Phonological and semantic processes in children aged 8-9 years with different types of developmental dyslexia

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I, Silvia Roncoli, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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ABSTRACT

The locus of naming impairment in dyslexic children has been attributed to difficulty in retrieving the phonological representations of words due to a phonological deficit, but none of the studies reviewed included an independent assessment of dyslexics' phonological abilities. Moreover, recent research indicates that dyslexia is not a homogeneous disorder and that there can be different underlying causes. A deficit in phonological processes has been associated with developmental phonological dyslexia. Conversely, individuals with developmental surface dyslexia are generally reported to have unimpaired phonology, and there appear to be different cognitive loci of impairment, of which semantics is one of the possible sources. On the basis of this evidence, the phonological deficit hypothesis of naming problems in dyslexic children was revisited, and investigation of naming in relation to different reading profiles was undertaken. The picture naming paradigm was employed to investigate possible naming deficits and to examine relationships with measures of semantics and phonology, and, in turn, their connection to reading in 35 dyslexic children aged 8-9 years. Furthermore, 122 typically developing (TD) children aged 4 to 9 were assessed with the aim of providing a context within which to interpret the results of the dyslexic children. Standardised and newly developed tasks of naming, phonology and semantics, were employed. Dyslexic children were assigned to subtypes on the basis of nonword and irregular word reading. Overall, results indicated that a naming and phonological deficit was apparent in the sample of dyslexic children when compared to age-matched controls, but naming accuracy was in line with that of reading age controls. However, only the children classified as having a primary sublexical reading deficit were identified as having a naming and phonological deficit. The findings are consistent with the view that classifying developmental reading difficulties is crucial in order to identify underlying deficits.

CONTENTS

List of Tables

LIST OF FIGURES

CHAPTER I. Reading Models

I.1. Introduction

In *The Science of Reading*, Snowling and Hulme (2005) state that word recognition is the basis for reading and that all the other processes depend on this mechanism. The apparently simple process of recognising a word subtends several, intensively investigated, yet not fully understood, cognitive mechanisms. These mechanisms include letter identification, graphemes-to-phonemes translation, access to the phonological lexicon, semantic knowledge and the link between semantic knowledge and the phonological lexicon. Both reading and naming share cognitive processes, including the selection of a word from the semantic store, retrieval of the phonological code and, finally, the articulation of the word itself (see Johnson, Paivio, & Clark, 1996; Levelt, 1992; 1996; 1999; 2001; Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1998). Indeed, neuroimaging studies with adult readers have suggested that reading and object naming involve close or overlapping neural circuits (DeLeon et al., 2007; McCrory, Mechelli, Frith, & Price, 2004; Murtha, Chertkow, Beauregard, & Evans, 1999).

The study of word recognition and picture naming has a long history in the area of experimental psychology. In the past two centuries, Cattell (1886) stated that the time taken to name a letter or word was shorter than the one taken to name a picture because for words and letters the "association between the idea and the name has taken place so often that the process has become automatic, whereas in the case of colours and pictures we must by a voluntary effort choose the name" (p. 65). The historical interest in reading and naming and the cognitive processes underpinning these two, apparently straightforward, activities have motivated many studies, especially in the field of acquired language disorders.

However, reading does not represent a straightforward process for everyone since there are individuals who, in the absence of neurological disorders and despite a genuine interest in reading and a clear effort to engage with this activity, still experience significant reading difficulties.

Dyslexia is primarily identified through problems in literacy but there is increasing evidence for other problems in language of children with dyslexia, including inaccurate retrieval of words demonstrated, for example, in poor performance in picture naming. The presence of naming difficulties in children with developmental reading impairments has motivated research investigating the nature of the problem and the development of hypotheses concerning the cause or causes of the naming difficulties. Developmental dyslexia has often been explained in terms of a difficulty in establishing phonological representations. However, increasing evidence indicates that children with literacy problems do not form a homogeneous group. Based on recent evidence regarding the possible factors underlying reading difficulty, this research aimed to revisit the well-established phonological deficit hypothesis of naming problems in children with reading difficulties and to investigate the naming profiles in relation to different reading profiles. Moreover, the naming abilities of typically developing (TD) children of different ages were investigated with the aim of providing a context that would aid in understanding how naming skills develop in both TD children and those with reading difficulties.

In the following chapter, two influential theoretical models of reading and reading development will be outlined in order to provide a framework for understanding the processes involved in reading. A description of normal reading processes allows for determining the potential locus of the failure when a child experiences reading difficulties. The cognitive processes thought to underpin reading and reading development are then discussed in order to provide the framework for the examination of the cognitive profile of children with reading difficulty that I carried out in the research for this thesis. Studies examining the naming abilities of dyslexic children are reviewed, followed by a description of the picture naming paradigm as it is one of the best-studied paradigms in language production research.

Dyslexia: A working definition

This section begins with a brief discussion of the term dyslexia. A recent debate has again opened the discussion about the meaningfulness of this diagnostic category (Elliott & Gibbs, 2008; Elliott & Grigorenko, 2014; Ramus, 2014). It is beyond the scope of this work to discuss the validity of this term but it is important to delineate a working definition, which will motivate the selection criteria for the participants in this study.

Developmental dyslexia (DD) is a specific disability in learning to read adequately despite at least normal intelligence, adequate instruction and socio-cultural opportunities, and the absence of sensory defects in vision and hearing (DSM-IV - American Psychiatric Association, 1994). The DSM-IV is a classification system with a global influence on how the disorder is diagnosed. However, because the definition is based on the medical system, its use in the educational field is controversial. The new DSM-V (American Psychiatric Association, 2013) offered a change in how reading disorder is defined, although itself not immune to criticism (Snowling, 2012).

Another international definition of dyslexia, which has been adopted in several published studies (e.g., Silani, 2005; Landerl et al., 2012; Ramus & Ahissar, 2012; Richlan, 2012; Pacheco et al., 2014), is the one given by the World Health Organization (2008). Specific reading disorder [1] is defined as "specific and significant impairment in the development of reading skills, which is not solely accounted for by mental age, visual acuity problems, or inadequate schooling. Reading comprehension skill, reading word recognition, oral reading skill, and performance of tasks requiring reading may all be affected (…)" (ICD-10 Classification of Mental and Behavioural Disorders, Clinical description and diagnostic guidelines, WHO).

In a review of provision for children and young people with dyslexia and reading difficulties commissioned by the UK government (Rose, 2009) the definition given is "Dyslexia is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling. Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed (…)" (p. 9). This definition goes beyond those previously described, in that it conceptualises the existence of a cognitive profile associated with the reading difficulty and implies that the same reading behaviour pattern (i.e., a difficulty in reading acquisition) might be caused by different cognitive impairments.

Despite the numerous definitions of dyslexia[2], all of them emphasise a specific and persistent unexplained reading problem. There is a crucial difference between the

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[1] In the ICD-10 the term "Specific Reading Disorder" instead of "Dyslexia" is used.

[2] Snowling (2000) defined dyslexia as a problem with word decoding, which in turn impact spelling performance and the developmental of reading fluency, in absence of cognitive, neurological, educational or psychological limitations. According to the International Dyslexia Associations,

definition provided by Rose Review (2009) and the one given by the ICD-10, in that the latter requires a discrepancy between actual reading attainment and the reading ability predicted by a child's IQ (for a definition of dyslexia in terms of discrepancy between reading attainment and general intelligence, see also Zoubrinetzky, Bielle, & Valdois, 2014). However, studies (e.g., before McArthur et al. 2013, but see also Colker et al. 2012; Snowling, 2012), have indicated that the reading difficulties experienced by children whose reading is discrepant from their level of intelligence do not differ from those found in children with low general attainment (children who were labelled 'garden variety poor readers' in the past, see Ellis, McDougall, & Monk, 1996; McDougall & Ellis, 1994; Stanovich, 1988; Swan & Goswami, 1997). The consequence of this is that more children with low general cognitive ability will be classified as dyslexic. This is likely to have important consequences, especially in terms of providing effective reading interventions (Russell & Pavelk, 2013).

The dyslexic children who participated in the research reported in this thesis were selected according to the specificity of their reading difficulties and the absence of other factors. These factors included having English as second language, general cognitive impairment, exposure to social or educational deprivation, sensory or motor impairment, and other documented developmental or neurological conditions. The selection criteria used in studies of dyslexia is highly likely to have an impact on the findings, and this has been discussed in several papers (e.g., Peterson & Pennington, 2012; Rutter & Maughan, 2005; Snowling, 2012b).

Whether dyslexia can be diagnosed only in the presence of average or above average nonverbal ability is again beyond the scope of this thesis. However, in the attempt to understand how reading difficulties can be specifically impaired, it is logical to study children whose reading impairment is as specific as possible (i.e., in this context, cannot be explained by general cognitive impairment).

I.2. Models of reading development

The process of young pre-literate children turning the pages of books while "reading

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dyslexia consists of "difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction" (Fletcher, 2009).

aloud" supported by the pictures they are looking at, could be considered a primitive reading attempt, in that they extract meaning from pictorial representations. The evidence that humans in a literate culture learn to speak before starting to read and write suggests that reading skill involves mapping spoken language onto written language (Pollatsek, Rayner, & Lee, 2000). Essentially, the processing of learning to read involves integrating a system for processing written language with the system, already established, for processing spoken language (Snowling, 2000). Evidence of a synergy between reading and language is also supported by neuroimaging studies: for example, studies by Price (2012) indicated that reading ability is mediated by the same cerebral regions involved in spoken language processing. Since the focus of this dissertation is on the link between reading ability and disability and picture naming, in this section the most significant models of reading aloud will be discussed.

A number of models have been proposed to understand how reading is acquired in children. One of the most influential is the stage model proposed by Frith (1985; 1986). According to Frith, children start to read words by recognising partial cues. For example, a child may read the word *yellow* correctly because it contains 'two sticks' (Stuart & Coltheart, 1988), or by recognising the first letter. Their reading errors derive from words the children know, and they may mis-read words of the same length as the target ones. Also, reading errors often share features of the target (e.g., a child might read *yellow* as "pull" because it contains two sticks). In a revision of Frith's theory, Morton (1989) proposed that children in the logographic stage recognise words in the same way as they recognise pictures, through the direct activation of the semantic system[3] (Morton, 1989).

According to Frith's model, the alphabetic stage starts when the child is motivated by the desire to write. This stage depends on parsing of the printed word into components and on learning the rules to convert phonemes into graphemes. In this phase, the child acquires an explicit knowledge of phonemes, their correspondences with letters, and how to merge phonemes into words. Alphabetic skills seem to develop first in spelling and then the same skills are transferred into reading when the child attempts to read novel words. This stage is characterised by

[3] In his elaboration of the information-processing model, Morton (1989) proposed that the logographic recognition units map directly onto object semantics rather than verbal semantics. For the purpose of the present work, no distinction will be made between verbal and picture semantics, but the general term 'semantics' will be used instead.

dissociations between reading and spelling. Sometimes children are able to decode sounds into letters, but the decoding could be at a phonetic level (e.g., writing "U" instead of *you*, "R" instead of *are*) (Read, 1971) and they might encounter difficulties in reading what they have written. At this stage, a child might be able to spell regular words correctly (alphabetically) but they might not be able to recognise them and yet, they might be able to recognise logographically 'tricky' words such as *who* but not be able to spell them accurately.

As alphabetic reading ability develops and semantic knowledge increases, children come to be able to instantly recognise parts of words (e.g., morphemes) and become fluent readers (the orthographic stage), while they may remain in the alphabetic stage in terms of writing.

Despite the criticisms of Frith's model, such as lack of clarity regarding the passage between stages, a typical problem for stage models, the framework is useful for several reasons. First, the model hypothesises that in order to become a fluent reader, a child needs to establish a good sight vocabulary at the logographic phase, develop a good phonological awareness [4] (at the alphabetic stage) and precise orthographic representations. Additionally, the model explains developmental dyslexia as an arrest in the typical developmental process of reading and hypothesises different types of dyslexia according to the different steps in reading acquisition.

If there are possible multiple loci of impairment (i.e., multiple possible explanations for an arrest in the typical development process of reading), it follows that the same difficulty in reading (expressed at behavioural level) might be mediated by different mechanisms at the cognitive level (for a discussion of delay versus deviance see Thomas, Annaz, Ansari, & Scerif, 2009). Subtypes of acquired dyslexia were first identified in adult skilled readers after having sustained brain damage. The existence of double dissociations in neuropsychology provided strong evidence for the argument that fluent English readers use two separate routes for reading aloud, a lexical and a sublexical route, providing the basis for a dual-route framework[5]. Two most prominent theoretical models of reading are presented next.

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[4] For a comprehensive review of the "phonological awareness" theoretical construct, see Castles and Coltheart (2004).

[5] For a recent discussion about the validity of applying the cognitive neuropsychological approach to developmental disorders see Castles, Kohnen, Nickels and Brock (2014), but also Bishop (1997).

I.3. Cognitive Models of reading

One of the influential theoretical frameworks in the field of skilled reading and reading disorders is the Dual Route (DR) model (Coltheart, 1978; 1980) which proposes two mechanisms: a sublexical or phonological pathway and a lexical or semantic pathway. These are depicted in Figure 1.

