of the established cognitive-linguistic predictors of word reading accuracy (i.e., letter-sound knowledge, phoneme awareness and RAN). In total 5/11 of the students had an oral language deficit (taking into account both receptive vocabulary and recalling sentences subtests).

Attention Profiles

The following table summarizes the mean performance scores of the at risk readers and the typically developing group on attention measures.

Table 8.3: Descriptives of attention measures of typically developing and at risk groups

	TD				RD			
	Mean	SD	CI 95%		Mean	SD	CI 95%	
			LB	UB			LB	UB
HTKS	32.48	6.13	30.57	33.90	31	9.41	24.67	37.32
VCPT Rt	720.67	94.45	699.76	750.22	716.43	81.76	661.50	771.36
VCPT O.	3.05	2.39	2.51	3.81	3.36	3.85	2.04	4.68
VCPT C.	2.46	2.17	1.79	2.93	2.00	2.05	.62	3.37
ACPT Rt	1016.00	119.25	976.60	1040.96	1003.28	88.47	943.84	1062.71
ACPT O.	3.69	3.54	2.60	4.48	3.90	4.08	1.16	6.65
ACPT C.	3.74	2.59	3.17	4.58	4.81	1.83	3.59	6.05
Flanker	1.08	.09	1.06	1.10	1.05	.06	1.01	1.10
VSFA	4.88	3.26	4.15	5.91	5.69	3.97	3.02	8.35
VSTpH	1.71	.51	1.57	1.85	1.75	.66	1.30	2.19
VSDpH	2.70	.53	2.53	2.82	2.63	.51	2.29	2.97
DVSFA	7.68	6.80	5.92	9.44	10.82	6.69	6.32	15.31
DVSTpH	2.22	.53	2.08	2.36	2.49	.65	2.05	2.93
DVSDpH	4.81	.72	4.62	5.00	5.12	1.06	4.41	5.83
Day-Night	1.64	.40	1.54	1.74	1.64	.35	1.41	1.88
SWAN Im.	-1.51	9.00	-3.80	.77	1.36	9.12	-4.77	7.49
SWAN In.	-.74	9.05	-3.07	1.60	5.36	8.44	-.31	11.03

Note: HTKS= Head-Toes-Knees-Shoulders; VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O.= Visual Continuous Performance task Omission Errors; VCPT C.= Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors; VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; SWAN Im. = Impulsivity index in SWAN rating scale; SWAN In. = Inattention index in SWAN rating scale.

A case by case analysis followed in order to identify the participants whose scores in the attention measures were more than 1 standard deviation below the mean of the control group. Tables 8.4-8.6 present summaries of the deficits exhibited by the participants in the at risk of reading difficulties group.

Table 8.4: Sustained attention deficits for the at risk poor readers

Case No.	VCPT Rt	VCPT O.	VCPT C.	ACPT Rt	ACPT O.	ACPT C.
06					✓	
10						✓
12						
18					✓	✓
20						✓
21					✓	
31					✓	
32					✓	
45	✓				✓	
48			✓	✓	✓	
55	✓	✓			✓	
Total	**2**	**1**	**1**	**1**	**8**	**3**

Note: Ticks indicate performance 1SD below the control group; VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O.= Visual Continuous Performance task Omission Errors; VCPT C.= Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors

From Table 8.4, it can be observed that the majority of the students had a deficit in their auditory sustained attention (8/11; as measured by the omission errors in the auditory CPT task) and only 1 participant (case 55) performed below 1 SD in the visual sustained attention measure (omission errors in the visual CPT).

Table 8.5 summarizes the attentional control (inhibition and shifting) profiles of the at risk group.

Table 8.5: Attentional control deficits of the at risk group

Case No.	HTKS	Day-Night	DVSFA	DVSTpH	DVSDpH
06			✓	✓	
10					✓
12					
18			✓	✓	✓
20					✓
21					
31				✓	✓
32					
45	✓				
48	✓	✓			
55			✓		
Total	**2**	**1**	**3**	**3**	**4**

Note: Ticks indicate performance 1SD below the control group; HTKS= Head-Toes-Knees-Shoulders; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit;

Most of the participants had a deficit in one of the attentional control components (either inhibition control or shifting of attention). However, the most prevalent difficulty was in shifting (n=6), as only 2 students performed worse in the inhibition control measures.

Inspection of Table 8.6 indicates most of the at risk readers had an impairment in their selective attention, as indexed by their scores on the Visual search task. The results of the longitudinal analysis showed that performance on the Flanker uniquely predicted regular and exception word reading at Time 2 (see Chapter 5) and the at risk group had predominately a lexical reading difficulty profile (based on the profile provided by the DTWRP). Consequently, it was predicted that the majority of them would perform less well in the Flanker task. Nonetheless, only 1 child scored 1 SD below the mean of their peers.

Table 8.6: Selective attention deficits

Case No.	Flanker	VSFA	VSTpH	VSDpH
06			✓	
10				✓
12				✓
18		✓		✓
20		✓	✓	
21				
31		✓		
32				
45				
48	✓			✓
55				
Total	**1**	**3**	**2**	**4**

Note: Ticks indicate performance 1SD below the control group; VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit

Table 8.7 summarizes the attention profiles of the participants as rated by their teachers (SWAN questionnaire; see Chapter 4).

Table 8.7: Teacher rated impulsivity and attention profile[14]

Case No.	SWAN Im.	SWAN In.
06		
10		
12		
18	✓	✓
20		
21		
31		
32		
45	✓	✓
48	✓	
55		✓
Total	3	3

Note: Ticks indicate performance 1SD below the control group; SWAN Im. = Impulsivity index in SWAN rating scale; SWAN In. = Inattention index in SWAN rating scale.

There were only 3 children from this subgroup of 11 at risk readers who were rated as more impulsive than other children of their same age and 3 rated as more inattentive by their teachers. Cases 45 and 48, who were rated as impulsive by their teachers, have a profile consistent with mixed dyslexia at this age (struggling with nonwords and exception words) and also have the weakest oral language profile. Moreover, they were the only 2 cases with weaknesses on the HSKT in this subgroup.

The following table (Table 8.8) shows in which specific domain of word reading accuracy (lexical and/or decoding) and in which sub-component of attention each individual in the "at risk" group had a deficit (1 SD below their TD peers).

[14] There were 8 additional cases identified by teachers as inattentive (-1SD in SWAN compared to whole group). An examination of their profiles revealed that 6 of them had poor performance in at least one of the literacy variables (see Appendix 6).

Table 8.8: Summary of attentional profiles

Case No	**R.W.**	**E.W.**	**N.W.**	**VCPT Rt**	**VCPTO.**	**VCPT C.**	**ACPT Rt**	**ACPTO.**	**ACPT C.**	**HTKS**	**D-N**	**DVSFA**	**DVSTpH**	**DVSDpH**	**Flanker**	**VSFA**	**VSTpH**	**VSDpH**	**Imp.**	**Inat.**	***Total***
06		✓	✓					✓				✓	✓				✓				4
10		✓							✓					✓				✓			3
12																		✓			1
18		✓						✓	✓			✓	✓	✓		✓		✓	✓	✓	9
20*			✓						✓					✓		✓	✓				4
21		✓						✓													1
31		✓	✓					✓					✓	✓		✓					4
32		✓	✓					✓													1
45*	✓	✓	✓	✓				✓		✓									✓	✓	5
48	✓	✓	✓			✓	✓	✓		✓	✓				✓			✓	✓		8
55	✓		✓	✓	✓			✓				✓								✓	5

Note:*mixed reading difficulty profile (as identified by the DTWRP); All of the rest cases exhibit a lexical word reading difficulty. VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O.= Visual Continuous Performance task Omission Errors; VCPT C.= Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors; HTKS= Head-Toes-Knees-Shoulders; D-N= Day Night Reaction time; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; Imp.= Impulsivity index in SWAN rating scale; Inat.= Inattention index in SWAN rating scale

The majority of the children (8/11) had performed poorly in at least 3 different measures of attention. Out of the 8 children with a difficulty in lexical reading, 7 had a deficit in their auditory sustained attention. Also, out of the 7 children with a difficulty in nonword decoding, 6 performed poorly in at least one of the attention control measures (HTKS, Day-Night and Dual Visual Search).

Table 8.9 presents the percentages of participants in each group with a possible attentional difficulty; namely, the percentage of participants who performed 1SD below the mean of the control group. It is apparent that there was a higher percentage of inhibition control (HTKS), auditory sustained attention (ACPT), selective attention (Visual search), shifting difficulties in the at risk group. There was also a higher percentage of inattention and impulsivity as rated by teachers. The biggest difference was in the percentage of auditory sustained attention (72.72% compared to 15.15% in the control group).

Table 8.9: Percentage of participants -1SD the control mean

Task	TD %	RD %
HTKS	12.12	18.18
VCPT Rt	18.18	18.18
VCPT Om.	*13.63*	9.09
VCPT Com.	*16.66*	9.09
ACPT Rt	*16.66*	9.09
ACPT Om.	15.15	72.72
ACPT Com.	13.63	27.27
Flanker	9.09	9.09
VSFA	12.12	27.27
VSTpH	12.12	18.18
VSDpH	0	36.36
DVSFA	12.12	27.27
DVSTpH	15.15	27.27
DVSDpH	18.18	36.36
Day-Night	*19.69*	9.09
Impulsivity	10.60	27.27
Inattention	12.12	27.27

Note: TD = typically developing; RD = at risk of reading difficulty; VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O. = Visual Continuous Performance task Omission Errors; VCPT C. = Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O. = Auditory Continuous Performance task Omission Errors; ACPT C. = Auditory Continuous Performance task Commission Errors. VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; HTKS= Head-Toes-Knees-Shoulders; D-N= Day Night Reaction time; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; Imp.= Impulsivity index in SWAN rating scale; Inat.= Inattention index in SWAN rating scale

It should be noted that the control group appears to have a higher percentage of participants with a visual sustained attention and shifting (as measured by the Day-Night task) difficulty. This prompted the re-examination of the two groups.