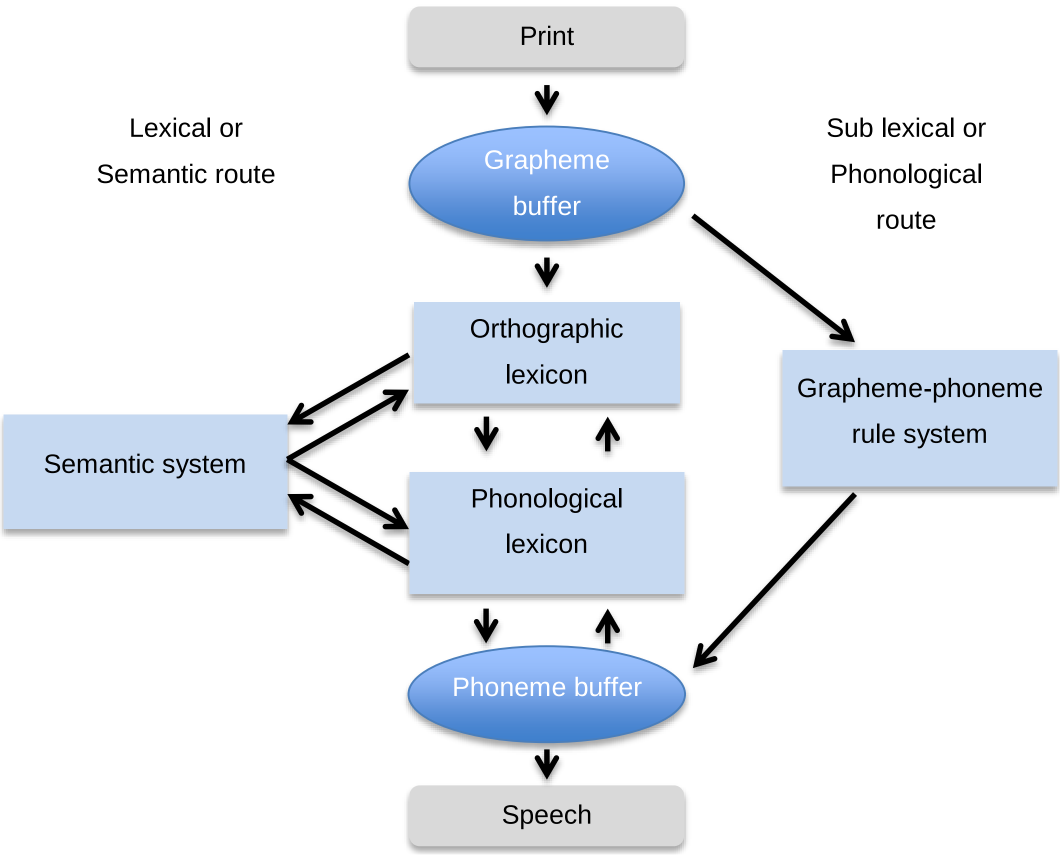


Figure I.1 Schematic representation of the Dual-Route model of single word reading (redrawn from Ziegler, Perry, & Coltheart, 2000)

The sublexical/phonological route operates in a serial and sequential way by transforming letters or letter clusters (graphemes) into sounds (phonemes) through the application of spelling-sound correspondence rules. These rules support effective pronunciation of novel or made-up words such as *mave* or *rint*. On the contrary, application of the rules to exception words (e.g., have or pint) would result in reading errors (e.g., *have* > /heIv/, *pint* > /pInt/). Exception words need a word-specific store where information about their pronunciation is accessed. The development of both routes will be necessary in order to become a proficient reader in English. The existence of a theoretical model describing the mechanisms involved in reading provides for the description of reading profile that may occur after impairment to one or both reading routes.

Predictions about the reading profiles resulting from damage to the reading routes can be made. A dysfunction specific to the nonlexical route would lead to impairment in nonword reading, but performance on familiar words could be unimpaired, as these words can still be processed by the lexical route. Lexicalisations are the typical errors characterising this profile; nonwords are read as real words (e.g., *brinth* read as "bright"). This pattern of performance has indeed been observed after brain damage (e.g., Beauvois & Derouesné, 1979; Berndt, Haendiges, Mitchum, & Wayland, 1996), and is known as acquired phonological dyslexia. Furthermore, the lexical route is required to read irregular words.

A selective impairment in the lexical route in adult readers will lead to poor performance on irregular words relative to regular words and nonwords. Typical errors of this profile are regularisations, where it appears as if the irregular word has been read by applying grapheme-to-phoneme conversion rules (e.g., *pint* > /pInt). Again, this pattern has been observed following brain damage (e.g., Marshall & Newcombe, 1973; Coltheart, 1981; Patterson, 1981; Shallice, 1981) and the profile is known as acquired surface dyslexia. Marshall (1984) proposed that the Dual Route model could also be used as a model of reading development and that it is possible to find cases of developmental dyslexia analogous to those described in the acquired dyslexia. Evidence for developmental analogues came from single cases studies of children with impairments of either nonword reading (e.g., Temple & Marshall, 1983; Campbell & Butterworth, 1985; Broom & Doctor, 1995a; Snowling, Stackhouse, & Rack, 1986) or irregular word reading (e.g., Coltheart, Masterson, Byng, Prior, & Riddoch, 1983; Broom & Doctor, 1995b; Hanley, Hastie, & Kay, 1992). These patterns of reading difficulty were also corroborated by group studies (e.g., Castles & Coltheart, 1993; Genard et al., 1998; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; Manis, Seidenberg, Stallings, & Joanisse, 1999).

It has been argued that a connectionist approach is better able to explain the development of reading skill than the static Dual Route framework (e.g., Plaut, McClelland, & Seidenberg, 1996). Connectionist models simulate the patterns of processing in the human brain: cognitive processes are represented by interaction (synapses) among a large number of units (like neurons) which are the basic information processing structures. Each unit is associated to a weight, which can be either positive or negative (inhibitory/excitatory synapses). Units are organized in layers, usually one group encodes the input and another encodes the response to that input. The layer between input and output - called the hidden units - constitutes the internal learning layer. In the connectionist or 'triangle' model (Plaut et al., 1996; Plaut, 1997) there is no distinction between the lexical and sublexical route: orthographic, phonological and semantic information are connected by means of hidden units mediating between inputs and outputs in word reading, and words and nonwords are all read by a single mechanism.

The phonological pathway consists of connections between representations of phonological and orthographic information, while the semantic one consists of mapping between phonological, semantic and orthographic representations. In their computational simulation, the balance between the two pathways changes with training: early in training, the resources are focused in establishing connections between phonology and orthography; however, later in training, the semantic pathway becomes more important for the computation of words with inconsistent correspondence between orthography and phonology. This has been interpreted as akin to normal reading development, from the early phase where mappings between letters and sounds need to be established until the later phase where the contribution of the orthography-semantics component increase (Seidenberg, 2005).

Based on the triangle model (Seidenberg & McClelland, 1989), Harm and Seidenberg (1999) developed a new connectionist model to simulate the development of normal reading as well as developmental reading disorders. The model had an orthographic input layer connected, through hidden units, to an output phonological layer. Each unit in the output layer was connected to a layer of clean-up units that were connected back to the output layer in order to help the model to settle in a more stable output state. This means that the output layer acted as a set of phonological attractor units, in that they could learn similarities among phonemes and maintain a stable phonological representation of the words (Thomas & Karmiloff-Smith, 2002; Monaghan & Ellis, 2010).

Once the model had learnt adequately, they damaged the network in different ways. The aim was to simulate phonological and surface dyslexia. Based on the evidence that phonological dyslexia is caused by a phonological processing deficit, Harm and Seidenberg (1999) damaged the phonological system through weight decay (by applying a factor close to 0) for the phonetic units and by removing the clean-up units. They found that both types of damage cause a difficulty in learning to read nonwords but exception word reading was also affected once the impairment was severe, leading to a prevalence of mixed cases in comparison to pure phonological cases. The evidence in the literature on children with pure phonological dyslexia (Campbell & Butterworth, 1985; Snowling et al., 1986; Broom & Doctor, 1995a) was one of the critiques of the Harm and Seidenberg connectionist model.

Regarding the modelling of surface dyslexia, Harm and Seidenberg argued that it reflects a 'general delay' rather than a selective impairment. They argued that the reading profile of children with surface dyslexia resembles that of younger children, in that in the early stage of reading acquisition, children are poorer at reading exception words than simple nonwords. This pattern was created in the model by lesioning the network in several ways. According to the authors, this evidence might be relevant to understand the variety of reading profiles among these children. They provided less training and they also reduced the number of hidden units. The results indicated that, early in training, exception words were more affected than nonwords but later in training both exception words and nonwords were impaired. Harm & Seidenberg explained the results suggesting that difficulty of dyslexic children in reading irregular words might be explained by an 'impoverished reading experience'. Yet, single case studies have described pure cases of surface dyslexia in which exception word reading was impaired despite normal nonword reading (Coltheart et al., 1983; Broom & Doctor, 1995b; Hanley et al., 1992; Romani, Ward, & Olson, 1999). It seems that the simulations did not fit well with the behavioural data and this was the most serious concern raised against the model (Coltheart, 2005).

Although the two models might seem different, nevertheless they have common characteristics: both models include two pathways that are activated simultaneously by printed words; one pathway is the phonological route or the connection between phonology and orthography in the connectionist model, and the other is the lexical route, or the connection between phonology, orthography and semantics. Yet, both models suggest that the lexical pathway, or the semantic pathway in the connectionist model, is important for irregular word reading[6]. The Dual Route model will be used in this study as a theoretical framework for studying the reading profile of the dyslexic children.

In 1979 Singer (Vellutino, 1979) wrote of Vellutino's verbal deficit hypothesis of dyslexia "Consequently, Vellutino's claim that a single skill deficit, a verbal deficiency, accounts for reading failure contradicts experimental evidence pertaining to the analysis of isolated words and ignores the complexity of the reading process. We should expect instead that poor readers comprise a heterogeneous group with individuals failing to read for a variety of reasons" (p. 125). Singer's view of developmental dyslexia as being caused by different potential underlying difficulties has been corroborated by numerous studies in recent years. In the next chapter the methodological implications of the different methods used to subgroup dyslexic children will be presented and discussed.

I.4. Subtyping of Reading Disorder

In the previous section we saw that early evidence for developmental analogues of acquired phonological and surface dyslexia came from single case studies of children who showed differential impairment on either nonword or exception word reading. For example, Temple and Marshall (1983) described the case of HM, a 17 year old with a reading age of 10 years, despite normal intelligence. She was unable to read long nonwords or long regular words that she was unfamiliar with. She frequently made lexicalization errors (for example, HM read the nonword *fime* as the word "firm"). These results led Temple and Marshall (1983) to conclude that HM's dyslexia could be explained in terms of a Dual Route model, specifically as a selective deficit to the sublexical route – developmental phonological dyslexia.

Evidence for the converse pattern of impairment that corresponds to acquired surface dyslexia was also found. Coltheart et al. (1983) were the first to describe such

[6] The computational model of reading aloud Dual Route Cascaded (DRC) (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) includes a direct lexical reading route that maps between the orthographic input lexicon to the phonological output lexicon, bypassing the semantic system. If this route exists, it means that a severe impairment of semantic memory in the absence of any other impairment will leave reading of irregular words intact, a profile consistent with semantic impairment without surface dyslexia (Blazely, Coltheart, & Casey, 2005). This profile would be compatible with the DRC connectionist model but not with the triangle model, in that a disruption to the semantic pathway would leave inevitably irregular word reading impaired.

a case. Their participant, CD, had a chronological age of 15 at the beginning of the study and a reading age of 11;0. She performed more poorly on irregular words than regular and produced many errors in spelling and reading that were phonically based (e.g., *come* was read as "comb"). The authors compared CD's reading profile to that of a participant with acquired dyslexia. Coltheart et al. (1983) concluded that developmental surface dyslexia also exists as a distinct clinical entity. Further studies presented similar results including for example, Broom and Doctor (1995b), Hanley et al. (1992), Judica, Luca and Spinelli (2002), and Romani et al. (1999).

The case study approach has provided important evidence for the components of the reading system and for the existence of subtypes of developmental dyslexia. It has been argued that the case study approach is the optimal neuropsychological technique for investigating the organization of the cognitive system (Shallice, 1979), however, it does not provide information about all aspects of developmental dyslexia (for example the relative rate of the different subtypes).

Group study methodology has been used to address these concerns, and different methods of identifying subtypes have been employed. A widely used method is to compare the dyslexic children with a chronological age[7] matched group of children on measures assessing their ability to read nonwords and irregular words. Castles and Coltheart (1993) used this method. Their study involved a sample of 53 children with reading ages at least 18 months behind their chronological ages, whilst falling within the normal IQ range for their age. These participants, along with 56 normal controls, were presented with a reading test consisting of 30 nonwords, 30 irregular words and 30 regular words for reading aloud. In analyzing the results Castles and Coltheart introduced the regression-outlier method. This identifies children who are below age level in only nonword reading or only exception word reading, as well as children with "relative" phonological or surface dyslexia. These relative cases are below age level in both processes, but one process is more impaired than expected based on the other. Castles and Coltheart reported that most of their dyslexic sample fitted either the phonological or surface subtype profile. 75% of participants showed relative poor irregular word reading and 72% relative poor nonword reading. 19% showed a pure surface profile, falling below the lower

[7] For a discussion about the employment of chronological-age and reading-age control groups, see for example Ellis et al. (1996); Snowling (2000); Thomas et al. (2009).

confidence interval of control group performance for irregular word reading but within the limits for nonword reading. Vice versa, 15% of the participants showed a pure phonological profile. These results therefore confirmed that the subtypes of developmental dyslexia could be found in large samples of dyslexic participants.