It was observed that there were 3 cases that had a standard score above 90 in the DTWRP, but they were 1 SD below compared to their peers. Namely, their z scores in the DTWRP were below 1SD compared to their peers, but their standard scores were within the normal range. This observation supports the view that reading difficulties do not have a clear cut-off point. According to the Rose Report (2009), 'Dyslexia is best thought of as a continuum, not a distinct category, and there are no clear cut-off points'. A closer examination of the profiles of these 3 participants revealed that 2 of them had also a phonological and language skills deficit with additional attentional difficulties. Case 77, who had the lowest score in the DTWRP, appeared to have the most attentional difficulties as well. Table 10 summarizes their literacy and attention profiles.

Table 8.10: Literacy and attentional profiles of children with a SS>90 in DTWRP but -1SD compared to the control group

Case No	**R.W.**	**E.W.**	**N.W.**	**PA**	**RV**	**VCPT Rt**	**VCPT O.**	**VCPT C.**	**ACPT Rt**	**ACPT O.**	**ACPT C.**	**HTKS**	**D-N**	**DVSFA**	**DVSTpH**	**DVSDpH**	**Flanker**	**VSFA**	**VSTpH**	**VSDpH**	**Imp.**	**Inat.**	***Total***
78		✓											✓				✓						2
85	✓			✓	✓			✓								✓		✓				✓	4
77	✓	✓		✓	✓		✓	✓			✓	✓	✓	✓		✓			✓		✓		9

Note: R.W.= regular word reading; E.W.= exception word reading; N.W.= nonword reading; PA = phoneme awareness; RV = receptive vocabulary; VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O. = Visual Continuous Performance task Omission Errors; VCPT C. = Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O. = Auditory Continuous Performance task Omission Errors; ACPT C. = Auditory Continuous Performance task Commission Errors; HTKS= Head-Toes-Knees-Shoulders; D-N= Day Night Reaction time; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; Imp.= Impulsivity index in SWAN rating scale; Inat.= Inattention index in SWAN rating scale

The addition of these 3 participants in the at risk group changed the percentages of Table 8.9. Table 8.11 presents the revised results.

Table 8.11: Revised results presenting the percentage of participants -1SD the control mean

Task	TD % (n=63)	RD % (n=14)
HTKS	11.11	21.42
VCPT Rt	*19.04*	14.28
VCPT Om.	14.28	21.42
VCPT Com.	14.28	21.42
ACPT Rt	*17.46*	7.01
ACPT Om.	15.87	57.1
ACPT Com.	14.28	28.57
Flanker	7.09	21.42
VSFA	11.11	28.57
VSTpH	11.11	21.42
VSDpH	0	28.57
DVSFA	11.11	28.57
DVSTpH	15.87	21.42
DVSDpH	15.87	42.85
Day-Night	17.46	21.42
Impulsivity	9.52	28.57
Inattention	11.11	28.57

Note: HTKS= Head-Toes-Knees-Shoulders; VCPT O. = Visual Continuous Performance task Omission Errors; VCPT C. = Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O. = Auditory Continuous Performance task Omission Errors; ACPT C. = Auditory Continuous Performance task Commission Errors; VSFA= Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit

It was found that within the at risk group there was a higher percentage of participants with attentional difficulties. However, there was a higher percentage of participants in the typically developing group with high reaction times both in the visual and auditory sustained attention tasks.

8.5 Interim Discussion

The aim of this study was to explore the attentional profiles of a subgroup of the whole sample, who were identified as presenting an at risk of reading difficulties profile. In particular, the hypothesis was that the at risk group would have quantitative differences in terms of attentional difficulties compared to the control group. In addition, it was expected that decoding and phonological recoding deficits would be linked to sustained and inhibition control difficulties and lexical-semantic reading difficulties would be linked to selective attention difficulties.

In summary, there were 11 participants whose standard score in the DTWRP was below 90. Hence, there were 11 subjects in the at risk group and 66 in the control group. The literacy and attentional profile of each participant in the at risk group was compared to the control group. Performance on any task below 1SD from the control group was marked as a deficit. Also, according to the reading profiles provided by the DTWRP, 9 of the participants presented a lexical-semantic reading difficulty and 2 a mixed profile.

Six out of the 11 at risk children had a phoneme awareness deficit; six also had a letter-sound knowledge deficit; 4 performed poorly in the RAN; 5 had language difficulties (as measured by recalling sentences) and only 2 (Cases 45 & 48) had a deficit in both measures of language (receptive vocabulary and recalling sentences).

Do children at risk of reading difficulties have more attentional difficulties than their typically developing peers?

Most of the participants (8/11) performed below 1SD in the auditory sustained attention task compared to their typically developing peers but only one performed poorly in the visual sustained attention task. Also, the difference in terms of percentage of auditory sustained attention deficit between the two groups was vast; 72% in the at risk group had a deficit compared to 15% in the control group. This is in line with the view that auditory sustained attention is more important in the classroom environment, in which the children have to attend to auditory information in order to be able to follow instruction and hence spend more time in educational activities (e.g., Aywald & Brager, 2002).

In contrast with previous studies reporting inhibition control as an important predictor of literacy (e.g., Wanless et al., 2011; Blair & Razza, 2007; but see Kieffer et al., 2013), it was found that the majority of the at risk group did not exhibit an inhibition control deficit, as only 2 (Cases 45 & 48) of them performed worse that their TD peers in the HTKS and Day-Night tasks. These cases were the ones who also had poor performance in both language skills tasks. This could be an indication that they exhibit co-occurring language and attention difficulties (Snowling, 2008).In total 6 of the participants performed worse in at least one of the shifting of attention indices. The percentage of participants with an inhibition control (HTKS) difficulty was slightly higher in the at risk group compared to the control group. Finally, the percentage of the at risk participants with poor performance in shifting (Dual visual search task) was approximately double in comparison to the control group.

In addition, selective attention as measured by Flanker and the visual search task appeared to be an area of a specific weakness in comparison to the TD group. Specifically, 7/11 of the participants had a deficit in at least one of the variables measuring selective attention. Also, the percentage of participants performing worse (in the visual search task, but not in the Flanker) was much higher compared to the control group. This finding was expected based on the results discussed in Chapter 6 and Franceschini et al.'s findings (2012, 2013). Specifically, as selective attention was found to predict uniquely lexical word reading (see Chapter 6) and it has also been suggested to be impaired in students with dyslexia (Franceschini et al., 2012; Valdois, Bosse & Tainturier, 2004), it was hypothesized that the majority of students at risk of reading difficulties would also perform worse in the selective attention measures. The findings of the present multiple case by case analysis support this hypothesis.

Surprisingly, the opposite pattern was observed in performance in the visual sustained attention and the Day-Night task. Namely, there was a higher percentage of participants with an attentional deficit in the control group. This probably reflects the limitations of the criterion used in order to identify the at risk group. A closer examination of the literacy skills of the whole sample revealed that within the control group there are 3 participants with possible reading difficulties, who did not fulfill the criterion employed. Namely, their standard score in the DTWRP was within the normal range for their age but they scored 1 standard deviation below the mean of the whole sample.

A case by case analysis of their profile indicated that they showed attentional difficulties as well. If those 3 participants were removed from control group and added in the at risk group, then the percentage of participants in the at risk group with poor performance in the VCPT omission and commission errors and Day-Night task becomes higher compared to the control group.

Nonetheless, the revised results revealed that within the typically developing group there was a higher percentage of outliers in terms of reaction time in the CPTs, compared to the at risk group. This can be explained through the findings of previous research which has showed that slower RTs had a negative correlation with commission errors but a positive correlation with omission errors (Silverstein, Weinstein & Turnbull, 2004). They argued that a slower RT helps avoid responding to non-target stimuli, but might have hindered the detection of correct targets. This finding was also replicated in the present study (see Appendix 5: Tables 7 & 8).

In regards to the teacher rating of inattention measure used, only 3 of the at risk participants scored 1SD below their peers. Again, this finding is inconsistent with other studies reporting the high correlation and predictive strength of inattention as measured by rating scales in terms of reading development in preschoolers (Rabiner & Coie, 2000; Dally, 2006; Saez et al., 2012). However, there was a much higher percentage of participants in the at risk group rated as inattentive and/or impulsive.

In sum, auditory sustained attention, shifting of attention and selective attention (as indexed by the visual search task) were found to be areas of weakness in the at risk group. A very small number of participants had a deficit in inhibition control and visual sustained attention.

Are sub-lexical and/or lexical-semantic difficulties related to specific difficulties in attention?

The analysis that was conducted aimed at answering the additional question of whether difficulties in specific sub-components of attention have a different impact on lexical and sub-lexical word reading. It was found that most of the children had a lexical word reading difficulty profile (9/11; according to the DTWRP). Seven of these 8 children also had an auditory sustained attention difficulty. None of the participants in this group had a phonological recoding deficit profile (according to DTWRP) and 3 had a mixed profile (lexical and phonological recoding deficit). There was no specific pattern of attention difficulties for the mixed profile children as they showed deficits in different measures of attention. Within this group, there were no participant with a pure phonological recoding deficit (as identified by DTWRP) and consequently, it was not possible to answer the question whether decoding is associated with a specific sub-component of attention. Future research should include carefully selected groups of participants with reading difficulties representing all three kinds of profiles (lexical, sub-lexical and mixed).

However, it was feasible to examine whether the hypothesis regarding the relationship of phoneme awareness and attention was valid. Based on the results presented in chapters 5 and 7, it was expected that participants with a phonological deficit would have specific sustained attention and inhibition control difficulties. Out of the 11 participants in the at risk group, there were 6 with poor phoneme awareness skills (-1SD compared to control mean). They all had an auditory sustained attention deficit; two had a deficit in inhibition control; three in shifting; and three in selective attention. Contrary to the hypothesis, inhibition control does not appear to be a specific weakness. An interesting finding is that there appears to be a difference in the two modalities of sustained attention; with auditory sustained attention being impaired in all of the participants in this subgroup, in contrast to visual sustained attention which appears to be normal for all of the cases apart from one (case 55).

To sum up, it was shown that the majority of the children at risk of reading difficulties (specifically a lexical reading difficulty) had also a deficit in at least one of the sub-components of attention and specifically in their auditory sustained attention.

One of the limitations of this study is that the reading profile of the children (i.e., lexical vs sub-lexical reading difficulty) probably reflects the strategies used in classroom for literacy instruction. This implies that those children might not have a pure lexical deficit but that their teachers focus more on phonics instruction and not sight word reading. This indicates the need for information regarding classroom instruction/practices when researching early literacy.

In addition, the use of a single criterion for the identification of children with reading difficulties appears to be inadequate as it was shown that there were additional cases that did not fulfil this criterion but had poor reading abilities compared to their peers. Finally, the at risk group used in this study did not reflect all the sub-types of reading difficulties.

The results from this case series suggest auditory sustained may be an additional factor in reading difficulties, but it is not possible from these data to establish the direction of causality. Future research should aim at addressing all the above mentioned limitations and follow longitudinally children at risk of reading difficulties with a focus on their attentional profile and by examining separately the three sub-components of attention. The evidence from such research would enhance our understanding about the possible role of attention on reading difficulties and would provide us with information relevant to the possible causal relationship between the two. The interpretation of the results is discussed in the General discussion chapter (pg., 259).

Chapter 9: General Discussion

9.1 Research background and aims of thesis

Recently there has been a number of studies examining the possible role of attention in typical and atypical reading development. It has been reported that older children with dyslexia perform worse in tasks measuring sustained attention, selective attention and inhibition control (Sireteanu et al., 2006; Bental & Tirosh, 2007; Altemeier, Abbott & Berninger, 2008; Lima et al, 2011; 2013; Miranda et al., 2012). However, other researchers have found no significant differences in attention skills for groups of students with dyslexia relative to control groups of typically developing or skilled readers (van der Sluis, de Jong & van der Leij, 2004; Marzocchi et al., 2008; 2009) and/or have suggested that any difference is due to comorbid language difficulties (Gooch, Hulme, Nash & Snowling, 2014). Very few studies have examined the role of the different sub-components and modalities (visual and auditory) of attention as possible predictors of variation in early word reading outcomes in the same sample of children.

Similarly, the evidence from studies in typical development is inconsistent. Studies using young children (3-6 years old) have found that sustained attention predicts concurrently variation in letter knowledge and word recognition skills (Sims & Lonigan, 2013), but other studies have found that sustained attention is neither a concurrent nor a longitudinal predictor of early reading (Steele et al, 2012). Attentional control has also been reported to predict concurrently and longitudinally word reading accuracy in young children (Burrage et al., 2008; Ponitz et al., 2009; Welsh et al., 2010; Connor et al., 2010; Wanless et al., 2011). Nonetheless, other studies report contradictory results. Namely, that attentional control does not predict reading (Davidse et al., 2011; May et al., 2013; Kieffer et al., 2013). Selective attention has been reported to predict lexical and sub-lexical word reading (Plaza & Cohen, 2007; but see Shapiro et al., 2013). In addition, Marzocchi et al. (2009) argued that the attentional difficulties of students with dyslexia might be due to processing speed difficulties, especially when presented with verbal stimuli.

Finally, studies using teachers' ratings of attention report a unique relationship of inattention with reading skills and specifically suggest that inattention predicts concurrently and/or longitudinally variation in children's word reading outcomes (Rabiner & Coie, 2000; Dally, 2006; Walcott et al., 2010; Dice & Schwanenflugel, 2012; Saez et al., 2012; but see Steele et al., 2012).

The aim of the present thesis was to examine the contribution of the sub-components of attention (sustained, selective and attentional control; Posner & Petersen, 1990)to the development of different components of word reading in English (i.e., lexical and sub-lexical word reading), across the verbal and visual modalities. A second aim was to explore which components of attention (if any) are impaired in young children presenting an early profile of a risk for difficulties learning to read

The hypotheses derived from the existing evidence was that visual sustained attention will affect word reading development through its effect on letter-sound knowledge and phoneme awareness (Sims & Lonigan, 2013). The role of auditory sustained attention on word reading will be explored in this chapter, however, based on the work of Dockrell and colleagues (Shield & Dockrell, 2003; Dockrell & Shield, 2012) regarding environmental noise and academic outcomes, it is expected to have a greater influence on word reading than the visual modality (see Chapters 4 and 5 for more details). Selective attention is hypothesized to be significantly related to lexical word reading (Plaza & Cohen, 2007; see Chapter 6 for more details). The hypothesis for attentional control was that it will be an independent predictor of word reading and particularly of sub-lexical reading (Bental & Tirosh, 2007; Altmeier, Abbott & Berninger, 2008; Wanless et al., 2011; see Chapter 7 for more details). At last, it was hypothesized that children with a developmental delay in reading will also exhibit attentional difficulties (Sireteanu et al., 2006; Bental & Tirosh, 2007; Lima et al., 2011; see Chapter 8 for more details).

9.2 Are attention skills a unique predictor of variation in early word reading outcomes?

9.2.1 Sustained attention

In Chapter 5, the predictive value of visual and auditory sustained attention in lexical and sub-lexical word reading accuracy was assessed concurrently and longitudinally. Assessment of auditory attention was particularly important as it has been suggested to reflect more accurately the typical attentional skills used in a classroom environment when learning takes place (Aylward, Brager & Harper, 2002). However, no previous study has looked at both auditory and visual sustained attention and early word recognition in a sample of children at this age.

Visual sustained attention (indexed by omission errors in the visual CPT) was not found to be a significant predictor of either lexical or sub-lexical word reading. It was found to be a concurrent (Year 1) and longitudinal (Reception to Year 1) predictor of phoneme awareness, even after controlling for the autoregressor, language skills and letter-sound knowledge. The findings in regards to visual sustained attention are consistent with a previous study reporting that it has no relationship with word reading accuracy (Steele et al., 2012) as well as with a study reporting a significant relationship with PA and letter knowledge (Sims & Lonigan, 2013).There is need for further research so as to replicate the results and explore why and how this modality of sustained attention (i.e., visual) can influence the ability to identify and manipulate the individual sounds of words.

Performance on the auditory sustained attention task (omission errors in the Auditory CPT) did not predict variation in the scores across the lexical and sublexical measures of reading, after controlling for the effects of language, LKS, PA and RAN. However, auditory sustained attention was only observed to be a concurrent predictor of variation in nonword reading (i.e., sub-lexical word reading; time 2), when RAN was not entered into the regression model. This might imply that there is some overlap in cognitive mechanisms measured by the RAN tasks and auditory sustained attention (e.g., see

Stringer, Toplak &Stanovich (2004) on the relationship between RAN and attention). It has also been suggested that RAN might tap speed of processing (Kail, Hall & Caskey, 1999). Hence, the above mentioned finding could be in line with the view that processing speed (PS) mediates the relationship between attention and reading (Marzocchi, 2009; Peterson et al, 2016). Namely, RAN might have played the role of a control variable for measuring speed of processing. If PS mediates the relationship between attention and reading then, any attention tasks that involve PS are expected to predict reading performance only when RAN is excluded from the analysis. It should be reminded that auditory sustained attention was measured by the number of omission errors variable of the auditory CPT, which could be influenced by the ability to rapidly process verbal stimuli and respond accordingly.

Otherwise, RAN colours and/or objects have been reported to correlate with measures of executive functions (inhibition, shifting and working memory) and behavioural ratings of inattention (Stringer, Toplak & Stanovich, 2004). The present thesis adds more evidence in support of the view that the RAN task might also tap attentional processes, since ACPT omission errors in Time 1 correlated with performance in RAN at Time 2. There should be caution in the interpretation of this finding as an examination of the scatter plot of scores in ACPT against RAN revealed that they had a non linear relationship (R^2 *Linear*= .00). Nonetheless, it was found that their relationship could be described as quadratic with very poor and very good performance on RAN being linked with good performance in the ACPT.

It might be the case that children can perform well on the ACPT (as indexed by a low number of omission errors) due to two very different reasons. Their skills in sustaining their attention, processing information rapidly and giving a response might be very good and hence the positive relationship between RAN and omission errors. Other children might be extremely cautious in giving a response leading to less omission errors, and a slow completion time in the RAN. This is consistent with Silverstein, Weinstein & Turnbull (2004) who found that omission errors had a positive correlation with reaction times in CPTs and argued the slower reaction times of participants reflected a strategy choice to avoid false responses to non-target stimuli (i.e., trading speed over accuracy).

The second possible interpretation is that auditory sustained attention might be important only when children have processing difficulties with RAN, and subsequent deficits in the cognitive mechanisms tapped by it; but when there are no deficits in these mechanisms then auditory sustained attention has no significant effects on their performance at the behavioural level. Specifically, it is suggested that in children with poor rapid naming skills, auditory sustained attention might be further developed due to the speed of processing difficulties that these children face and hence act as a compensatory mechanism.

The findings in terms of auditory attention are novel as there had been no previous research investigating this modality and early reading acquisition. At the beginning of literacy instruction, where teaching in the classroom focuses on phonics (letter-sound knowledge, grapheme-to-phoneme correspondence rules), children need to be able to sustain their attention on the visual and auditory stimuli presented to them to effectively learn in a classroom environment, such as the ability to correctly name letters or read aloud simple letter string sequences by applying their phonic knowledge (segmenting and blending),(Aylward, Brager & Harper, 2002). The results from this thesis offer some support for this view since visual and auditory sustained attention predicted phonological decoding reading measures and/or foundation skills essential for decoding (i.e., letter-sound knowledge and phoneme awareness), but not lexical word reading.

The observation that auditory or visual sustained attention did not relate to lexical word reading might indicate that the ability to focus attention for a prolonged period of time might be important for phonic decoding strategies during the early phases of word reading development, but less important as they move to the next phase to acquire fluent sight word reading. Based on Ehri’s (1995) model of reading development, the majority of participants of this study at Time 2, had now acquired simple knowledge of letter sounds (see Table 4.6; mean score 30.17) suggesting they had moved on from the partial alphabetic to the full alphabetic phase. Their stronger nonword reading skills relative to their irregular word reading, suggested a reliance on a phonic decoding strategy. The data of this study indicate that at time 2 the word reading accuracy skills of the children had greatly improved in comparison to time 1 (p<.001, η^2=.87). In addition at time 2 there were no floor effects and there were more children who could read aloud many words accurately (60% of the words in the EWR and 26% of the words in the DTWRP; for more details see Chapter 4: Developmental changes). It could be argued that at time 2, when there is more variation in word reading, the possibility of finding associations between the variables is higher.