A study by Manis, Seidenberg, Doi, McBride-Chang and Peterson (1996) confirmed these results. Their sample comprised 51 dyslexics aged 12 years together with 51 chronological age matched children and 27 reading age matched controls aged 8 years. Children were asked to read 48 single syllable nonwords (e.g., *feap*, *peef*) and 45 exception words (e.g., *island*, *sword*). Manis et al. (1996) identified pure cases of surface and phonological dyslexia using cut-off scores based on the chronological age group mean and standard deviations. Using a stringent criterion (they adopted a cutoff of 1 standard deviation below the control average on a task and normal performance on the other), they found 5 (9.8%) children having a low score in nonword reading and 5 (9.8%) a low score in exception word reading. Following Castles and Coltheart (1993), Manis et al. (1996) used the regression-outlier method using a 90% confidence interval (CI) (instead of 95% as used in Castles & Coltheart's study) and they found that 17 cases had a lower nonword reading score relative to exception word reading when they used the confidence interval for the chronological age group, and 15 were below the confidence interval in exception word reading relative to nonword reading.

When Manis at al. (1996) compared the performance of dyslexics children on exception words and nonwords using the confidence interval for the reading age control group, they found that 12 out of 17 children identified as having phonological dyslexia fell below the confidence interval for the young comparison group while only 1 child out of the 15 with surface dyslexia fell below the CI for the reading age control group. This led the authors to conclude that the profile specific to surface dyslexia is typical for a certain level of reading and that surface dyslexia could be due to an underlying deficit causing a general delay in the acquisition of reading skills, in line with the connectionist model of Harm and Seidenberg (1999).

Not all researchers agreed on the usefulness of characterizing developmental reading disorders in Dual Route terms and, more importantly, many criticisms have been raised claiming that developmental surface dyslexia may simply reflect delayed reading and that characterizing it in terms of the Dual Route model might not be informative (e.g., Bryant & Impey, 1986; Murphy & Pollatsek, 1994; Snowling, Bryant, & Hulme, 1996).

Recently, a novel method for constituting control groups in studies of surface and phonological dyslexia has been proposed by Wybrow and Hanley (2015). These authors argued that it is inappropriate to use a reading age control group where group membership is on the basis of word reading performance on standardized reading tests. This is because such tests consist of irregular and regular words and lead to the selection of controls with similar irregular word reading ability as surface dyslexics, making it unlikely that this subtype will be identified in the sample of dyslexics. Wybrow and Hanley advocated a method whereby dyslexics and controls are matched on nonword reading accuracy to investigate the incidence of surface dyslexia and, conversely, on irregular word reading accuracy to investigate the incidence of phonological dyslexia. In their own study using this method, Wybrow and Hanley identified 5 out of 41 dyslexic children with relative surface dyslexia and 7/41 dyslexics with relative phonological dyslexia, indicating that the incidence of phonological and surface dyslexia is similar if appropriate comparisons groups are used. The findings argue against the use of reading age controls to compare dyslexics (see also McDougall & Ellis, 1994) and confirm that poor irregular word reading in developmental dyslexics reflects a specific reading disorder rather than a general reading delay.

McArthur et al. (2013) compared different methods of classifying the dyslexic children into surface and phonological subtypes. Because of the importance of this issue to the present study, the findings of McArthur et al. will be outlined in some detail next. McArthur et al. aimed to investigate literacy-related deficits associated with surface and phonological dyslexic profiles in children. They recruited a sample of 138 children with developmental reading difficulties. The criteria to be included in the study were a) no history of neurological or sensory impairment, investigated through a background questionnaire, b) English as a first language at school and at home, and c) a score of at least 1 standard deviation below the age group mean on a nonword reading test. They did not exclude children on the basis of low IQ on the grounds that intelligence is not a predictor of reading ability and on the evidence that the percentage of children classified as phonological, surface and mixed dyslexic did not differ, regardless of their nonverbal IQ score. Chronological age-matched controls were children who scored within one standard deviation of their age group mean on the Castles and Coltheart reading test (CC2, 2009). The CC2 reading test comprised 40 nonwords, 40 irregular words and 40 regular words. Raw scores were converted into *z* scores on the basis of the scores of the normative sample.

McArthur et al. (2013) needed to classify the dyslexic children into those with lexical deficits, those with sublexical deficits and those with a mixed pattern, in order to look at cognitive impairments associated with the different reading profiles, however, they noted that there were no standard criteria, and that studies have used diverse methods. They therefore employed five different sets of criteria, four of which had been used in previous studies, using standard *z* scores calculated on the performance of age-matched control children. The schemes are reported in Figure I.1. The classification schemas differ in the cut-off *z* score used and in the ability to identify a clear gap between lexical and sublexical reading ability. McArthur et al. compared the effect these had on the percentage of children identified with the different profiles. They found that Classification 1, 4 and 5 identified a similar percentage of children with a sublexical primary impairment (12, 9 and 16%) and lexical primary impairment (19, 17 and 10%). Classification 2 identified a similar percentage of children with sublexical and lexical impairment (23% and 20%, respectively) and Classification 3, which used a more stringent criterion, identified 5% of children with primary sublexical impairment and 4% with primary lexical impairment, with a higher percentage (40%) of children classified as mixed impairment. McArthur et al. chose to adopt Classification 5 on the grounds that a) it did not much differ from Classification 1 and 4 in terms of the percentage of children classified as having a primary sublexical and lexical impairment, b) it provided a clear gap between lexical and sublexical reading impairment and c) it produced a substantial group of children in order to perform statistical analyses.

In summary, it seems that there is no substantial difference between the classification schemas used to identify children with a sublexical and lexical reading impairment (Classifications 1, 4 and 5). Classifications 2 and 3 differed from the others, in that they used extreme cut-off points: Classification 2 used a lenient cut-off point (< -1 *z* score), while, on the contrary, Classification 3 adopted a very stringent criterion, which was designated to select very pure cases of phonological (i.e., poor nonword reading only) and surface dyslexia (i.e., poor lexical reading only).

Although the imbalance between primary lexical and sublexical impairment is assumed to fall along a continuum, with pure phonological and surface dyslexia cases allocated at the extremes, it seems important to use discrete reading categories. This would provide not only important information about the development of the cognitive architecture for single word reading (Castles, Bates, & Coltheart, 2006), but it would also help in the endeavor of identifying the most frequent cognitive profiles associated with each type of reading disorder (e.g., Menghini et al., 2010; Moll, Loff, & Snowling, 2013; Park & Lombardino, 2013; Pennington, Cardoso-Martins, Green, & Lefly, 2001; Peterson, Pennington, & Olson, 2013; Sprenger-Charolles, Siegel, Jiménez, & Ziegler, 2011; Ziegler et al., 2008). In addition, and importantly, it would allow for targeted reading interventions focused on the specific cognitive difficulty (or difficulties).

Having established that there are different patterns of developmental dyslexia, attention is now turned to the cognitive processes that might be associated with different reading profiles. As reading is a relatively new cultural invention, it is thought that the brain has not developed specialized neural systems specific for reading. What is thought to be more likely is that some general cognitive mechanisms (which have their counterpart in distinct cerebral areas) have become progressively adapted to the reading process during learning to read (Cohen, Lehéricy, Chochon, Lemer, & Rivaud, 2002; Price & Devlin, 2003). In the next section cognitive processes that are expected to be involved in particular reading skills are reviewed.

Table I.1 Classification schema for subtyping developmental dyslexics adopted by McArthur et al. (2013)

Author	Schema in McArthur et al. (2013)	Criteria for surface dyslexia	Criteria for phonological dyslexia	Criteria for mixed dyslexia
Castles & Coltheart (1993)	1	Irregular word reading z score < -1.64 SD or lower & nonword z score > -1.64 SD	Nonword reading z score < -1.64 SD or lower & irregular word reading z score > -1.64 SD	Nonword and irregular word reading z scores equal to -1.64 SD or lower
Sprenger-Charolles, Colé, Lacert, & Serniclaes (2000)	2	Irregular word reading z score < -1 SD or lower & nonword z score > -1 SD	Nonword reading z score < -1 SD or lower & irregular word reading z score > -1 SD	Nonword and irregular word reading z scores equal to -1 SD or lower
Castles & Coltheart (1993)	3	Irregular word reading z score < -1.64 SD or lower & nonword z score > -1 SD or higher	Nonword reading z score < -1.64 SD or lower & irregular word reading z score > -1 SD or higher	Nonword reading z scores equal to -1.64 SD or lower & irregular word reading z score of – 1 SD or lower and vice versa
Edwards & Hogben (2011)	4	Irregular word reading z score ≤ -1.64 SD, at least 0.5 SD lower than nonword reading	Nonword reading score ≤ -1.64 SD, at least 0.5 SD lower than irregular word reading	Nonword reading z scores < -1.64 SD & irregular word reading z score less than 0.5 SD higher or vice versa
McArthur et al. (2013)	5	Irregular word reading z score ≤ -1.3 SD or lower & nonword z score > -1 SD or higher	Nonword reading z score ≤ -1.3 SD or lower & irregular word reading z score > -1 SD or higher	Both nonword reading & irregular word reading z scores ≤ -1.3 SD

CHAPTER II. Cognitive process underlying development dyslexia

II.1. The phonological deficit hypothesis

The evidence that poor readers have difficulties in identifying and synthesizing verbal information for their storage and retrieval posed the basis for the seminal work of Vellutino and the dyslexia verbal-deficit hypothesis (Vellutino, 1977). Subsequent research, including reports of dyslexics with no evidence of verbal or phonological difficulties, have run counter to the hypothesis.

The hypothesis that all dyslexics had a verbal deficit appeared to be too general, as this cannot explain the heterogeneity of reading difficulties (Castles & Friedmann, 2014). Nevertheless, the large body of evidence that the difficulties shown by dyslexic people affected a range of tasks requiring phonological processing, has led to the proposal that dyslexia is due to a *core phonological deficit* (Stanovich, 1986). One of the major arguments in favor of a central role of phonology in decoding printed words is that language is primarily oral and that humans are biologically programmed to speak and understand spoken language, while reading and writing are relatively recent cultural inventions. Since humans are biologically programmed to encode sequences of speech sounds, it has been suggested that the sound code is the 'glue' that holds the mental representation of a word together (Share, 1999). When acquiring language, one of the early processes is assigning a meaning to a specific combination of sounds. The forms of these sound sequences are the phonological representations of the words. Over the course of language acquisition, thousands of phonological representations must be stored to allow accurate recognition across different speakers, accurate production, and later, the development of orthographic connections. Phonology is one of the components of the linguistic system (together with semantics, morphology and syntax); and phonemes are the smallest finite linguistic units that can change the meaning of a word within a language. Phonemes do not have a meaning *per se*, but they acquire it in the context of a word.

For decades the underlying difficulty in dyslexia has been explained in terms of verbal theories alone: terms such as "imprecise phonological representations"; "inaccurate phonological representations" and "poorly specified phonological representations" have been used (for a review see Caylak, 2010). It has been argued that dyslexics have a deficit at the level of underlying phonological representations which can emerge either in tasks requiring implicit access to phonology, as in the case of phonological processing, or explicit access to phonology, as in the case of phonological awareness tasks (Snowling, 2000). The phonological deficit appears to be more evident in tasks tapping phonological output (e.g., naming) rather than phonological input (e.g., speech perception) processes[8] (Hulme & Snowling, 2009).

In this section, studies showing the phonological deficit as the primary cause of dyslexia will be presented. In particular, phonological awareness, nonword repetition, short-term memory and naming will be reviewed as they represent the most widely used procedures to assess children's phonological abilities.

II.1.1. Phonological awareness

Phonological awareness is defined as the ability to manipulate and make explicit judgments on words' sounds. Many researchers in the field of dyslexia have argued that there is a causal connection between dyslexic children's phonological awareness deficits and their reading difficulties (e.g., Goswami & Bryant, 1990; Høien, Lundberg, Stanovich, & Bjaalid, 1995; Wagner et al., 1997; Messer & Dockrell, 2006; Melby-Lervåg & Lervåg, 2012). In particular, evidence supporting a causal relationship comes from studies showing that training phonological awareness improves reading (e.g., Schneider, Küspert, Roth, & Visé, 1997, but see also Schneider, Roth, & Ennemoser, 2000 for the combined effect of letter-sound knowledge and phonological awareness trainings).

The manipulation of phonemes in particular (as assessed in, for example, blending tasks) has been reported to be a predictor of early reading acquisition (Høien et al., 1995). A large number of developmental studies have suggested that children develop awareness of syllables and onset and rimes prior to an awareness of phonemes (e.g., Lonigan, Burgess, & Anthony, 2000) and that phonemic awareness might depend on reading acquisition (e.g., Wagner, Torgesen, & Rashotte, 1994; Wagner et al., 1997; Swan & Goswami, 1997b; Metsala, 1999; Goswami, 2000;

[8] The relationship between input and output phonological processes is a matter of debate in the field of cognitive psychology and neuropsychology in the attempt to understand the architecture of the language processing system (see for example, Romani, 1992; Martin & Saffran, 2002; Howard & Nickels, 2005). Results from Truman and Hennessey (2006) suggested that input and output phonological systems are distinct, and that reading disability might be related more specifically to impairment at the level of phonological output.

Carroll, Snowling, Stevenson, & Hulme, 2003; Anthony & Francis, 2005; Alcock, Ngorosho, Deus, & Jukes, 2010; Cunningham & Carroll, 2011). More complex interpretation has been offered by Perfetti, Beck, Bell and Hughes (1987) who proposed a reciprocal influence between phonological awareness and reading. In the wake of research into the relationship between phonological awareness and reading, Nation and Hulme (2011) discussed the hypothesis that learning to read influences the development of nonword repetition, a task which poor readers find difficult to perform, and to which we will now turn.

II.1.2. Short term memory and nonword repetition

There are a large number of studies indicating that children with reading difficulties are poor at nonword repetition (e.g., Snowling, 1981; Snowling, Goulandris, Bowlby, & Howell, 1986; Brady, 1997), however, the underlying cognitive skills involved in nonword repetition are not well understood. Originally, nonword repetition was proposed to be a measure of phonological short-term memory (Gathercole, 1995a). Phonological short term memory is a component of the working memory system, according to Baddeley's influential theory (e.g., Baddeley, 1986), that is used to store verbal information for a limited amount of time, such as when remembering a telephone number for a few seconds. The amount of information that can be retained in phonological short-term memory is limited (the normal range for digit span forward[9] is 7 plus or minus 2 digits - Miller, 1956).

Researchers have suggested that because dyslexics experience difficulties in nonword repetition, particularly with long nonwords, the underlying cognitive deficit is a reduced phonological short-term memory. However, a number of researchers

[9] Forward and backward digit span tasks have been employed in numerous studies as an assessment of short-term memory (STM). Studies with children with reading difficulties, up to now have attributed the reduced digit span to short-term memory difficulties, *per se*. The empirical and computational findings by Jones and Macken (2015) turned this *well-established* explanation completely around. Jones and Macken (2015) offered a novel, thought-provoking, demonstration of the role of STM. In particular, they argued that long-term associative knowledge is used to perform digit span tasks, i.e., the ability to repeat sequence of numbers, as in the digit span task, depends on participants' linguistic repertoire and experience and the nature of the materials to be remembered, rather than on memory system magnitude and efficiency. It easily follows that this argument would radically change what we have thought and learnt so far regarding the assessment, diagnosis, interpretation and treatment of children with developmental dyslexia.

have argued that this alone cannot explain the difficulty that dyslexic children experience in nonword repetition, since it is a complex psycholinguistic task with many underlying phonological processes, including speech perception, construction of phonological representations, segmentation of the nonword representation, articulation and, at the same time, maintenance of the phonological representation (e.g., Snowling et al., 1986; Bowey, 2001; Chiat, 2001). In addition, other factors have been demonstrated to affect nonword repetition such as wordlikeness (e.g., Gathercole, 1995b), phonotactic frequency (e.g., Edwards, Beckman, & Munson, 2004), prosodic structure (e.g., Roy & Chiat, 2004), and syllabic structure (e.g., Tamburelli & Jones, 2013).

Nation and Hulme (2011) proposed an alternative causal relationship whereby learning to read improves nonword repetition ability. They carried out a longitudinal study with 242 Year 1 children (mean age 6 years old) assessed at Time 1 and one year later (Time 2) when they were aged 7 years. Assessments were carried out of word reading, language (expressive and receptive vocabulary), phonological awareness (an elision task) and two measures of nonword repetition (the Children's Test of Nonword Repetition, Gathercole & Baddeley, 1996; and the nonword repetition subtask from the Comprehensive Test of Phonological Processing, Wagner et al., 1999). The results indicated that in the early stages of learning to read (Time 1), reading was not the only predictor of nonword repetition, while, by the age of 7 years, reading was found to be the only predictor of nonword repetition, even after controlling for phonological awareness and oral language ability. Moreover, reading at Time 1 predicted nonword repetition accuracy at Time 2. The finding challenges the explanation of dyslexia as a deficit in nonword repetition – it may be the consequence of the reading impairment rather than the cause.

II.1.3. Rapid naming

Rapid naming is assessed with the Rapid Automatized Naming (RAN) paradigm developed by Denckla and Rudel (1976). This consists of speeded naming of a series of familiar items, such as letters, digits, objects or colours, and the time taken to name the stimuli is the dependent variable. Findings from a number of studies seemed to indicate the involvement of RAN in reading (e.g., Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007; Kirby et al., 2011; Georgiou, Parrila, Cui, & Papadopoulos, 2013) and there is extensive evidence that children with dyslexia are slower on rapid naming tasks than typically developing readers of the same chronological age (e.g., Denckla & Rudel, 1976; Fawcett & Nicolson, 1994; Wolf & Bowers, 2000). Despite the studies documenting the association between RAN and reading, it is still unclear why RAN is implicated. Several explanations for the relationship between reading and RAN have been proposed (see Logan, Schatschneider, & Wagner, 2009 for a review). One possible explanation is that slow RAN speed is an indicator of an underlying phonological deficit (e.g., Wagner et al., 1994), in that a difficulty with storing phonological representations in memory would lead to slow word retrieval. In this view, RAN is seen as one of the several phonological processes involved in reading, which might explain the difficulty in reading acquisition.

In 1999 Wolf and Bowers proposed an alternative view, that naming speed deficits should be separated from phonologically-based difficulties. They reviewed data from several studies investigating the cognitive processes underlying naming speed. The studies included different populations (dyslexics and children with severe learning disabilities), cross-linguistic research, and provided evidence for an independent contribution of naming speed processes from phonological awareness processes. The data were from correlational analyses between phonological awareness scores and naming speed and from correlational analyses between phonological awareness scores and naming speed to reading measures. In addition, evidence of dyslexic children with naming speed difficulties but unimpaired phonological abilities corroborated the hypothesis of two separate loci of reading disorders. In line with a view of dyslexia as a heterogeneous disorder, Wolf and Bowers (1999) argued that a deficit in speeded naming may be independent from a phonological deficit and that children with dyslexia may experience a double deficit, one involving phonological processing, the other involving problems with speed in serial naming tasks.

Another possible explanation that has been put forward for the relationship between RAN and reading is that RAN may tap executive processes. Rapid naming tasks are highly demanding and Clarke, Hulme and Snowling (2005) suggested that if participants have difficulty in retrieving the phonological code that is a low-level operation, then fewer resources would be available for (higher-level) executive processes. Besides the current debate on the cognitive processes underlying the relationship between speeded naming and reading (Clarke et al., 2005; Savage & Frederickson, 2005; Georgiou, Parrila, & Kirby, 2006; Powell et al., 2007), there is not a general consensus yet on what components (attention, memory, phonology, semantic, motor processes) contribute strongly to naming speed ability.

There is a conflict in findings between whether RAN or discrete naming is the best predictor of reading ability. Discrete naming involves asking the child to name a picture one at a time. Results from studies including both types of naming task have tended to indicate that RAN correlates more strongly with reading ability than discrete naming (e.g., Bowers & Swanson, 1991; Pennington, Cardoso-Martins, Green, & Lefly, 2001). Although discrete and serial naming both involve lexical retrieval (Bowers & Swanson, 1991) and word production, they seem to not tap the same cognitive processes, in that RAN seems to comprise other cognitive process in addition to lexical retrieval. More recently, Messer and Dockrell (2011) analyzed the relation of serial and discrete naming to literacy abilities in 18 children with word finding difficulties in a longitudinal study. Children were aged 9 years at Time 1 and 10 years at Time 2. A battery of tests was used to assess rapid and discrete naming besides a combination of simple stimuli (letters and single-digit numbers) and complex stimuli (objects and actions) to assess discrete naming. Findings showed that scores in the discrete and rapid naming tasks were not significantly correlated. Regarding the relationship between naming and reading, results indicated that at Time 1 rapid naming of simple stimuli was related more closely to decoding (assessed by single word reading from BAS II Word Reading Scale - Elliott et al. 1996) and reading comprehension (Woodcock Reading Mastery Test (WRMT) Passage Comprehension Test – Woodcock, 1998). At Time 2 results resembled those found at Time 1, in that rapid naming of simple stimuli was significantly related to decoding, but not reading for comprehension.

In the context of the relationship between rapid and discrete naming, Logan, Schatschneider and Wagner (2009) examined the contribution of rapid serial and discrete naming to reading performance. They adopted a longitudinal study with 288 typically developing children assessed from kindergarten through second grade (aged 6 years at Time 1). Isolated naming was assessed with three different sets of stimuli (letters, digits or a combination of letters and digits). These stimuli were used also in serial naming. Phonological analysis (assessed by elision, sound categorization, and first sound comparison tasks), phonological synthesis (assessed by three tasks requiring children to add or blend sounds together), phonological memory (repetition of 19 recorded sentences and digit-span task) and reading ability (isolated word and non-word reading) were also assessed. Serial naming was found to be more strongly correlated with reading scores than isolated naming. Logan et al. (2009) stated that one of the possible explanations for this result is the integration of multiple constructs shared between rapid naming and reading, which, on the contrary, is not required in the isolated naming.

In this section, RAN and its relation to reading have been reviewed. Apart from RAN, investigators have used the discrete naming task [10] as a means to investigate aspects of lexical production in children (Snowling & Hulme, 2009). Due to the central role of picture naming in the present study, a separate section is devoted to this topic.

In Chapter I, we acknowledged that, according to the Dual Route Model, reading involves the co-ordinated functioning of two procedures, the sublexical and the lexical procedure. In this section, we have seen that several processes, including phonological abilities, short-term verbal memory and rapid naming abilities, are involved in reading and reading disability and that difficulties in any of them might be ascribed to poorly specified phonological representations (a 'core phonological deficit', Stanovich, 1986). Since effective functioning of the sublexical procedure requires well specified phonological representations, impairment of the processes underpinning phonology is associated with a reading profile consistent with phonological dyslexia. Now attention is turned to the cognitive processes that might play a role in impairments of units representing whole words (the lexical procedure).

II.2. The role of semantics as a possible cause of dyslexia(s)

The case of LF, a girl aged 6;6, described by Stothard, Snowling and Hulme (1996) seems to run counter to the *phonological core deficit* hypothesis of dyslexia, in that LF was good at reading (scoring in the average range on standardised assessments) but she experienced phonological difficulties. In Chapter I, it was noted that word recognition is a complex process, with a number of underlying cognitive processes. It is therefore likely that several factors will have a causal role in reading difficulties. Indeed, cases of developmental dyslexia caused by cognitive impairment in domains other than phonology are reported, such as for example: visual memory (e.g., Goulandris & Snowling, 1991), visual attention span (e.g., Bosse, Tainturier, &

[10] "Discrete naming", "isolated naming" or "confrontation naming" all refer to tasks in which children are required to retrieve and produce words in response to a picture.

Valdois, 2007; Valdois et al., 2011), and visual-orthographic analysis (e.g., Friedmann & Gvion, 2001; Kohnen, Nickels, Castles, Friedmann, & McArthur, 2012) (for a review see for example, Castles, 1996; Lukov et al., 2015). Although acknowledging other potential causes of developmental dyslexia, for the purpose of the present study attention will be focused on semantic knowledge and its relationship to reading ability and disability.

Not all poor readers have difficulties at the level of word recognition. Children with specific difficulties in reading comprehension can have normal word recognition skills (Nation & Snowling, 1998) but they have been shown to have impairments in tasks requiring semantic processing. On the other hand, it has been demonstrated that semantic processing ability is not only involved in reading comprehension but it can influence word recognition. For example, Nation and Snowling (2004) in a longitudinal study with 72 typically developing children assessed at the age of 8;5 and then again when they were 13, showed that early measures of expressive vocabulary, listening comprehension, semantic fluency and synonym judgement not only contributed to the development of vocabulary and reading comprehension but also to word recognition. Bowey and Rutherford (2007) in their study involving a sample of 304 children aged 13 and 95 children aged 9 found that both exception word and nonword reading accuracy correlated with verbal ability, assessed by the Peabody Picture Vocabulary Test (PPVT-R - Dunn & Dunn, 1981), but exception words were more strongly correlated to verbal ability than nonwords. Bowey and Rutherford (2007) claimed that this differential association could not be explained solely by the fact that exposure to reading contributes to vocabulary growth because nonword reading might have been affected as well, for example by enabling the recognition of orthographic regularities. Instead, Bowey and Rutherford suggested that high vocabulary knowledge helps to correctly pronounce an irregular word that is unfamiliar in print. Moreover, in a cross-sectional study with 67 children from grade 1 and 56 children from grade 6, Ouellette and Beers (2009) investigated the role of vocabulary in single word reading. Measurement of phonological awareness, nonword reading, irregular word reading, listening and reading comprehension and two measures of vocabulary were taken. Results showed that vocabulary was a significant predictor of nonword reading in grade 6 but not in grade 1, while irregular word reading was predicted by vocabulary in both grades, after controlling for phonological awareness.

Another study investigating the link between vocabulary and word reading is the one by Ricketts, Nation and Bishop (2007). A sample of 81 children aged between 8 and 9 years was given an assessment of general cognitive ability, reading and language skills. Results revealed that vocabulary was a significant predictor of exception word reading, but not of nonword and regular word reading. In a recent study, Ricketts, Davies, Masterson, Stuart and Duff (submitted) found that vocabulary knowledge predicted both regular and irregular word reading in six year old children. They suggested that perhaps in the early stages of reading development semantics contributes to both regular and irregular word reading while, as reading abilities develop, semantics becomes involved more specifically in irregular word reading.