9.2.2 Selective attention

In Chapter 6, the role of visual selective attention was explored. It was found that it was a unique concurrent predictor of regular and exception word reading (i.e., lexical reading) in Year 1, even after controlling for LSK, PA, RAN and language.

One possible interpretation could be derived through the connectionist multi-trace model of polysyllabic word reading (Ans, Carbonnel & Valdois, 1998). In this model a visual selective attention deficit defined as a narrow Visual Attention Window (which affects the processing of the visual input) hinders lexical word processing. In line with Share's (1995) Self-teaching hypothesis, Ans et al.'s (1998) model postulates that children learn to read through two ways: (1) by being provided with the phonological correspondence of the written word and/or (2) by decoding the word themselves and consequently developing their mental lexicon. A narrow visual attention window would affect lexical word reading as the child would not be able to attend to and process all the letters in the word in a single step. A severely narrow window would also affect sub-lexical word reading as the amount of 'sublexical segments' that the child could attend to would be extremely limited.

It appears that the findings of the present study, regarding the predictive value of selective attention on lexical word reading only, is in consonance with Ans et al.'s (1998) model. It is suggested that poor performance in the visual search task as indexed by completion time might be due to a narrow visual attention window, which in turn hinders whole word processing.

The relationship between visual selective attention, lexical word reading (as found in the present study) and fluency (e.g., Leppänen et al., 2006)might indicate that selective attention is linked with orthographic processing. According to Share(1999), visual selective attention may be more important for orthographic learning and fluency measures, building on the solid foundation of phonological knowledge. Namely, it is suggested that the ability to effectively orient our visual attention to relevant stimuli, ignoring any distractors is involved in recognizing the visual pattern of a word (see Posner & Petersen, 1990 for selective attention and visual pattern recognition).

Another possible interpretation is based on Ehri's (1991, 1995) phase model of reading. The participants of the present study at time 1 (Reception Year) could be described as being in the partial alphabetic phase of their sight word reading development according to Ehri's model, as they were assessed in the Spring term of Reception Year (i.e., after one term of literacy instruction) and the data collected indicates as a group they could name on average 16/32 letter sounds, however the range of scores indicates much variation at this age (range: 2-29; see Table 4.3). Hence, children in this sample were still learning their letter sound knowledge at time 1. According to Ehri, during this phase, reading of unfamiliar words is achieved through the application of partial or full alphabetic strategy. The correlational results from this study suggest selective attention does not appear to have an impact during the partial alphabetic phase. On the other hand, at time 2 (Year 1 of school) the majority of children in the group now have a solid foundation in simple letter-sound knowledge, and their phonic decoding skills indexed by the nonword reading test (DTWRP) suggests they are developing this strategy at the appropriate rate for their age. Children will be expected to use a range of different strategies when reading aloud words, including a sight word reading strategy, as their orthographic spelling knowledge develops, and they are able to recognize some words as a whole instead of decoding each grapheme separately. It is possible that selective attention is important for children as they move from relying on a phonological reading strategy to an orthographic, sight word strategy (Ehri's full alphabetic and consolidated alphabetic phases).

In line with the Dual Route model of reading, it is suggested that during this phase of literacy development the lexical pathway is used more when reading familiar real words (regular and exception) and that children with better selective attention skills are better readers (in terms of single word reading accuracy).

An alternative explanation has been proposed by Sperling et al. (2005, 2006) who considered the visual and auditory processing deficits presented in individuals with developmental dyslexia as being related to a difficulty in external noise exclusion. In their perceptual noise exclusion hypothesis, they suggest that individuals with dyslexia may have an impairment in ignoring environmental distractors (visual and auditory) and form perceptual categories. They suggested that specifically in reading acquisition, the ability to form phonological categories may be impaired in dyslexia. Equally, Sperling et al.(2006) consider a possible early visual letter processing difficulty (abstracting the noise in variations in different fonts, letter shapes e.t.c.) may lead to insecure connections between orthographic and phoneme representations. According to Share's (1995) self teaching hypothesis, this would impair the children ability to become skilled readers. In addition, Harm and Seidenberg (1999) argued that a phonological deficit (that could be a phonological perceptual deficit as noted by Sperling et al., 2006) would be expected to not only have an impact on sub-lexical word reading, but also on lexical word reading.

Consequently, it could be argued that the association found between selective attention measures and word reading could be explained through multiple causal pathways. Hence, further research is needed in order to elucidate this relationship.

9.2.3 Attentional Control

In Chapter 7, attentional control and specifically inhibition control and shifting of attention were investigated as predictors of variation in word reading development, using the HTKS and the Day-Night tasks as measures of inhibition control and a dual target visual search task as a measure of shifting. However, none of the attentional control variables used in this study were found to be unique predictors of variation in word reading accuracy, after controlling for language, PA, LSK and RAN. However, inhibition control and shifting were predictors of variation in phoneme awareness concurrently in Year 1, even after controlling for language and LSK.

The findings from previous studies regarding attentional control (i.e., inhibition and shifting) have been inconsistent due to the differences in the age groups and the variety of tasks used. However, the present study adds to the evidence in support of the role of attentional control in phonological awareness (e.g., Welsh et al., 2010). Welsh et al. (2010) used a single factor for performance on working memory, inhibition and shifting tasks in preschool children. The findings of both Welsh et al. and the present thesis are consistent with prior research which has reported that attentional control has an impact on early literacy skills (e.g., McClelland et al., 2007; Blair & Razza, 2007). Bull and Scerif (2001) have also reported that shifting and inhibition have moderate to strong correlations with a measure of phonics and reading accuracy skills (Performance Indicators in Primary School). In line with the above mentioned studies, Bull and Scerif found that the relationship between those attentional control sub-components and reading skills declined over time (i.e., strong correlations in Year 1 to weak correlations in Year 3).

Connor et al. (2010) provided a theoretical model explaining the mechanisms through which student's inhibition control, general attention and working memory could influence their academic achievement in literacy. They proposed that students who can focus their cognitive abilities (e.g. attention and inhibition control) on the learning task might have better academic outcomes as they will be more able to ignore distractors and maximize the time spent in literacy activities and learning. This model is partly supported by the findings of this thesis, as inhibition control had statistically significant moderate correlations with early word reading accuracy.

However, the findings also reveal one major weakness of this model. That is the fact that it is silent as far as cognitive-linguistic predictors of literacy are concerned. This was clearly shown through the results of the regression analysis of the present study as inhibition control lost its significance as a predictor of word reading when vocabulary, letter sound knowledge, phoneme awareness and rapid naming were controlled. This implies the latter skills are more important in early literacy acquisition than inhibition control.

It is suggested that when children are mostly in Ehri's (1995) partial alphabetic phase of word reading, inhibition control is important for advancing into the full alphabetic phase. Namely, inhibition control is more important during the phase that children use more sub-lexical word reading strategies and are in the process of learning to read using more automatic, lexical word reading strategies (what Ehri refers to as 'sight word reading' at the full alphabetic phase in her model). This is supported by the finding that inhibition was a unique predictor of phoneme awareness but not word reading accuracy. Hence, in accordance with Connor et al. (2010), it is argued that inhibition is important in learning (see also St Clair-Thompson & Gathercole, 2006).This view is further supported by Gathercole et al. (2006) who proposed that poor executive function skills hinder children's ability to attend effectively to learning activities in the classroom and consequently they miss opportunities for learning.

It should be noted that the predictive power of attentional control on phoneme awareness reported in the present thesis cannot be attributed to the influence of working memory in general as the attentional control tasks used had limited working memory demands (e.g., Simpson & Riggs, 2005).Instead it is suggested that this relationship is specific to inhibition control and shifting skills. This is in line with Chiappie, Siegel and Hasher's (2000) suggestion that 'inefficient inhibitory mechanisms may exacerbate weak performance on phonological awareness tasks' (pg. 45). Specifically, they found that individuals with poor reading skills made more intrusion errors (indicative of poor inhibitory control) in a listening span task and also that these errors explained variance in phonological awareness.

These findings could be conceptualized through two different frameworks. Firstly, based on connectionist models of reading (e.g., 'triangle' model; Seidenberg & McClelland, 1989; Plaut et al., 1996) the written word is distributed across several elements representing its orthography, phonology and meaning, which interact through hidden units. These hidden units are responsible for learning the correct mappings between orthography, pronunciation and meaning. Hence, it is possible that attentional control is responsible for the effective activation of these hidden units by suppressing irrelevant information and responses and enabling the reader to shift their attention effectively towards the relevant information and hence read the word accurately. It is also suggested that the demands on attentional control are high at the beginning of reading development (i.e., when reading is not an automatic process yet and the reader has to make an effort in order to decode a word). In conclusion, attentional control may be an underlying cognitive process that when impaired, may constrain a child's ability to learn to read at the usual developmental rate and its influence is reflected by its relationship with phonological awareness (see also Share's (2005) self-teaching hypothesis regarding the role of PA on learning to read).

The second framework through which this finding could be interpreted is the 'pathway control hypothesis' (Rastle & Coltheart, 1999; Zevin & Balota, 2000; Reynolds & Besner, 2005), in line with the Dual route model of reading. In brief, the Dual route model suggests that there are two pathways through which reading is achieved: the lexical and sub-lexical; the pathway control hypothesis suggests that the relative activation of each pathway will be strengthened or weakened depending on the type of word that has to be read. Namely, when reading exception words, the lexical pathway will be emphasized as the correct pronunciation is not generated through the grapheme–phoneme conversion rule.

Inhen, Petersen and Schlaggar (2015) proposed a unified account (Figure 12) of the dual route model of word reading and its pathway control hypothesis, in line with Petersen and Posner's (2012) model of attention. It was suggested that attentional control is required during two different reading processes. The first is during the *pathway control* and the second during the *response checking process*. The response checking process involves the selection and verification of the correct response between the two routes.

It is important to note Inhen et al.'s (2015)account refers to adult readers. Considering the current results of the thesis, one could argue that attentional control is important when deciding which pathway will be more effective to read a word accurately, during the early phases of sight word reading development, when strategies are less automatic than later phases (see Ehri's (1995) partial and full alphabetic phases). Some evidence for this comes from the present findings of attentional control to be an independent predictors of phonological awareness which is essential in identifying whether a written word can be read through phonological decoding alone.