To summarize, the studies reviewed so far have demonstrated a connection between vocabulary knowledge and exception word reading in the development of reading acquisition. However, less clear is how vocabulary knowledge influences irregular word reading. One possible explanation is by Share (1995), who argues that top-down processes help in facilitating word recognition in an explicit manner: if a child attempts to read an exception word, his/her good vocabulary competence may help to read the word, finding the phonological form close to the word, rather than attempting to match exactly to the response produced by grapheme to phoneme conversion. Duff and Hulme (2012) examined the role vocabulary plays in reading acquisition by carrying out a study with children learning to read new words. Sixteen children aged 5;6 years took part in the study. All the children were selected for not being able to read the words comprising the word learning task. Children were administered tests of single word reading, receptive vocabulary, phoneme awareness, and phoneme deletion over three consecutive days. In the same occasion, children were taught 24 new words. Children were also asked to a) indicate whether they had heard the taught words before (word familiarity), b) to define the target words and c) to use them in an appropriate spoken sentence (semantic knowledge). Besides corroborating the findings that those children with better phonological skills learn to read better, results revealed that children's knowledge of a word's meaning helps them to learn to read that word. Since these findings might have been explained by children's pre-existing vocabulary competence, another experiment was carried out (Experiment 2) in order to disentangle the role of semantics in learning to read from the children's pre-existing vocabulary knowledge. In this second experiment, phonology and semantics were directly manipulated prior to the children learning to read nonwords. Eighteen children aged 6 were taught to read 12 nonwords over three sessions of 20 minutes each. There were three conditions: phonological pre-exposure, phonological and semantic pre-exposure, and no exposure. Children were first familiarised with the phonology of all pre-exposed nonwords. Four nonwords received additional phonological training (e.g., a phonological discrimination task) and four received additional semantic training (e.g., a semantic discrimination task). The results of Experiment 2 indicated that children did not benefit from learning to associate meaning to the nonwords. Duff and Hulme concluded that both experiments supported the already well-established role of phonology in learning to read, and, more importantly, Experiment 1 demonstrated that semantics played a key role in learning to read. The lack of evidence for an involvement of semantics in learning to read nonwords in Experiment 2 was attributed to the training sessions being too short (20 minutes for 3 days) to allow establishing robust semantic representations. Children were in fact first familiarised with the phonology of the pre-exposed nonwords and then they received additional phonological training, therefore they were exposed to lot of phonological association with the stimuli in comparison to sematic training, which might explain why they did not benefit from learning to associate meaning with the nonwords. Nevertheless, results from Experiment 1 in Duff and Hulme's study are in line with the view that a child will be facilitated in learning to read words which are part of his/her spoken vocabulary (Vellutino, Fletcher, Snowling, & Scanlon, 2004). It follows that a child with limited vocabulary knowledge might have difficulties in learning to read, in particular irregular words, despite adequate phonological abilities.

The research reviewed so far has linked vocabulary knowledge to irregular word reading in typically developing children, and this association seems to not be solely explained by the effect of reading experience upon vocabulary (see Bowey & Rutherford, 2007). Other research has found that children at risk of reading impairment have weaker receptive vocabulary knowledge in comparison to more able readers (e.g., Swanson, Trainin, Necoechea, & Hammill, 2003). The evidence that a possible cause of irregular word reading impairment is an inadequately developed oral vocabulary (a measure of semantics) suggests that one of the plausible sources of surface dyslexia (or dyslexias cf. Friedmann & Lukov, 2008), which is characterised by difficulty in exception word reading, might be a semantic impairment (Coltheart, 1987; Friedmann & Lukov, 2008; Gvion & Friedmann, 2013).

As we saw earlier, a deficit in phonological processes has been associated with developmental phonological dyslexia. Conversely, individuals with developmental surface dyslexia are generally reported to have unimpaired phonology, and there appear to be different cognitive loci of impairment (for a review see Lukov et al., 2015), of which semantics is one of the possible sources. In synthesis, both phonology and semantics play a key role in learning to read (Ehri & Robbins, 1992). In light of these considerations, the picture naming paradigm has been employed in this study to investigate the link between semantic knowledge and phonology, and in turn their connection to reading. In the next chapter, the processes involved in picture recognition and name production will be introduced and studies of picture naming deficits in dyslexic children will be reviewed.

CHAPTER III. Picture naming and developmental dyslexia

III.1. Introduction

Picture naming has become an important experimental paradigm in cognitive psychology and neuropsychology and it has been widely used to investigate lexical organisation (for a review see Glaser, 1992; Johnson, Paivio, & Clark, 1996). In the conventional picture naming task participants are asked to produce a single word in response to a picture. According to the theory of lexical access developed by Levelt and colleagues (Levelt, 1992; 1999; 2001), lexical selection is completed when the *lemma* [11] is selected and it is followed by three stages of form encoding: a phonological code of the lemma, a morphological stage where syllabification is the core process), and phonetic encoding. Dell (1986) and colleagues have proposed a variant model of spoken word production (Dell & O'Seaghdha, 1992), and this has been used in research with adult aphasic speakers (Foygel & Dell, 2000) and, recently, children. Foygel and Dell's model has been adopted to explain the naming errors made by children aged 5 to 11 years by Budd, Hanley and Griffiths (2011).

Although Levelt's model and Dell's model differ in the way in which the activation spreads through the nodes from the conceptual level to the articulation of the words, and in the nature of the links among the nodes (facilitatory/inhibitory connections), both share the same stages from the conceptual level to the articulation of the selected word. Three processes have been demonstrated to be involved in naming: object recognition, semantic activation and phonological assembly. First is the process of object recognition where, following a perceptual analysis of the picture, a stored visual or structural representation is activated. Once recognised, familiar pictures will trigger the semantic level where the comprehension of pictures takes place. The next stage is the level of lexicalisation (lexeme retrieval in Levelt's model of word production) where the stored phonology of words is activated. A naming deficit might occur therefore in a number of ways: a perceptual deficiency may prevent the object from being recognised, a disruption at the level of semantics, a problem at the level of phonological representations and output, or in the links between the different levels.

[11] A *lemma* is defined as the word mental representation and its syntactic feature (Johnson et al., 1996; Levelt, 1999).

III.2. Picture naming deficits and dyslexia

One of the pioneering studies in the field of naming deficits and dyslexia is by Katz (1986). Thirty-three children aged 9 participated, of whom 10 were poor readers, 12 were average readers and 11 were good readers. They were asked to name 40 pictured objects from the Boston Naming Test (BNT) (Kaplan, Goodglass, & Weintraub, 1983). The findings revealed that poor readers named significantly fewer objects than either the average or the good readers. Moreover, the difference remained when the children's naming scores were adjusted by eliminating items that were unfamiliar to the children. Also, in an attempt to establish the locus of the naming deficit, a task was administered in which participants were asked to judge the length of verbal label of pairs of pictured items projected simultaneously on a white screen. Children were asked to respond as quickly as they could by pressing one of two keys labeled 'Yes' and 'No' whether the depicted items had names of the same length or not. Poor readers were found to have difficulty in making the word length decisions. In addition, poor readers had more difficulty retrieving long words than short words. Katz concluded that poor readers find difficulty in retrieving information stored in long-term memory, possibly due to underlying phonological deficiencies.

Katz's seminal work has been replicated in subsequent studies (for example, Snowling, Wagtendonk, & Stafford, 1988; Swan & Goswami, 1997; Nation, Marshall, & Snowling, 2001). Snowling et al. (1988) assessed twenty dyslexic children ranging from 9;2 to 11;11, matched to 15 chronological age (CA) controls ranging in age from 10;6 to 11;11, and 14 reading age (RA) controls aged from 7;10 to 9;4. The three groups did not differ in receptive vocabulary, as measured by the British Picture Vocabulary Scale (BPVS) (Dunn, Dunn, Whetton, & Pintilie, 1982). In Experiment 1, participants were asked to name 66 objects and accuracy and reaction times were recorded. Six weeks later, participants were read a definition of an object and they were asked to produce the object name as fast as possible. Results indicated that dyslexic children made more naming errors (M = 7.65, SD = 2.1) than the CA (M = 3.8, SD = 1.2) ($p < .05$), while no significant difference was found between dyslexics and RA controls (M = 8.43, SD = 2.6). Experiment 2 was carried out to investigate whether the explanation for the results from Experiment 1 could perhaps have been that the dyslexics lacked vocabulary knowledge for the items included in the picture naming task. Another group of 11 dyslexic children aged 8;00 to 10;6 were matched for age to 13 normal readers aged 8;7 to 10;9. They were administered a picture vocabulary task to assess their knowledge of word meaning and a picture naming task. The picture vocabulary task consisted of a picture-word matching task in which children were asked to match 40 target words spoken by the examiner to one of 4 pictures. Three pictures served as distractors (phonologically, semantically and unrelated to the target word) and one picture depicted the target word. Results corroborated the previous findings in that dyslexics made significantly more errors in the picture naming task than controls. Furthermore, the two groups did not differ in the picture vocabulary task, leading Snowling et al. (1988) to conclude that the dyslexics' difficulties in naming pictures were not attributable to a lack of vocabulary knowledge but instead to their impoverished phonological representations of the words. Nevertheless, the forty items used in the picture naming task differed from those used in the picture vocabulary task so that the question to what extent the naming difficulty was due to a problem in retrieving the phonological form of words or to a lack of vocabulary knowledge still remains. Additionally, the results found in Snowling et al. (1988) that RA control children performed as well as dyslexics was not later supported in the study of Wolf and Obregón (1992). The results by Wolf and Obregón (1992) revealed that dyslexics were less accurate than younger RA controls in the Boston Naming Test (Kaplan et al., 1983), suggesting that the naming of dyslexic children is significantly impaired.

The study of Swan and Goswami (1997) is considered one of the most comprehensive studies of picture naming in dyslexic children because it provides an explanation for the discrepant findings obtained by Wolf and Obregón (1992) and Snowling et al. (1988). Swan and Goswami (1997) explored picture naming performance in four groups of children: 16 dyslexic children with mean age 11;97, 16 CA controls with mean age 11;27, 16 RA controls with mean age 9;5, and 16 non-dyslexic-garden-variety poor readers with mean age 11;5. In the naming task they manipulated the spoken word frequency and length of the picture names. Age-of-acquisition, familiarity, and number of orthographic and phonological neighbours were also taken into account. Reading and naming of the same stimuli was administered and accuracy was recorded. In addition, a qualitative analysis of the errors was conducted.

To follow Katz (1986), Swan and Goswami excluded from the analyses those incorrectly named objects where the concept depicted in the picture was not familiar to the children, assessed by asking children to describe an incorrectly named object's use or where it had been seen before (familiarity questioning). The results showed a picture naming deficit for both the groups with reading difficulties (dyslexic and garden variety poor readers). With respect to the *locus* of the picture naming errors, Swan and Goswami stated "dyslexic children have a unique difficulty in the retrieval of known names which suggests that they have a selective difficulty in retrieving the phonological codes of the names on demand" (p. 349). They supported their conclusion with analyses of the effects of psycholinguistic variables: the dyslexic group made more errors on pictures with long names than short names and they had higher scores when reading low frequency names than when naming the corresponding pictures. Swan and Goswami argued that the conflicting results reported by Snowling et al. (1988) and by Wolf and Obregón (1992) may be explained by the phonological properties of the words selected as stimuli in the studies. These findings seem to support the hypothesis of a phonological impairment as a possible source of dyslexia.

However, the conclusions from the study need to be considered in the light of several issues: Swan and Goswami concluded that the dyslexic children in their study had a phonological retrieval deficit, however, no assessment of phonological abilities was included in the measures employed. Looking at the assessments used, Swan and Goswami administered a dated reading test (the Schonell Graded Word Reading Test, Schonell & Goodacre, 1971) to assess reading ability, and an object recognition task that consisted of presenting the target picture alongside a semantic foil, a phonological foil and an unrelated distractor to investigate knowledge of the pictures the children had failed to name correctly in the picture naming task. Regarding the latter, it has been noted by Cole Virtue and Nickels (2004) and Breese and Hillis (2004) that word-picture verification tasks are more sensitive than multiple choice semantic tasks, and this stems from the elimination of forced guessing in the word-picture verification task. Finally, in order to exclude the presence of dyspraxia among the dyslexics in the Swan and Goswami study, the authors asked children to repeat some of the items used in the picture naming task without administering a standardised measure of articulation. It is suggested therefore, that the conclusions of the study need to be reviewed in the light of these considerations.

Nation, Marshall and Snowling (2001) carried out a further picture naming study with dyslexics, where, as in the study of Swan and Goswami, they examined the effect of word length and word frequency on naming, as markers of phonological and semantic processes respectively. They recruited dyslexic children as well as three other groups: a reading-age control group, ten chronological age matched typically developing readers and ten poor comprehenders. Decoding ability, text reading accuracy and reading comprehension were also assessed. To examine picture naming ability Nation, Marshall and Snowling employed fifty-six line-drawings of objects, varying in phoneme length and rated frequency, taken from the study of Morrison, Chappell, & Ellis (1997). Accuracy and latency in naming were recorded, and a qualitative analysis of the response errors was conducted. The results showed that both dyslexic children and poor comprehenders were impaired at naming pictures. Nation et al. (2001) suggested that the underlying difficulty in these two groups of children was different. Dyslexic children were worse than RA controls in naming pictures with long names. This replicated the finding of Swan and Goswami (1997), and supported the hypothesis of an underlying phonological deficit in dyslexic children. Turning to the poor comprehenders, Nation et al. (2001) found that they were slow and inaccurate at naming pictures with low frequency names. It needs to be noted that, although Nation et al. attempted to investigate how semantic and phonological skills are related to picture naming, the assessments did not include independent evaluation of phonological or semantic abilities.