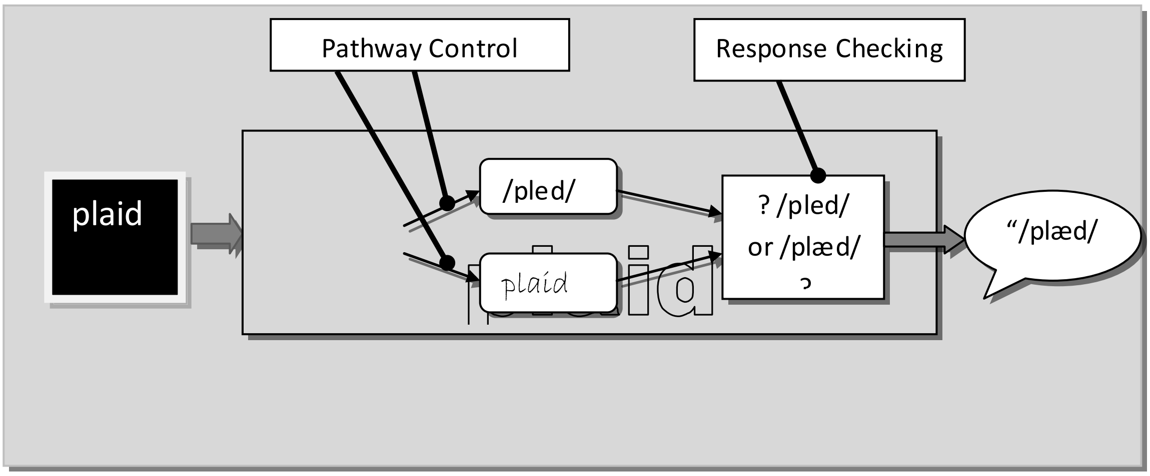

Figure 12: Mechanisms of interaction between attentional control systems and reading processing (copied from Inhen, Petersen & Schlaggar, 2015).

To conclude, it appears that attentional control might be influential during the phase of effortful word reading, when children are still learning to use strategies effectively for decoding accuracy. This has been illustrated by three separate frameworks/models (Connor et al., 2010; Triangle model, Plaut et al., 1996; Inhen, Petersen & Schlaggar, 2015). However, the evidence is still very limited and further research examining attentional control and word reading through these specific frameworks is required. Based on these frameworks a possible prediction is that inhibition control will have an impact in the process of learning GPC rules and the development of phoneme awareness. This hypothesis could be investigated through a longitudinal study which would include measures of inhibition control, phoneme awareness and new word learning (e.g., paired-associate learning).

9.3 Attentional Profiles of children at risk for reading difficulties

In Chapter 8, a case series analysis was conducted to explore the attentional profiles of a sub-group of participants identified as at risk for reading difficulties, on the basis of exhibiting a developmental delay in their early word reading acquisition, relative to other typically developing readers in the class.

A higher percentage of participants in the at risk group were observed to show a deficit (i.e.,<1SD) in each sub-component of attention, relative to the group of typically developing readers. Auditory sustained attention, visual selective attention and shifting appear to be common areas of weakness in the at risk group, with 8/11 participants presenting a deficit in at least one of these domains. In contrast, visual sustained attention and inhibition control appeared to be intact, relative to the other children in the year group.

A network of cortical areas which is responsible for visual selective attention has been suggested to be subtly impaired in individuals with dyslexia (Sireteanu et al., 2006). The behavioural findings of the present study add to that evidence as the group with a developmental delay in early word reading had relatively poor performance on the tasks of visual selective attention.

In contrast with previous studies (e.g., Snowling, 2008), the present study did not find an impairment in the language skills of the at risk group – although the children in Snowling's (2008) study had a genetic, family risk for dyslexia. It had been suggested that language plays an important role in the acquisition of word reading (e.g., Nation & Snowling, 2004; Verhoeven, van Leeuwe & Vermeer, 2011) and that it mediates the relationship between literacy (letter-sound knowledge, early word reading and letter writing) and attention (Gooch et al., 2014). The findings of the present thesis indicate that there is no relationship between the language skills measured (vocabulary and recalling sentences) and performance on the specific attention tasks and/or reading accuracy for children in this sample.

The inconsistency of the findings might be explained by the differences in the age groups and control variables (i.e., Nation & Snowling (2004) used 8.5 years old children and their control variables included rhyme awareness instead of phoneme awareness; also they did not include RAN nor letter knowledge) as well as the difference in languages (i.e., Dutch in Verhoeven et al.'s study) and the difference in the language measures used (i.e., expressive vocabulary, semantic skills and listening comprehension); hence the inclusion of a more comprehensive language measure in this thesis might have yielded different results. In addition, the difference in the findings between the present study and Snowling's (2008) case series analysis might be due to age differences in the sample (i.e., 12-13 years old students in Snowling's study), and also, their sample of children were identified as at risk on a biological basis (i.e., a family risk for dyslexia).

Taking into account the lack of association between auditory sustained attention and word reading, as reported in Chapter 5, and the findings of the case series analysis, it is suggested that impairment in this modality of attention reported in other studies, is a comorbid difficulty rather than a cause of reading difficulties when observed in older children. Performance in auditory sustained attention could be a marker of a language learning difficulty. In the present sample there were only two cases who presented a cognitive profile that would suggest a comorbid language and literacy difficulty. It might also be the case that auditory sustained attention does not have any impact on the learning of typically developing children, but only if there is a developmental delay or disorder. The current data cannot directly address either of these questions.

On the other hand, selective attention appears to have a more consistent relationship with variation in early lexical word reading attainment in this sample (i.e., delay in sight word reading) as it appears to be both a unique predictor above and beyond phonological skills and an area of weakness in children with a lexical word reading delay. This is in line with a series of studies which have focused on visual selective attention and reading (e.g., Bosse, 2007; Facoetti et al., 2009; Casco et al., 1998) and have used training of selective attention as an intervention for reading difficulties with positive results (Franceschini et al., 2013; but for a critique see Goswami, 2015).

Attentional control (specifically shifting but not inhibition) was an area of weakness for 6 out of 11 children showing delays learning to read words. As previously noted, the task used to measure shifting of attention was a dual target version of the visual search task (Visearch; Wilding, 2001), which placed demands on the ability to shift attention between two targets. Research on dyslexia and attention skills has provided some evidence consistent with the current findings. Namely, children (10-15 years old) and adults with reading difficulties have been reported to have a deficit in rapidly engaging and disengaging (i.e., shifting) their visual attention (Visser, Boden &Giaschi, 2004; Facoetti et al., 2005; Hari & Renvall, 2001). In particular, Hari et al. (1999, 2001) found that dyslexic adults were slower in processing serial visual and auditory stimuli and proposed that this is due to the fact that their attention is captured on a target for a longer duration in comparison to controls. Facoetti et al. (2008) further suggested that this phenomenon (i.e., sluggish attention shifting) could impair reading through sub-lexical mechanisms. It was proposed that ineffective engagement and disengagement of attention for each grapheme and/or groups of graphemes might explain the difficulties individuals with dyslexia have in decoding.

Menghini et al. (2010) also found that older children with dyslexia perform significantly worse in measures of visual selective attention and auditory sustained attention. They suggested that children with dyslexia show multiple impairments on cognitive domains beyond phonology. Pennington's (2006) multiple cognitive deficit hypothesis postulates that the etiology of dyslexia is multifactorial, recognizing the importance of the interactions between several risk factors (e.g., genetic and environmental factors).

The results of the present thesis highlight the importance of using multiple measures of attention in longitudinal studies. For example, if only teacher ratings or a visual CPT had been used, it would not have been possible to identify the additional attentional difficulties (e.g. difficulties in their auditory sustained attention) of the children in the at risk group. This finding has important implications for practice which will be discussed in a later section of this chapter.

9.4 Methodological considerations and limitations

The interpretation of the present findings has been hindered by the vast variability in terms of definitions of attention and measures employed by previous studies. It was clear by the studies reviewed that the broad picture on this topic suggests that attention does play a role in reading development. However, when comparing and discussing the results of the present study in light of previous studies, it is apparent that there are various fundamental differences in what is implied by using the terms: sustained, selective attention, attentional control and executive functions.

This variability in definitions has a great impact on the tasks selected to measure different components of attention. Factor analysis using multiple measures of attention have revealed that there are 3 separate but interrelated sub-components of attention (e.g., Manly et al., 2001; Breckenridge et al., 2012). However, Gooch et al. (2014) viewed attention as a unitary factor (with selective attention, sustained attention and executive functioning all loading onto one factor). It should be noted though that the later study by Gooch et al. did not include multiple measures for each sub-component of attention, and hence this might explain the difference in their results.

The present study followed a specific model of attention which has a clear operationalization for each attention sub-component (see Chapter 3 for details). Nonetheless, each measure employed still had limitations with the most important being the issue of task impurity.

In order to assess sustained attention the paradigm of the Continuous Performance task (CPT) was used as it is the most popular test for the specific subcomponent of attention in the literature. The CPTs used in the present study aimed to assess both modalities of attention (i.e., auditory and visual). The rationale for this is that firstly, auditory skills have been suggested to be particularly important in later academic outcomes (e.g., Elliott, Hammer, & Scholl, 1989; Shapiro, Hurry, Masterson, Wydell & Doctor, 2009); and at the time of the start of the study, there had been no other study examining its role in emergent word reading skills. The measure of visual sustained attention was included as there were previous studies reporting contradicting results on its role in reading (e.g., Sims & Lonigan, 2013; Steele et al., 2012).

CPTs in general have many variations in the type of stimuli used, duration, number of targets/distractors and inter-stimulus intervals. As mentioned they are intended to measure sustained attention, however, the participant also has to use their selective attention skills (as they have to select a target among distractors) and inhibition control skills (as depending on the number of the targets, the participant pressing the button can be the prepotent response). Nonetheless, the specific types of CPTs used in the present studies were designed so as to place minimum demands in selective attention and inhibition control. The stimuli were presented one after another and hence the participant did not have to search in order to select the target. Also there was a small number of targets compared to distractors and hence, giving a response did not become a pre-potent reaction that would need to be inhibited when a distractor was presented. Consequently, it is suggested that the specific CPTs (Steele et al., 2012; Gooch et al, 2013) that were used were fairly good markers of sustained attention.