In order to investigate the locus of naming deficits in dyslexic children, Truman and Hennessey (2006) carried out a study with 24 dyslexic children aged 7;8 to 12;1, as well as an age matched control group. The dyslexics, as a group, showed relatively poor expressive and receptive language ability. Twenty-two children out of 24 were recruited from a language development centres so most of the dyslexic sample comprised a number of children with quite severe oral language difficulty or delay. The picture naming task consisted of twenty digitised black and white photographs of everyday objects. Participants were asked to name pictures aloud while hearing nonsense syllables either phonologically related or unrelated to the target picture name. The researchers manipulated two levels of stimulus onset asynchrony (SOA)[12] to investigate phonological facilitation and interference at early (50 msecs) and late (200 msecs) stages of phonological encoding. Naming latencies, not accuracy, were analysed. The findings showed that compared to the age-matched

[12] Stimulus Onset Asynchrony (SOA) is defined as the duration between the presentation of the target picture and the onset of the auditory distractor.

control group, dyslexics had longer picture naming latencies and were advantaged by hearing related rather than unrelated auditory distracters, especially for low frequency items. An effect of phonological facilitation was present for the CA controls as well, but to a lesser degree. The authors, in the context of interactive activation models, suggested that the picture naming difficulties of some dyslexic children are associated with impairments at the level of output phonological representations. As a consequence of a poorly specified phonological representations, phonological encoding is likely to be less efficient or slower.

Truman and Hennessey noted that the some of the dyslexic children showed overlap with the normal readers in terms of phonological facilitation, although their picture naming latencies were still significantly slower. Slower naming latency scores could be ascribed to inefficient activation of the semantic level which, is a possible explanation given the oral language difficulty of the participants in Truman and Hennessey study. Also, it is possible that those dyslexic children who overlap with the CA controls in terms of phonological facilitation might represent a distinct subtype of dyslexia. These reflections led the authors to hypothesize that there is something other than impairment in phonological output at the basis of the deficit shown by dyslexic children, and they therefore suggested other possible causes of word retrieval difficulty, such as poor semantic activation. A difficulty with the conclusions of Truman and Hennessey is that, as in the study of Nation et al., there was no independent assessment of semantic or phonological ability, which would have provided additional verification of the conclusions from the experimental task.

Finally, in a recent study Araújo et al. (2011) found that the performance of dyslexic children in a picture naming task was affected by changes in the visual attributes of objects. The stimuli they used varied in terms of colour (colour versus black & white drawings) and dimensionality (2D versus 3D), including three-dimensional real objects, two-dimensional coloured representations and black & white drawings. Participants consisted of 18 dyslexics (Mean age 9;5) matched with 19 chronological age controls (Mean age 9;4) and 20 reading age controls (Mean age 7;3). Reaction times for correct responses were analysed. The results revealed that the CA controls were faster than dyslexics (p = .019) and RA controls (p = .013), while there was no significantly difference between dyslexics and RA controls (p = 1.0). Dyslexics' performance was not affected by the stimulus attributes, while the two controls groups named coloured pictures faster than real objects (p = .004). Araújo et al. suggested that processes in the early stages of object recognition or the integration of visual information within long-term memory might be affected in dyslexic children. In particular, because dyslexic children differed from controls in terms of latencies but not accuracy, it was suggested that the difficulty experienced by dyslexic children in picture naming might be the speed with which the cognitive system handles visual information or the speed in transferring visual information to the language system.

To summarize, although picture naming impairments in dyslexic children have been explained as a symptom of an underlying phonological deficit, all the studies reviewed so far do not provide an independent assessment of phonological abilities. Moreover, the study of Araújo et al. (2011) has offered an alternative explanation of the naming difficulties of dyslexic children, alongside the well-established phonological deficit hypothesis. The psycholinguistic variables associated with picture naming are presented in the next section since the influence of these, as noted above, has been used to supplement findings on accuracy and latency in studies of picture naming in dyslexics to provide additional information concerning the locus of deficits.

III.2.1. Psycholinguist variables associated with picture naming

The picture naming paradigm offers the opportunity to investigate which attributes (psycholinguistic variables) associated with the target stimulus affect the process of lexical retrieval and word production. It has been demonstrated that psycholinguistic variables influence word selection and phonological retrieval during lexical access (Barry, Morrison, & Ellis, 1997; Bonin, Fayol, & Chalard, 2001) and besides studies with healthy speakers, there is evidence showing that psycholinguistic variables such as word frequency, phonological neighbourhood size, and syllable length facilitate naming in speakers with aphasia (e.g., Best, 1995; Gordon, 2002). Exploring the influence of psycholinguistic variables on naming contributes to investigating how earlier processes (word selection) interact with later (encoding) processes in lexical access.

The variables that have been found to affect picture naming performance have been considered important since successful models need to account for their influence. I will present the variables that have been shown to affect both adult and child picture naming and particularly those that have been studied in recent research into children's picture naming (D'Amico, Devescovi, & Bates, 2001; Masterson, Druks, & Gallienne, 2008).

Starting with the first stage of picture naming (object perception and recognition), there are several variables that are thought to be influential, including image agreement, structural similarity and visual complexity. The latter variable was first investigated in the context of the picture naming task by Snodgrass and Vanderwart (1980). It was defined as the amount of detail or intricacy of line in the picture. Visual complexity may affect picture naming latencies as the complexity of a drawing influences the time taken to recognize the image (Vitkovitch & Tyrrell, 1995; Ellis & Morrison, 1998; Alario, Ferrand, Laganaro, & New, 2004). However, a visual complexity effect on naming latency is not always reported (see Barry et al., 1997; Chalard, Bonin, Meot, Boyer, & Fayol, 2003; Cuetos, Barbón, Urrutia, & Domínguez, 2009). D'Amico, Devescovi and Bates (2001) reported significant effects of visual complexity on naming latencies for both children and adults using an objective estimate of visual complexity, while Masterson et al. (2008) reported a significant effect of visual complexity on object naming accuracy for three-year-old children and on object naming latency for five-year-olds. D'Amico et al. (2001) measured visual complexity as the number of pixels in each digitized image rather than using a subjective measure as in the study of Masterson et al. (2008).

While traditionally visual complexity measures have been taken from subjective ratings, Székely and Bates (2012) investigated the influence of an objective visual complexity measure taking as a basis the file size of picture stimuli (using PDF, TIFF and JPG formats). In their analysis, the objective and subjective measures of visual complexity significantly correlated ($p < .01$) with each other, indicating that both approaches effectively measure the amount of detail in pictures. Nevertheless, subjective visual complexity only had a significant effect on naming latency for a subset of 168 pictures ($p < .05$) while the objective complexity measure did not correlate with naming performance ($p > .05$).

Turning to the level of semantic activation, the variable of imageability has been widely investigated in cognitive psychology (Paivio, Yuille, & Madigan, 1968; Barry et al., 1997; Funnell, 2000; Bird, Franklin, & Howard, 2001; Burani, Arduino, & Barca, 2007). Imageability is defined as the capacity of a word to arouse a sensory experience, such as a mental picture, sound, smell or taste. Paivio et al. (1968) argued that because concrete nouns are associated with specific objects and events, they arouse sensory images that support processing in linguistic tasks (Funnell, 2000). On the basis of this, Paivio et al. proposed that the psychological construct underlying the abstractness-concreteness effect was imagery. Imagery was found to be significantly correlated to performance in verbal learning and free recall tasks (Paivio, 1967) and its powerful effect was explained by considering that highly imageable nouns can be stored in memory either as words or as mental pictures of their referent objects, improving the probability of them being easily and more speedily recalled (Paivio, 1967). Evidence for a strong relationship between sensory information and measurements of imageability/concreteness comes from a study by Funnell and Allport (1987). They found significant positive correlations between ratings for imageability and concreteness and ratings for eight sensory dimensions (shape, taste, smell, sound, colour, movement of the object, touch and weight) on a large set of words.

More recently, in an object and action picture naming task with young children, Masterson et al. (2008) provided evidence for the role of imageability in lexical processing. Imageability was found to be the most robust predictor of object naming but not of action naming for the three-and-five year old children. This result supported the assumption that sensory features play an important role in underpinning the representations of nouns, at least for the concrete and early acquired objects that constituted the stimuli in the study.

Strain, Patterson and Seidenberg (1995) found that imageability influenced word recognition in skilled readers, especially naming low frequency exception words. The authors stated that semantics is more involved when the contribution of phonology is decreased. The role of semantics in phonological coding was also examined in Strain and Herdman (1999) with adult participants who differed in phonological ability. The results corroborated previous findings by demonstrating a greater influence of imageability on naming words, especially low frequency irregular words. In particular, the interaction between word regularity (regular versus irregular words) and imageability changed according to the level of phonological abilities: participants with high phonological abilities exhibited a larger effect of imageability on irregular in comparison to regular words while no interaction between regularity and imageability was found in the group with low phonological abilities. This pattern of results was interpreted as the contribution of semantics to phonology when the latter is weak, like reading low frequency irregular words. The lack of interaction in the low-phonological ability group was explained by inefficient orthography-to-phonology mapping, which affects indiscriminately both irregular and regular words. Finally, imageability was also found to influence word recognition in children with dyslexia (Baddeley, Ellis, Miles, & Lewis, 1982).

Phonological neighborhood density [13] (PND) in lexical access has been attributed to interactive feedback between lexical and phonological processing levels within the framework of the interactive activation model of word production of Dell (1986). An example of a study in this vein is that of Middleton and Schwartz (2010) who analysed the effect of PND on the picture naming of three aphasic speakers who differed in terms of level of impairment. Two of the patients demonstrated a tendency for phonological errors[14], and the third semantic errors and comprehension difficulty. Controlling for a wide range of psycholinguistic variables including familiarity, phonotactic probability, word frequency, homophony, number of phonemes, syllable length, age of acquisition, concreteness, imageability, name agreement, and two measures of neighbourhood frequency, results indicated an effect of PND on naming performance. Not only the two participants with phonological retrieval deficits but also the patient with semantic impairment made fewer phonological errors with words with a high number of phonological neighbours. Phonological similarity seems to facilitate lexical access for words sharing the same phonemes (i.e., those with a high-density neighbourhood). In other words, the activation of phonological neighbours seems to increase the selection of the target word while it does not provide any or little benefit to semantically related (but phonologically unrelated) competitors.

Moving to the stage where phonological assembly takes place, it has been argued that word length has its locus here. Word length can be measured in phonemes, syllables or in terms of number of letters for printed words. Word length has been interpreted and widely accepted in the literature as having its locus at the last stage of

[13] Phonological density is the number of similar-sounding words to a particular target word in the spoken language. It was defined as the set of words generated by the addition, deletion or substitution of one phoneme to a target word. When many words resembled the target, the neighbourhood for that word was said to be dense. When few words resembled the target, the neighbourhood for that word was said to be sparse (Thomson, Richardson, & Goswami, 2005; Middleton & Schwartz, 2010). For example, according to the Children's Printed Word Database (Masterson, Stuart, Dixon, Lovejoy, & Lovejoy, 2003), the noun *pear* has 26 phonological neighbours, while the word *apple* has 0.

[14] The second patient presented also with articulation problems.

phonological representations. This assumption is based on the results of a number of word production studies. Klapp, Anderson and Berrian (1973) and Klapp (1974) found a word length effect for object and two-digit number naming (e.g., 27, 26, 24). Since the effect was evident in both types of naming, Klapp et al. (1974) suggested that this phenomenon was not due to perceptual analysis of the stimuli into syllabic units, as syllables are represented at the graphemic level only for words and not for the two-digit numbers. Klapp et al. (1974) assumed that a vocalization must be programmed before it can be produced, and this is why more syllables need longer programming time, leading to longer latencies. Most relevant, word length effects have been reported in picture naming studies. For example, word length has been demonstrated to affect naming performance in adult and child object naming (Gerhand & Barry, 1999; Barry, Johnston, & Williams, 2001; D'Amico et al., 2001; Masterson et al., 2008).

A large number of studies have confirmed that two different variables have strong and robust effects in word production: word frequency and age-of-acquisition (AoA). Frequency refers to how often a word is used in the language while AoA to the age at which a word is acquired. Pictures whose names occur more frequently in the language are named faster than those with less frequent names (e.g., Morrison, Ellis, & Quinlan, 1992; Jescheniak & Levelt, 1994). Both word frequency and AoA effects are reported in picture naming studies (e.g., Morrison et al., 1992; Barry et al., 2001).

In the picture naming task, both word frequency and AoA are assumed to have their loci at the lexical level, either in the process of lexical identification, that is, at the stage of selecting the lexical form that best matches the conceptual representation aroused by the picture, or lexical retrieval, i.e., at the stage of gaining access to the lexical-phonological specification of a selected word (Barry et al., 2001). Since most studies have involved adults' subjective ratings of the age at which words were first acquired, in many picture naming experiments the frequency effects reported were the result of a confounding of AoA and word frequency (e.g., Morrison et al., 1997; Gerhand & Barry, 1999; Barry et al., 2001).

While there is agreement that word frequency and AoA tend to be highly correlated, discord exists over whether word frequency and AoA are separate variables (e.g., Dewhurst & Barry, 2006; Cuetos et al., 2009) or two aspects of the same underlying learning mechanism (e.g., Ellis & Lambon Ralph, 2000; Meschyan

& Hernandez, 2002). Several hypotheses have been proposed regarding the locus of AoA effects. Gerhand and Barry (1999) concluded that AoA effects reflect access to phonology, since they have been most prevalent in tasks involving the activation of phonology, such as list recall tasks that involve phonological output. This supports the view that the phonological representations of early acquired words are accessed more readily than the phonological representations of late acquired words (the phonological completeness hypothesis of Brown & Watson, 1987). This hypothesis states that early learned words are stored as wholes in the speech output lexicon, while later acquired words are stored in a fragmented way and must be assembled each time they are produced. Other accounts consider AoA to be a variable which affects the semantic system, on the basis of findings of strong AoA effects in semantic processing tasks such as object naming or lexical decision tasks (e.g., Brysbaert, Wijnendaele, & Deyne, 2000). Brysbaert et al. (2000) affirmed that the order of acquisition of concepts/words is the most important organizing factor within the semantic system and determines the speed with which the semantic representations of concepts can be activated. Early acquired concepts are thereby more accessible than late-acquired concepts. The issue of the locus of AoA effects still appears to be an open one.