Assessment of selective attention proved to be more complicated due to the tasks used in this thesis. One of the disadvantages of the visual search task (both conditions: single for selective and dual target for shifting; Visearch; Wilding, 2001) was that the participants had to identify the targets by tapping on a touch screen. It was observed (especially, at time 1/Reception Year), that there was some variation on children's motor skills, which might have affected their performance in terms of completion time. Future research should measure motor skills, to control for this, or develop alternative measures which place fewer demands on motor skills.

On the other hand, the second task used to measure selective attention in this sample, the Flanker task, did not reliably correlate with the visual search task at any time-point (see Appendix 5: Tables 7 & 8). This implies that the two measures are not tapping the same underlying cognitive skills, contrary to the assumptions when using these tasks in other studies reported in the literature (e.g., Breckenridge et al., 2012). Previous research has used the Flanker task as a measure of inhibition control (see chapter 3 for details) as the participants are requested to ignore the direction of the distractors which are more than the targets.

Consequently, the impact of motor skills and the demands on inhibition might be the reason why mean performance scores on the two tasks did not correlate. It was not possible to control for the effects of motor skills (as there were no relevant measures included) and this is one important limitation of this study. Motor skills have been reported to be significant predictors of later reading skills (Gooch et al., 2013) and hence the relationship between performance on the visual search task and reading might have been due to children's motor skills rather than the efficiency of their selective attention. In regards to the Flanker task's limitation it was possible to address it by including inhibition control tasks as control variables. The results did not change and Flanker remained a significant predictor of lexical word reading.

The measures used for attentional control also had their limitations. Both tasks have been suggested to have working memory demands as the participants have to remember a series of verbal instructions so as to provide the correct response (i.e., in the picture of sun, they have to say moon). However, in a study by Simpson and Riggs (2005) examining this limitation in the Day-Night task, it was found that performance on a working memory condition of the same tasks did not affect performance of the inhibitory condition (which was used in the present study). The demands of working memory on the HTKS were limited as the last set of trials of the task was not included. This last set had clearly high working memory demands (the participants had to remember 4 sets of instructions; they had to touch their toes when asked to touch their shoulders; their knees when asked to touch their head and vice versa).

Finally, another limitation of the present study was the lack of a general processing speed task, as it has been found that performance on attention tasks is affected by speed of processing (Marzocchi, 2009). However, it should be noted that performance on the RAN task, which was included, is influenced by speed of processing (e.g., Powell et al, 2007) and has also been suggested being an index of processing speed (Kail, Hall & Caskey, 1999).

Assessment and identification of attention difficulties

Another methodological issue arises from the use of rating scales as a marker of inattention. It was found that the inattention factor on the SWAN scale correlated with performance in the HTKS, omission errors in the VCPT, commission errors in the ACPT and all the variables of the Dual Visual search task. It should be noted that the strongest correlations were with the attentional control tasks (HTKS and Dual Visual search).

The review of the literature in Chapter 1 revealed inconsistent findings regarding the relationship between performance on experimental cognitive measures of attention and teacher ratings of inattention for individual children. Some studies have reported a significant relationship between visual CPTs and attention rating scales (e.g., Sims & Lonigan, 2013; Egeland, Johansen & Ueland, 2009), whereas others report no reliable correlations between these measures (e.g., Steele et al., 2009). The results of the present thesis replicate the findings of Sims & Lonigan (2013) who used a similar paradigm and age group (3-6 years old children) in finding that there was a weak correlation between teacher ratings of inattention and CPT performance (omission errors).

There are several reasons which could account for this inconsistency; the first being the variety of rating scales used and the differences in the parameters of the cognitive tasks. Another reason might be the differences in the sampling – for example, typically developing and/or clinical groups with ADHD/ADD, or differences in sample age across studies. Findings from the present thesis indicate that depending on the criteria and cognitive assessment measures used, the identification of specific sub-groups can vary (e.g., see Chapter 8, pg. 221, and Appendix 6). In addition, it should be noted that, according to Gathercole and Alloway (2004), teachers may perceive a child as inattentive if the child has poor working memory. A closer examination of the items included in rating scales reveals that there are items which indirectly tap on children's working memory skills (e.g., 'Follow through on instructions'). Consequently, when using rating scales, children without attention difficulties but weak working memory, might be wrongly identified as inattentive (and vice versa).

Another limitation of the present study concerns the use of a sample from a single school, which means the generalizability of the results need to be interpreted with caution. Difficulties in school recruitment most probably arose due to the time commitment expected by schools over the duration of the longitudinal study, and the large number of individually administered tests. However, the mean performance of the participants across the standardized literacy measures suggested the sample included the typical distribution of scores expected for the general population. Their performance was also comparable to that reported by other studies using similar or the same experimental tasks on this age group.

The sample size was also limited, taking into account the large number of measures/variables. This might have affected the results by weakening possible significant effects. However, in all the regression analysis conducted the number of variables was within the acceptable range in relation to the sample (i.e., at least 10 cases per variable; VanVoorhis & Morgan, 2007). Nonetheless, there is still the risk that small size effects were not detected as a larger sample would be required (Tabachnick & Fidell, 1996).

Moreover, taking into account the characteristics of the sample (low socio-economic background; see Chapter 4, pg. 78) it would have been useful to include measures of environmental factors in the analysis. As discussed it has been shown that socio-economic status and home literacy environment have a significant impact on literacy developemt (Mol & Bus, 2011; Senechal & LeFevre, 2002; Lonigan et al., 1998).

In conclusion, the main limitations of the present research were task impurity and sampling. It was attempted to address these issues as discussed in this section, however, they should been taken into account when interpreting the results.

9.5 Implications for practice

Taking into account the findings regarding selective attention and lexical word reading, and sustained attention and PA, it is important that the children demonstrating early difficulties on these sub-components of attention are identified early. It is suggested that even if these attentional difficulties are not an additional cause of reading difficulties, they might hinder learning, academic achievement, and the effectiveness of reading interventions, if appropriate adjustments to teaching, learning and assessment are absent.
Practitioners should take into account that there is a reciprocal relationship between many predictors and literacy outcomes during development. Moreover, the pattern of predictors of reading is also changing depending on the developmental stage of the child (e.g., from learning to read to reading to learn). Drawing from the Simple View of Reading framework (Hoover & Gough, 1990), it is acknowledged that children in order to become skilled readers, they must have not only good word decoding skills, but also good language comprehension skills. The importance of attention (particularly attentional control) on later stages of reading development has been highlighted by research both on reading comprehension but also on academic achievement in general (e.g., Sesma et al., 2009; Best et al., 2011). The current results are also silent to the role they may play in reading fluency, which is another characteristic of skilled reading and important for comprehension.

The findings of this thesis provide support for the view that some children who struggle with literacy learning may also have attention difficulties. There is evidence that those children who typically respond less well to otherwise effective reading intervention, are those with co-occurring attention and/or oral language difficulties (for a review see Griffiths & Stuart, 2013). Teachers should be aware of the importance of assessing attention and adjust teaching and intervention accordingly.

Also, given the relative weaknesses observed in the auditory sustained attention of some students with a reading delay and the evidence from previous studies on the importance of language on the development of literacy skills, it is suggested that teachers might need to adapt teaching strategies in relation to verbal instructions in class (Gathercole & Alloway, 2004) and focus on developing children's oral language skills before reading instruction begins (the Early Years Foundation Stage (EYFS) framework, Department of Education, 2014, already highlights the importance of the development of language and listening skills).

The findings from this thesis also have implications for the early assessment of reading. In the U.K. at the end of Year 1 all schools administer the Phonics Screening Check aiming at identifying students who might need extra phonics support. This test includes 40 regular words and nonwords and there is a specific pass threshold (i.e., 32 out of the 40 words). It has been reported that it is a valid and sensitive measure of phoneme awareness (Duff et al., 2014). However, based on the results of this thesis it appears that using a single measure of reading might not be effective in identifying all the students with a mild reading difficulty; also the Phonics Screening Check in particular is not effective in identifying students with a lexical word reading difficulty as it does not include exception words in contrast to the Diagnostic Test of Word Reading Processes (developed by the Forum for Research in Literacy and Language, 2012) which was used in the present thesis.

Nonetheless, it should be taken into account that even though this thesis aimed to address some of the gaps in the literature review, there is still need for further research, especially longitudinal, which would replicate the present results. Studies following a cohort of children over a longer period of time and examining the role of attention skills as foundations and predictors of later reading outcomes, including measures of fluency, spelling and reading comprehension, would possibly enhance our understanding. The above mentioned implications might be premature given the limited number of studies which have looked at the development of attention and reading.

In conclusion, the findings of this thesis have important implications for both the early identification of literacy learning and attentional difficulties, and in the development of effective reading interventions for struggling readers, but further research is required to examine the robustness of the present results.

9.6 Conclusions and Future directions

This thesis provides some limited evidence that visual sustained attention may affect sub-lexical word reading through its impact on PA and auditory sustained attention is more influential when acquiring emergent literacy skills.. It was also suggested that the relationship between sustained attention and foundation literacy skill might be mediated by speed of processing (Peterson et al., 2016)

In addition, although the present findings are correlational, they provide some support for theories suggesting a possible causal link between weaknesses in selective attention and orthographic learning – beyond the alphabetic phase of sight word reading development. It was also suggested that the findings may be in line with the perceptual noise exclusion theory (Sperling et al., 2006). However, the methodological limitations discussed earlier (e.g. possible impact of motor skills on performance on the visual search task) suggest caution when interpreting the current set of findings.

Attentional control is suggested to affect word reading during the early stages of reading development either by enabling the reader to suppress distractors and shift their attention effectively to relevant stimuli or by allowing them to choose which pathway is more appropriate when reading a word (see Inhen et al., 2015) Finally, the findings from the case study analysis suggest that children identified in this study with a developmental delay in early word reading (relative to the other children in their class) present a profile of weaknesses in the auditory modality of sustained attention, in selective attention and shifting. These findings are in line with the hypothesis that children with delayed development of foundation reading skills have a greater risk for co-occurring attentional difficulties (for a review see Germano, Gagliano & Curatolo, 2010).Although, it is important to note the arbitrary cutoffs used to identify this group of children, at least two children in the sample showed a profile of relatively consistent difficulties across the measures of language, attention and foundation literacy skills. This finding could indicate that language might mediate the relationship between attention and word reading (Gooch et al., 2014).