Both AoA and word frequency have been shown to influence naming then (e.g., Meschyan & Hernandez, 2002). Since the two attributes may be naturally confounded, with early-acquired words tending to be higher in frequency than late-acquired words (Gilhooly & Gilhooly, 1979; Morrison et al., 1992), attempts have been made to derive an objective measure of AoA. Morrison et al. (1997) suggested that rated age-of-acquisition is both a reliable and valid measure of word learning age as there is a close correspondence between the ratings and the objective measure of AoA derived from an examination of children's vocabulary development.

Recently, Funnell, Hughes and Woodcock (2006) reported a new theory of age-of-acquisition effects in visual object naming. They constructed developmental trajectories for naming and knowing in children aged 3;7 to 11;6, and found more evidence of perceptual-type knowledge in the younger children. They suggested a developmental change in the nature of information underlying representations, whereby they are strongly underpinned at first by sensory information and later involve linguistic mediation, and that this influences the ability to find the name of an object.

In summary, psycholinguistic variables described so far have been shown to affect picture naming performance. In the present research, ratings for visual complexity, spoken frequency, imageability, and measures of phonological neighbourhood and word length were examined for their potential influence on picture naming, and whether the pattern might be different for typically developing children and dyslexics. The analyses were conducted in order to provide an additional source of information that would supplement the results obtained from the analyses of picture naming accuracy and latency and from qualitative analysis of the response errors.

III.3. Rationale for conducting the research

In this chapter, studies on naming abilities in dyslexic children were discussed. In particular, Swan and Goswami (1997) and Nation et al. (2001) found that the naming deficit in dyslexic children was due to difficulty in retrieving long words. If we examine first the study of Swan and Goswami (1997), the authors reported that dyslexic children made, in addition, more phonological errors than controls and this supported an explanation of a deficit in retrieving the phonological representations of words (due to a phonological core deficit). Yet, we have seen that one of the main problems of this study is that it did not include an independent assessment of the dyslexics' phonological abilities. Only word length was used to index phonology. Moreover, Swan and Goswami used the Schonell Graded Word Reading Test (Schonell & Goodacre, 1971) to assess reading ability of the participants. The Schonell Graded Word Reading Test comprises a combination of real words with regular (e.g., *milk*) and irregular (e.g., *gnome*) grapheme-to-phoneme conversion rules. It provides a Reading Age (RA) score according to the total number of words correctly read. At least two considerations should be made: first, since it is now accepted that dyslexia is a heterogeneous disorder, assessment of reading should include types of words which are sensitive to the different types of dyslexias (for example, by including nonwords and irregular words[15]). Second, the Schonell Graded Word Reading Test does not provide a standard score that is considered to be the most accurate normative score for interpreting performance on standardized tests (Maloney

[15] Castles and Friedmann (2014) have recently recommended that, in addition, dyslexic children should be assessed with words with migratable letters, and irregularly stressed words (for Italian) in order to detect the range of possible types of developmental dyslexia hitherto documented.

& Larrivee, 2007; GL Assessment, 2013). Finally, as outlined in section III.2, use of the multiple-choice semantic task employed in the Swan and Goswami study has been criticized. The word-picture verification task has been demonstrated to be a more sensitive measure of concept knowledge (e.g., Breese, 2004). In the light of these considerations, it was thought important to verify the conclusions of Swan and Goswami.

Turning to consideration of the study of Nation et al. (2001), these authors based their investigation on the different stages specified in models of lexical retrieval. According to these, two steps are involved after the initial stage of object identification: activation of semantic and syntactic information followed by retrieval of the phonological representation of the target word. Since both semantic and phonological processes are involved in the picture naming task, Nation et al. (2001) aimed to investigate at which stage of the naming process, whether semantic or phonological, dyslexic children's naming difficulty originates.

Nation et al. recruited two types of poor readers, classic dyslexics, whose naming deficit was thought to be due to a phonological deficit, and poor comprehenders, who despite having nonword reading scores in the average range, performed significantly worse than controls on reading comprehension tasks. The picture naming of these two groups of children was examined in an attempt to uncover dissociations and thereby disentangle the role of phonology and semantics in dyslexic children's naming. However, as we noted for Swan and Goswami's study, no assessment of semantics and phonology was employed. Instead, word length and word frequency of the pictures in the naming task were used as an index of phonology and semantics, respectively. Consideration should also be given to the stimuli employed by Nation et al. (2001) Looking at the 56 items selected from Morrison et al. (1997), it should be noted that some of the verbal labels have the same root, such as *<u>tele</u>phone*, *<u>tele</u>scope* and *<u>tele</u>vision*, or same suffix, such as *micro<u>scope</u>* and *tele<u>scope</u>*. Although the items were randomly split into two sets, it is possible that repetition priming may have occurred (see Shao, Roelofs, Acheson, & Meyer, 2014). In line with the interactive model of Foygel and Dell (2000), it follows that the activation of more lemmas could increase the rate of both semantic and phonological errors, depending on the locus of a potential deficit. The former because there is an increased probability to select a word that shares semantic features with the target, and the latter because of an increase in activation at the phoneme level.

The studies on picture naming in dyslexic children described so far have shown no differences between dyslexics and age-matched controls in performance on standardized vocabulary tests (Snowling et al., 1988; Swan & Goswami, 1997) suggesting that the dyslexic children's naming difficulties could not be attributed to weak vocabulary knowledge.

We saw in section III.2 that naming deficit was also reported in dyslexic children by Truman and Hennessey (2006). They observed that dyslexics as a group were slower at retrieving names and less accurate than chronological age controls in a picture naming task. However, as noted in Chapter I (p. 16) the sample selection might have impacted on their findings. Since the majority of the dyslexic children (84%) were recruited from centres for the treatment of children with language disorders, it is reasonable to think that most of them had an underlying phonological deficit given the well-established link between reading difficulty in children with speech and language disorder (e.g., Bishop & Snowling, 2004; McArthur, Hogben, Edwards, Heath, & Mengler, 2000; Ramus, Marshall, Rosen, & van der Lely, 2013). Moreover, Truman and Hennessey used the short form of the Woodcock Reading Mastery Test-3rd Edition to select dyslexic participants. This standardized test comprises several subtasks such as letter identification, phonological awareness, RAN, word identification, word attack, word comprehension, oral reading fluency, passage comprehension. Truman and Hennessey did not specify which subtasks were used, apart from the word attack subtask. If the short form consisted of subtasks tapping phonological skills only, it is plausible to assume that children with a surface dyslexia profile might not have been identified (since they generally have relatively good phonological abilities) and therefore not selected for the study. Hence, the importance of employing reading tests comprising stimuli that will identify different types of dyslexia (Castles & Friedmann, 2014).

The literature on acquired aphasia has linked surface dyslexia with different forms of naming deficit (Funnell et al., 2006; Patterson & Hodges, 1992). The reasoning is that lexical retrieval and oral reading share the same component, the phonological output lexicon (e.g., Gvion & Friedmann, 2013). If the phonological output lexicon activated in word production is also used in reading aloud, it follows that a naming deficit (which involves the phonological output lexicon) might explain also a reading disorder (Kay & Ellis, 1987).

Friedmann and Lukov (2008) have linked developmental surface dyslexia with different forms of anomia. According to Friedmann and Lukov different subtypes of surface dyslexia can occur due to impairment at three different loci: orthographic input, semantics and phonological output. A problem at semantics or phonological output might result in both reading and naming difficulties. Seventeen participants with a diagnosis of developmental surface dyslexia took part in Friedmann and Lukov's study. The sample comprised two adults and 15 children aged from 10;8 to 15;10. Sixteen out of the 17 participants had naming performance within the normal range. None of the participants produced phonological naming errors, indicating intact phonological output (formal naming errors were phonologically and semantically related to the target word). Friedmann and Lukov stated that the orthographic lexicon was the locus of impairment for the developmental surface dyslexics, and that reading impairment in surface dyslexics was not due to phonological lexicon impairments.

The literature therefore leads to the prediction that developmental phonological dyslexics should have naming problems that would be characterized by poor accuracy, slow naming speed, difficulty with longer words and a high rate of phonological errors in picture naming since this form of reading disorder seems to be associated with a phonological deficit. Surface dyslexics, on the other hand, should be free from naming problems, according to the findings of Friedmann and Lukov, since the locus of their reading difficulty is in the orthographic input lexicon and this is a reading-specific process.

III.4. Research aims of the present study

Having reviewed the critical studies and identified the issues in need of addressing, I outline next the aims of the research and how they were addressed. Detailed descriptions of the methodology and of the findings are presented in Chapter IV and V.

The primary aim of the present research was to revisit the naming and phonological deficit hypothesis of dyslexia. This was achieved by using standardised and newly developed tasks of naming and its components, phonology and semantics, to assess a sample of dyslexic children. In addition, since there is increasing acceptance that there are different forms of developmental dyslexia (with different underlying causes), a classification scheme was used for delineating the reading profile of dyslexic children to examine whether picture naming difficulties might be specific to a dyslexic subtype (or subtypes).

In order to address the primary aim of the study, first a sample of typically developing (TD) children was assessed in the critical tasks. The relationship of semantics and phonology to naming and of all three to reading ability was examined in order to establish a context for the analyses of the data for the dyslexic children. This would provide a firm grounding for interpreting the results for the dyslexic sample and would also be likely to increase our understanding of the development of naming in children in general, since this is currently an under-researched area.

Children aged four to eight years with no known educational or reading difficulty constituted the typically developing sample. This age range was targeted because is thought to be important for the development of naming abilities (Funnell et al., 2006). The main sample of interest, dyslexic children, was recruited from school years 3 and 4 (ages 8 to 9) since literacy difficulties are often clearly established by this age. The dyslexic children were administered tests of text and single word reading. Subtyping was carried out on the basis of scores in a newly standardized test containing regular words, irregular words and nonwords.

In order to explore naming, a picture naming task was employed as a) it is a natural task for children, even young children (D'Amico et al., 2001), b) it involves all the stages of language production, (e.g., *lemma* access, phonological access) and c) it can provide information concerning semantic knowledge and phonological output (e.g., semantic and phonological naming errors). Many studies have explored naming abilities, but, as far as the author is aware, no study has provided both latencies and accuracy (as well as a qualitative analysis of the naming errors) in a representative age-range sample of children. For example, Funnell et al. (2006) recorded only accuracy and D'Amico et al. (2001) used an inadequate instrument to gather latencies (Masterson et al., 2008). Studies of picture naming in TD children demonstrated that the task can be used to collect latency data also in young children (D'Amico et al., 2001; Masterson et al., 2008). Naming latencies can provide a window into lexical processing, and in combination with qualitative analysis of naming errors, can offer further insight into the nature of the naming deficit.

To investigate whether children had knowledge of the items they were asked to name in the picture naming task, a word-picture verification task (WPVT) was developed. The reason for including this task was to ascertain whether a child was unable to name a picture because of a lack of knowledge of that particular item or whether it was because s/he was not able to retrieve the name. Alternative versions of this task consist of presenting a picture three times (not consecutively): once with a semantically related word, once with a phonologically related word and once with the target word. Another alternative is the multiple-choice task, which requires identifying a picture that matches a spoken word when the picture is presented with related distractor pictures. The WPVT was employed in the present research since, as noted in section III.2, it has been shown to be more sensitive than the multiple-choice task in identifying deficits in word comprehension and, in general, to eliminate forced guessing (Breese & Hillis, 2004; Cole Virtue & Nickels, 2004).

A picture-judgment task was developed to assess children's semantic knowledge. The reason for developing a non-verbal semantic task was the limitations of the previously available Squirrel-Nut Test (Pitchford & Eames, 1994). One of the main limitations of the Squirrel Nut test is that in some cases both the choice pictures and the target belong to the same semantic category (e.g., *violin*, *trumpet* and *guitar* are semantically associated). This reduces the sensitivity of the task. Also, some of the stimuli are repeated throughout the test (e.g., *sun*, *guitar*, etc). In the PJs task, the relationship between items was carefully controlled, so that the choices are semantic coordinates (one a distractor). Also, repetition of stimuli was avoided and psycholinguistic variables were available, as the words associated with the pictures were drawn from published sets (Druks & Masterson, 2000; Funnell et al., 2006). Finally, since the experimental task described previously requires speeded responses, two measures of reaction times, simple and choice reaction time tasks, were devised to control for individual variability in sensory-motor response times.

In order to examine the component processes of naming children were administered assessments of phonology and semantics. To ascertain whether any naming difficulties in the dyslexic children might be due to articulatory or verbal memory problems standardized tasks of articulation and digit span were included. There is evidence (reviewed in Chapter II) for impairment of working memory components in some children with reading difficulties (e.g., de Jong, 1998; Helland & Asbjørnsen, 2004; Beneventi, Tønnessen, Ersland, & Hugdahl, 2010; although also see Jones & Macken, 2015), and, as far as we know, there is no evidence yet concerning whether working memory would differ between children with different subtypes of dyslexia.