The results presented indicate that, even though foundation literacy skills (i.e., letter-sound knowledge and phonemic awareness) are the strongest predictors of word reading accuracy (Chapter 4: Part 2; see also Caravolas et al, 2012), attention is also an independent predictor of lexical and/or sub-lexical word reading. It was also shown that attentional difficulties are prevalent amongst children with a reading delay. In consonance with Pennington's (2006) proposal for a multiple deficit model of developmental disorders, it is suggested that it might be useful to examine the development of reading through a multifactorial framework, recognizing that there may be multiple risk and protective factors which interact and alter the development of cognitive skills. Through this model, it is also acknowledged that identification of reading or attentional difficulties is arbitrary, as discussed in the present thesis (see Chapter 8). Further research is needed to better understand the attentional profiles of children with lexical and/or sub-lexical reading difficulties, but the results from this thesis make a clear contribution to this literature.

Issues that have arisen from this thesis and should be considered for future research include:

1. There is a need for a clear definition of attention and operalization of each sub-component of attention in developmental studies, which will aid the selection and/or development of reliable and relatively pure measures.
2. Teacher ratings of inattention should be included in assessments but results should be interpreted with caution as there is the risk of identification of children with working memory deficits as inattentive and/or impulsive; equally, children with attention difficulties may not be necessarily identified through a rating scale.

3. Both modalities of attention (auditory and visual) should be explored in relation to their possible differential developmental trajectories and impact on domain specific cognitive skills.
4. The relationship between RAN and the sub-components of attention should be examined more closely.

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Appendices

Appendix 1

Table 1: Predictive value of visual sustained attention in Reception on nonword reading in Year 1 after controlling for vocabulary

Model		B	SE B	Beta
Step 1				
	(Constant)	3.94	.732	
	Vocabulary	-.01	.018	-.04
	Literacy	.11	.016	.68***
Step 2				
	(Constant)	4.67	.99	
	Vocabulary	-.01	.02	-.08
	Literacy	.11	.02	.66***
	VCPTOm.	-.07	.07	-.11

Note: R^2= .44 for Step 1, ΔR^2= .01 for Step 2 (p=.29). ***p<.001

Table 2: Predictive value of auditory sustained attention in Reception on nonword reading in Year 1 after controlling for vocabulary

Model		B	SE B	Beta
Step 1				
	(Constant)	3.53	.73	
	Vocabulary	.00	.02	.01
	Literacy	.11	.02	.68***
Step 2				
	(Constant)	4.43	.86	
	Vocabulary	-.00	.02	-.00
	Literacy	.10	.02	.63***
	ACPTOm.	-.08	.04	-.18

Note: R^2= .48 for Step 1, ΔR^2= .03 for Step 2 (p=.06). ***p<.001

Appendix 2

Table 3: Predictive value of auditory sustained attention on phonological awareness in Reception Year after controlling for vocabulary

Model		B	SE B	Beta
Step 1				
	(Constant)	-7.68	2.40	
	Vocabulary	.34	.05	.63***
Step 2				
	(Constant)	-4.17	2.75	
	Vocabulary	.32	.05	.58***
	ACPTOm.	-.32	.13	-.22*

Note: R^2= .40 for Step 1, ΔR^2= .05 for Step 2 (p=.05). ***p<.001, *p<.05

Table 4: Predictive value of auditory sustained attention on letter-sound knowledge in Reception Year after controlling for vocabulary

Model		B	SE B	Beta
Step 1				
	(Constant)	6.79	3.29	
	Vocabulary	.20	.07	.33**
Step 2				
	(Constant)	10.94	3.80	
	Vocabulary	.17	.07	.28**
	ACPTOm.	-.37	.18	-.23*

Note: R^2= .11 for Step 1, ΔR^2= .05 for Step 2 (p=.04). **p<.01, *p<.05

Appendix 3

Table 5: Predictive value of Flanker on Regular word reading in Year 1, after controlling for language, LSK, PA, RAN and HTKS.

Model	B	SE B	Beta
Step 1			
(Constant)	-29.04	12.41	
Language	.07	.04	.18
LSK	.93	.41	.25*
PA	.67	.22	.36**
RAN O.	-.05	.03	-.16
Step 2			
(Constant)	-13.13	13.18	
Language	.09	.04	.22*
LSK	1.06	.39	.28**
PA	.53	.22	.29*
RAN O.	-.03	.03	-.11
HTKS	-.00	.11	-.00
Flanker	-18.87	6.90	-.24**

Note: R^2= .52 for Step 1, ΔR^2= .05 for Step 2 (p=.03). **p<.01, *p<.05

Table 6: Predictive value of Flanker on Regular word reading in Year 1, after controlling for language, LSK, PA, RAN and Day-Night.

Model	B	SE B	Beta
Step 1			
(Constant)	-29.86	12.59	
Language	.07	.04	.19
LSK	.95	.41	.25*
PA	.65	.23	.35**
RAN O.	-.04	.03	-.15
Step 2			
(Constant)	-16.77	14.35	
Language	.09	.04	.24*
LSK	1.22	.40	.33**
PA	.47	.22	.26*
RAN O.	-.04	.03	-.13
Day-Night	2.93	1.64	.16
Flanker	-23.70	7.71	-.26**

Note: R^2= .52 for Step 1, ΔR^2= .07 for Step 2 (p=.01). **p<.01, *p<.05

Appendix 4

In order to categorize the sample in terms of the profile of reading difficulties that they exhibit, the instructions of the DTWRP test were followed. In particular, a comparison of the Stanine scores in the Exception Word Reading and Nonword Reading subtests can reveal three different kinds of profile of reading difficulties: Lexical-Semantic profile, indicating relative difficulty in developing lexical-semantic processes; a Phonological profile, indicating a relative difficulty in developing phonological processes; a Mixed profile, indicating difficulty in developing both sets of processes

Figure 1: Example of Reading difficulties profile table adapted from the DTWRP (Forum for Research in Literacy and Language, 2012).

	Nonword reading stanine score				
Exception word reading stanine score		1	2	3	4
	1	M	M	L-S	L-S
	2	M	M	M	L-S
	3	P	M	M	L-S
	4	P	P	M	M

Appendix 5

Table 7: Inter-correlations of attention measures at Time 1

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Flanker**	1													
2	**D-N**	-.08	1												
3	**HTKS**	-.05	-.31**	1											
4	**VCPT RT**	-.14	.09	-.15	1										
5	**VCPT C.**	.06	-.05	-.05	-.17	1									
6	**VCPT O.**	-.03	.27*	-.45**	.38**	-.05	1								
7	**ACPT RT.**	-.03	.12	-.02	.34**	-.06	.25*	1							
8	**ACPT C.**	-.14	-.09	-.02	.04	-.03	.20	-.03	1						
9	**ACPT O.**	-.07	.27*	-.36**	.17	.16	.42**	.18	.19	1					
10	**VSFA**	.12	.23*	-.24*	.03	.01	.06	-.04	.03	-.00	1				
11	**VSDpH**	-.02	.22	-.14	-.10	-.01	.08	-.15	-.14	.06	.20	1			
12	**VSTpH**	-.03	.02	-.15	.04	-.06	.01	.00	-.25*	-.10	.19	.49**	1		
13	**DVSFA**	-.09	.24*	-.36**	.19	.14	.34**	.04	.01	.23	.45**	.16	.05	1	
14	**DVSDpH**	-.14	.23*	-.26*	.21	-.09	.24*	.00	-.18	.15	.21	.18	.19	.60**	1
15	**DVSTpH**	-.09	.15	-.31**	.29**	-.07	.25*	.29*	-.08	.16	.36**	.12	.38**	.64**	.53**

Note: ***p*<.01; **p*<.05; see note in Table 8 for an explanation of abbreviations

Table 8: Inter-correlations of attention measures at Time 2

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**HTKS**	1														
2	**VCPTRt**	-.00	1													
3	**VCPTO.**	-.18	.58**	1												
4	**VCPTC.**	-.19	-.11	.16	1											
5	**ACPTRt**	.01	-.04	.01	.11	1										
6	**ACPTO.**	-.23*	.01	.20	.09	.36**	1									
7	**ACPTC.**	-.18	.29*	.30**	.29*	.00	.03	1								
8	**Flanker**	-.02	.13	.10	.11	.18	.26*	-.06	1							
9	**VSFA**	.01	.03	.04	.12	.12	-.10	-.01	-.00	1						
10	**VSTpH**	.10	.15	.17	.06	.09	-.08	-.10	-.07	.13	1					
11	**VSDpH**	-.12	-.13	-.24*	.00	-.12	-.13	.12	.04	.15	-.53**	1				
12	**DVSFA**	-.21	-.06	.21	.09	.09	.16	.08	.00	.37**	.07	.12	1			
13	**DVSTpH**	-.10	.00	.00	-.01	-.16	-.06	.24*	-.03	.46**	-.03	.27*	.44**	1		
14	**DVSDpH**	-.19	.04	.07	.03	.15	-.03	.26*	-.08	.33**	.03	.35**	.64**	.61**	1	
15	**D-N**	-.11	.03	.16	.14	.38**	.23*	.02	.13	.04	.12	-.14	.10	-.09	.02	1

Note: ***p*<.01; **p*<.05; HTKS= Head-Toes-Knees-Shoulders; VCPT Rt= Visual Continuous Performance task Reaction time (msecs); VCPT O.= Visual Continuous Performance task Omission Errors; VCPT C.= Visual Continuous Performance task Commission Errors; ACPT Rt= Auditory Continuous Performance task Reaction Time (msecs); ACPT O.= Auditory Continuous Performance task Omission Errors; ACPT C.= Auditory Continuous Performance task Commission Errors; VSFA=

Visual Search False Alarms; VSDpH= Visual Search Distance per Hit; VSTpH= Visual Search Time per Hit; DVSFA= Dual Visual Search False Alarms; DVSTpH= Dual Visual Search Time per Hit; DVSDpH= Dual Visual Search Distance per Hit; D-N= Day-Night task reaction time.

Appendix 6

Table 9: Attentional Profiles of children identified as inattentive by their teachers

Case No	BPVS	PA	LSK	DTWRP	EWR	N.W.	R.W.	E.W.	CELF	VCPT Rt	VCPT O.	VCPT C.	ACPT Rt	ACPT O.	ACPT C.	HTKS	D-N	DVSFA	DVSTpH	DVSDpH	Flanker	VSFA	VSTpH	VSDpH
65		✓						✓**								✓								
07															✓				✓					
85		✓			✓*	✓	✓	✓**						✓	✓			✓						
52								✓**						✓							✓		✓	
50	✓																	✓	✓	✓		✓		
64			✓		✓	✓				✓														
38						✓					✓				✓									
74	✓	✓			✓			✓**			✓	✓			✓	✓	✓	✓	✓	✓			✓	

Note: *: *z-score*= -.98; **: *z-score*= -.94

It was found that 6/8 participants had poor performance in at least one of the literacy measures, but their standard score and/or z-score in the DTWRP composite were not sufficient in identifying them as at risk of a reading delay. In addition, all of the participants had also poor performance in at least one attention measure. Five out of 8 children had a deficit in their auditory attention. It should be noted that case 74 appears to have multiple deficits in the majority of the literacy, language and attention tasks, even if he/she was not identified as at risk of a reading difficulty. This finding is not directly relevant to the research questions of this thesis, however, it indicates that as discussed single measures of literacy and/or attention might be not effective in identifying all the students at risk of literacy and/or attentional difficulties.

Appendix 7

Ethics Application Form: Research Degree Students

All student research that use research methods to collect data from human participants is required to gain ethical approval before starting. Please answer all relevant questions. Your form may be returned if incomplete. Please write your responses in terms that can be understood by a lay person.

For further support and guidance please see Ethics Review Procedures for Student Research http://www.ioe.ac.uk/about/policiesProcedures/42253.html, contact your supervisor or researchethics@ioe.ac.uk.

	Section 1 Project details	
a.	Project title	The relationship between the development of attention and reading skills.
b.	Student name	Emmanouela Chatzispyridou
c.	Supervisor	Dr Yvonne Griffiths
d.	Advisory committee members	Prof Jackie Masterson, Dr Julie Radford, Dr Chloë Marshall
e.	Department	Psychology and Human Development
f.	Faculty	Policy and Society
g.	Intended research start date	01/2014
h.	Intended research end date	03/2014
i.	Funder (if applicable)	
j.	Funding confirmed?	
k.	Country fieldwork will be conducted in *If research to be conducted abroad please check www.fco.gov.uk If the FCO advice against travel a full travel risk assessment form should also be completed and submitted: http://intranet.ioe.ad/ioe/cms/get.asp?cid=14460&14460_0=22640*	U.K.
l.	All research projects at the Institute of Education are required to specify a professional code of ethics according to which the research will be conducted. Which organisation's research code will be used?	BPS
m.	*If your research is based in another institution then you may be required to submit your research to that institution's ethics review process. If your research involves patients recruited through the NHS then you will need to apply for ethics approval through an NHS Local Research Ethics Committee. In either of these cases, you don't need ethics approval from the Institute of Education.*	
	Has this project been considered by another (external) Research Ethics Committee?	Yes ☐ No ☐ ⇨ *go to Section 2*
	If so, please insert the name of the committee, the date on which the project was considered, and attach the approval letter in either hard or electronic format with this form.	

Department of Psychology and Human Development

Faculty of Policy and Society, Institute of Education

25 Woburn Square, London WC1H OAA

Research Study Information Sheet

Attention and Early Reading Development

December 2012

In partnership with the Institute of Education, your child's school has agreed to take part in a research project that is studying the relationship between attention and early reading development. We would like to invite your child to be involved in the project. We very much hope you would like to take part, but before you decide, it is important that you understand why the study is being done and what it will involve. This information sheet tells you about our work and we hope it will be useful. After reading this information sheet, please explain the project to your child and discuss whether they want to take part. We will also ask the children if they are happy to do the tasks during the sessions and make it clear that they can stop at any time.

Who is conducting this project?

The project is organized by Emmanouela Chatzispyridou, PhD student at the Institute of Education, under the supervision of Dr Yvonne Griffiths. Dr Griffiths conducts research on reading and spelling development and difficulties. Please feel free to contact Emma by email on echatzispyridou@ioe.ac.uk or by telephone on 07423 068652 if you have any questions. Emma and Yvonne have certificates to show they have undertaken recent police checks (CRB) to work with children for research purposes in schools.

Why is this work being done?

We are interested in the relationship between attention and early reading development in typically developing and children with a risk of dyslexia. There has been very little research in this area for the specific age group (5-7 year old children) and we are hoping that this study will help us better understand why some children struggle to learn to read and to inform teaching for such pupils.

Who will be in the project?

We will choose approximately 80 children aged 5 years (Reception Year) from several schools for the study. They will be picked at random from the register.

What will happen if my child takes part?

A researcher would come to see your child at school for three sessions lasting for approximately 20-30 minutes each. In these sessions we will look at different aspects of attention and early reading skills. For example, children will be presented with a picture of a dog and will have to respond with the word cat and vice versa. We will stop if the tasks become too difficult. Any tasks involving spoken responses will be audio-recorded. The same tests will be administered 12 months later (when the child will be at the beginning of Year 1).

What will happen to the results of the project?

The information we collect is kept strictly confidential. Children are identified by a code number only. Your child's school will be informed about the outcome of the research.

Do I have to take part?

It is up to you whether or not you and your child want to take part. At the end of this information sheet there is a form for you to sign if you wish to give consent for your child to take part. Anyone who signs a form is still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect your child's education in any way.

What should I do next?

If you would NOT like your child to take part in this study, please fill in the enclosed form and return it to your child's class teacher by **11/01/13.** If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

Emmanouela Chatzispyridou (Student Researcher)

Department of Psychology and Human Development

Faculty of Child and Health, Institute of Education

25 Woburn Square, London WC1H OAA

Tel. 07423068652 Email echatzispyridou@ioe.ac.uk

This study is undertaken as part of the PhD in Psychology and Human Development by the Institute of Education and has been reviewed and approved by the Faculty Research Ethics Committee.

Thank you for reading this information sheet.

Department of Psychology and Human Development
Faculty of Child and Health, Institute of Education
25 Woburn Square, London WC1H OAA

Leading education and social research
Institute of Education
University of London

Opt Out form

Attention skills and early reading development

January 2013

Parent copy - Please complete this copy and return it to your child's teacher by **Monday 14th January 2013.**

I have read the information sheet about the research. ☐ (please tick)

I **DO NOT** give permission for my child to take part in the study ☐ (please tick)

Name of child:_____________________ _______________________
(Forename) (Surname)

Date of Birth:____________ **School**:___________________________________

Home address:____

Post code ________________

Name of parent/guardian (please print):____

Signature: _________________________________ **Today's date:**________________

Department of Psychology and Human Development
Faculty of Policy and Society, Institute of Education
25 Woburn Square, London WC1H OAA

Leading education and social research
Institute of Education University of London

Research Study Information Sheet

Attention and Early Reading Development

January 2014

In partnership with the Institute of Education, your child's school has agreed to take part in a research project that is studying the relationship between attention and early reading development. We would like to invite your child to be involved in the project. We very much hope you would like to take part, but before you decide, it is important that you understand why the study is being done and what it will involve. This information sheet tells you about our work and we hope it will be useful. After reading this information sheet, please explain the project to your child and discuss whether they want to take part. We will also ask the children if they are happy to do the tasks during the sessions and make it clear that they can stop at any time.

Who is conducting this project?

The project is organised by Emmanouela Chatzispyridou, PhD student at the Institute of Education, under the supervision of Dr Yvonne Griffiths. Dr Griffiths conducts research on reading and spelling development and difficulties. Please feel free to contact Emma by email on echatzispyridou@ioe.ac.uk or by telephone on 07423 068652 if you have any questions. Emma and Yvonne have certificates to show they have undertaken recent police checks (CRB) to work with children for research purposes in schools.

Why is this work being done?

We are interested in the relationship between attention and early reading development in typically developing and children with a risk of dyslexia. There has been very little research in this area for the specific age group (5-7 year old children) and we are hoping that this study will help us better understand why some children struggle to learn to read and to inform teaching for such pupils.

Who will be in the project?

The children that were tested last year when they were in Reception Year.

What will happen if my child takes part?

A researcher would come to see your child at school for four sessions lasting for approximately 20 minutes each. In these sessions we will look at different aspects of attention and early reading skills. For example, children will be presented with a picture of a dog and will have to respond with the word cat and vice versa. We will stop if the tasks become too difficult. Any tasks involving spoken responses will be audio-recorded.

What will happen to the results of the project?

The information we collect is kept strictly confidential. Children are identified by a code number only. Your child's school will be informed about the outcome of the research.

Do I have to take part?

It is up to you whether or not you and your child want to take part. At the end of this information sheet there is a form for you to sign if you wish to give consent for your child to take part. Anyone who signs a form is still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect your child's education in any way.

What should I do next?

If you would NOT like your child to take part in this study, please fill in the enclosed form and return it to your child's class teacher by **13/01/14.** If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

Emmanouela Chatzispyridou (Student Researcher)

Department of Psychology and Human Development

Faculty of Child and Health, Institute of Education

25 Woburn Square, London WC1H OAA

Tel. 07423068652 Email echatzispyridou@ioe.ac.uk

This study is undertaken as part of the PhD in Psychology and Human Development by the Institute of Education and has been reviewed and approved by the Faculty Research Ethics Committee.

Thank you for reading this information sheet.

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25 Woburn Square, London WC1H OAA

Opt Out form

Attention skills and early reading development

January 2014

Parent copy - Please complete this copy and return it to your child's teacher by **Monday 13th January 2014.**

I have read the information sheet about the research. ☐(please tick)

I **DO NOT** give permission for my child to take part in the study ☐(please tick)

Name of child:____________________ ______________________
(Forename) (Surname)

Date of Birth:____________ **School**:_____________________________________

Home address:____

____ **Post code** _________________

Name of parent/guardian (please print):____

Signature: ____ **Today's date:**_________________