To conclude, the present study involved revisiting the naming and phonological deficit hypothesis of dyslexia by 1) exploring naming abilities in a representative sample of typically developing children aged 4 to 8 years and a group of dyslexics aged 8 to 9, 2) assessing picture naming with a task that takes into account accuracy, latency, a qualitative analysis of errors, by excluding on an item-by-item basis unfamiliar pictures according to the word-picture verification task, and examination of the influence of psycholinguistic variables, 3) including independent assessment of the components of naming: phonology and semantics, and 4) examining the potential naming deficit in the dyslexic children when their reading profile is classified into subtypes of dyslexia according to the Dual Route theoretical framework.

CHAPTER IV. Methods and Results for Typically Developing Children

IV.1. Introduction

This chapter outlines how the research aims of the present study were addressed in relation to the TD children. After this, the methodology used to investigate the performance of the TD sample (and the dyslexic children) in the critical tasks is discussed and the relative results are presented. In brief, experimental tasks were devised consisting of a picture naming task, a word-picture verification task, picture-judgment task and simple and choice reaction time tasks as measure of processing speed. The dependent variables of interest in the experimental tasks were accuracy and latency. In addition, qualitative analysis of picture naming errors was conducted and analyses were carried out looking at the effect of psycholinguistic variables on naming performance. Standardised tasks tapping semantics and phonology were also employed. Performance in the experimental and standardised tasks was examined in relation to lexical and sublexical reading ability. I next summarise the analyses that were conducted on the data to address the research aims, and then outline the experimental hypotheses, and how the data laid the foundation for the analyses of the results from the dyslexic children (reported in the next chapter). The methods and the results are presented after this.

Developmental progression of typically developing (TD) children in the experimental and standardised assessments

To examine for developmental progression of performance of the TD children in the tasks employed, data were plotted for accuracy and latency (where applicable), and regression equations with chronological age as the dependent variable were calculated. Following these, further examination of the picture naming data is reported. The reason for this is that we saw in Chapter III that a number of psycholinguistic variables affect picture naming accuracy and latency, according to the different stage of the speech production process studied. Therefore it was informative to conduct subsidiary analyses with the picture naming data looking at the effect of a range of variables. Ratings for spoken frequency, imageability and visual complexity were collected for the picture naming stimuli from adult participants. Values for phonological neighbourhood size and word length were also calculated. For the purposes of the analyses, TD children were divided in two groups according to their chronological age: a younger and older group. Regression analyses were conducted with the five aforementioned psycholinguistic variables as predictors, and naming accuracy per item was the dependent variable. Contrary to previous studies of picture naming in dyslexia, in which word frequency and word length of the items used in the picture naming task were manipulated (Nation, Marshall, & Snowling, 2001; Swan & Goswami, 1997), in the present study I examined the effect of a range of psycholinguistic variables tapping all the processes involved in speech production (from object recognition to the stage at which phonology is assembled). Grouping the children according to age meant that the analyses allowed for examination of whether the pattern of predictors showed developmental differences in the TD children. The results reported here allowed for comparison with equivalent analyses conducted with the data of the dyslexic children (reported in the next chapter).

Relationship of naming and semantics and phonology, and of all three to reading

This research question was addressed by examining the relationship between picture naming with the assessments of semantics and phonology, and by examining the correlations between picture naming, semantics, phonology and nonword and irregular word reading. Nonword and irregular word reading were assessed by means of the Diagnostic Test of Word Reading Processes (Forum for Research in Literacy and Language, 2012).

Experimental hypotheses

The experimental hypotheses were as follows. First, I hypothesised a developmental progression in the experimental tasks. According to the studies of naming in children reviewed (e.g., Budd, Hanley, & Griffiths, 2011), the rate of naming errors should decrease with age. Moreover, it was hypothesized that older children would be more accurate and faster than the younger children in all the experimental tasks. The performance of the TD children in the experimental tasks would be used to investigate whether dyslexic children perform accordingly. In particular, if there were a developmental progression in the experimental tasks for the TD sample, we would expect the same progression in dyslexic children as well. It follows that if the picture naming abilities of the dyslexic children in the present research are similar to those of the younger children of the same reading age, then we would affirm that dyslexics' naming abilities resemble those of younger children, in line with the arguments of Snowling et al. (1988). However, if the naming abilities of the dyslexic children were found to be worse than those of younger children of the same reading age, then we would infer that the dyslexic children's naming is severely impaired, and therefore deviant rather than delayed.

Regarding examination of the influence of the different psycholinguistic variables on naming, it was not possible to formulate precise hypotheses regarding which ones would have the strongest influence, since the range of variables explored in the current study has not been explored in regard to naming in children of the age sampled in the current research. On the basis of previous literature (Barry et al., 2001; D'Amico, Devescovi, & Bates, 2001; Masterson et al., 2008) it was expected that spoken word frequency and word length would be significant predictors (e.g., D'Amico et al., 2001), also imageability would be likely to exert an influence (Masterson et al., 2008). For the dyslexic children, Swan and Goswami (1997) and Nation et al. (2001) have found a strong influence of word length on picture naming. It was considered informative to examine whether the same patterns of prediction would be found in the dyslexic children, and whether these would differ according to potential differences in reading profiles among the dyslexic children.

With regard to the relationship of naming, semantic and phonological ability and reading, on the basis of the literature review I expected to find a stronger relationship of the semantic measures with irregular word reading and the phonological measures more strongly associated with nonword reading. This differentiation is expected to be stronger for older children when decoding skills are more well-established and so used less for processing real/familiar words (Ricketts, Davies, Masterson, Stuart, & Duff, submitted). This would provide the context for investigating whether the relationships that hold for the TD children also hold for the dyslexic children, in that if different patterns of reliance on lexical and sub lexical processes in the younger and older children are associated with strengths/weaknesses in specific cognitive processes (e.g., less well developed phonological skills and naming abilities in those children showing less reliance on sublexical skills), then we would expect to find the same relationship for the dyslexics.

In summary, in order to address the overarching aim of this thesis, data from typically developing children in the critical tasks were obtained. This would provide the foundation for interpreting the results from the dyslexic sample. The data for each experimental task were examined for developmental trends. Regression analyses were then performed in order to establish which psycholinguistic variable most affected naming in the TD children. This was followed by correlation analyses in order to establish how naming is associated to reading and how these two abilities are associated to semantics and phonology across the age range studied.

In the Participants section the characteristics of the TD children are given. Following this, there is a description of the standardised and experimental measures used to assess the children in the present study, and a description of the standardised tasks used to investigate phonological and semantic abilities.

IV.2. Method

IV.2.1. Participants

Typically developing (TD) children were recruited from two mainstream primary schools located in Windsor and Hertfordshire, UK. All the children spoke English as their main and first language, and none of the children selected had an official statement of special educational needs. Children who were unwilling to take part in one or more tasks during the assessment (N = 3) and those children whose percentile score was below 7 in the nonverbal ability test (described in the *Materials* section) (N = 1) were excluded from the final sample. Altogether, 86 children from nursery to Year 3 were included. A summary of the participant characteristics for the sample in terms of gender, age and number of children in each school year group is given in Table IV.1.

Table IV.1 Summary of participant characteristics of the first group of recruited typically developing children according to school year (standard deviations are in parentheses)

Year Group	Gender	N	Age in months	Min	Max
Nursery	4F, 7M	11	53.00 (2.57)	50	57
Reception	6F, 5M	11	61.36 (3.70)	55	66
Year 1	10F, 10M	20	72.00 (4.60)	63	81
Year 2	10F, 11M	21	84.95 (4.43)	76	95
Year 3	11F, 12M	23	97.68 (4.74)	91	106

When data collection began with the poor readers it became clear that more TD children were required to supplement the chronological age (CA) and reading age (RA) control groups. Therefore a further 36 TD children from Years 1-4 were recruited from five mainstream primary schools, where children with specific reading difficulties were also assessed. Four schools were located in north London and one in Surrey. Ten children were recruited in Year 1, two in Year 2, 15 in Year 3, and 9 in Year 4. A summary of the participant characteristics of the additional TD children is given in Table IV.2. The same criteria for inclusion/exclusion were applied as for the originally recruited TD sample.

Table IV.2 Summary of participant characteristics of the second group of recruited typically developing children according to school year (standard deviations are in parentheses)

Year Group	Gender	N	Age in months	Min	Max
Year 1	5F, 5M	10	75.10 (4.28)	68	83
Year 2	1F, 1M	2	81.50 (2.12)	80	83
Year 3	10F, 5M	15	99.13 (3.5)	93	105
Year 4	3F, 6M	9	110.00 (3.74)	104	115

A summary of the participant characteristics for all the TD children according to their school year group is given in Table IV.3.

Table IV.3 Summary of participant characteristics for the total sample of typically developing children according to school year (standard deviations are in parentheses)

Year Group	Gender	N	Age in months
Nursery	4F, 7M	11	53.00 (2.57)
Reception	6F, 5M	11	61.36 (3.70)
Year 1	15F, 15M	30	73.04 (4.66)
Year 2	12F, 11M	23	84.65 (4.37)
Year 3	21F, 17M	38	98.29 (4.27)
Year 4	3F, 6M	9	110.00 (3.74)

Participating schools served socially mixed catchment areas. The quality of education provided in English primary schools is assessed by Ofsted inspection. In the most recent inspections of the schools from which the children were recruited, pupil achievement was considered to be outstanding in three schools (43%) and good in four (57%). A summary of the nonverbal ability and receptive vocabulary scores for the TD children from the different primary schools is given in Table IV.4. Details of the assessments given to the children are provided in the next section (*Materials*). There was no statistically significant difference in the abilities of participating children according to school (one-way ANOVAs, with Welch–Satterthwaite correction, for nonverbal ability: $p = .134$, receptive vocabulary: $p = .257$).

Table IV.4 Summary of nonverbal ability and receptive vocabulary scores for the typically developing children according to school (standard deviations are in parentheses)

School	N	Nonverbal ability (T score)	Receptive vocabulary (SS)
1	42	52.24 (7.68)	100.21 (12.28)
2	44	53.19 (8.77)	101.19 (9.46)
3	8	49.22 (5.19)	99.11 (7.56)
4	7	52.00 (4.82)	103.43 (8.48)
5	8	52.50 (6.43)	99.88 (8.54)
6	6	49.50 (6.19)	103.17 (6.85)
7	7	51.33 (4.76)	95.57 (9.73)

IV.2.2. Materials

The standardised tests used to assess nonverbal ability, semantic, phonological abilities and reading, as well as the experimental tasks are described in this section (a diagram summarizing the dependent variables is given in Appendix A). The assessments and the procedure for their administration are described first, and then there is a section where the score used in the analyses for each of the experimental tasks are outlined.

IV.2.2.1. Standardised assessments

IV.2.2.1.1.Non-verbal ability

The Pattern Construction subtest from the BAS (Elliot, Smith, & McCullouch, 1997) was used to screen all the children in the present study. Children were asked to reproduce a two-colour geometric display of progressive complexity, using two to nine identical cubes and two-colour squares. This is a timed task with a maximum raw score of 74. Standardised *T* scores (*M* = 50, *SD* = 10) and percentiles are provided. A percentile score below 7 was used as a criterion for exclusion of children (both TD and dyslexic) from the study[16].

IV.2.2.1.2.Semantic measures

Two tasks were used to assess semantic knowledge: a receptive and an expressive vocabulary test. The assessment of receptive vocabulary was the British Picture Vocabulary Scale III edition (BPVS; Dunn et al., 2009). Each trial consists of four pictures, one of which is the match for the orally presented word, and three distractors. The test has been standardized in the UK on a sample of children ranging in age from 3;00 to 16;11. The BPVS test was administered to all the children, TD and dyslexics. The BPVS provides standardised scores (*M* = 100, *SD* = 15) and these are reported.

To assess expressive vocabulary in children aged 6 years old and above, the vocabulary subtask from the Wechsler Intelligence Scale for Children (WISC-IV, UK; Wechsler, 2004) was used. This consists of 36 verbally presented words to be

[16] This criterion was established in accordance with the WOrd project (Word Retrieval and Developmental project is a joint research project among three institutions: University College London, Birkbeck College and UCL Institute of Education). In the present study, all the typically developing and the dyslexic children obtained a standard score within 1 *SD* of the mean (i.e., *T* score > 40) in the pattern construction subtask from BAS.

defined by the participants with a score of 0, 1 and 2 given for answers (maximum score = 72). The vocabulary subtask from the Wechsler Preschool and Primary Scale Intelligence Revised (WPPSI-R, Wechsler, 1989) was used to assess expressive vocabulary of the children aged 4;00-5;11. The task consists of two parts: the first involves the presentation of three objects, which the participants are asked to name, with a score of 0 or 1. The second part consists of 22 verbally presented words to be defined with a score of 0, 1 and 2 (maximum score for entire subtest = 47). The expressive vocabulary test was administered to all the dyslexic children but to only 70 (57%) of the TD children, as it was introduced as an additional semantic measure after data collection had begun and when it seemed that the picture-judgment task (described below) was proving too easy for older children. The expressive vocabulary subtask from the WISC-IV, UK and from the WPPSI-R (used for the younger children) provides a scaled score (M = 10, SD = 3), which is reported in the present study.

IV.2.2.1.3.Phonological measures

Three assessments were employed to assess phonological skills: nonword repetition, blending and rapid naming. For the first, the Children's Test of Nonword Repetition (CNRep; Gathercole & Baddeley, 1996) was employed. This has been described as an assessment of phonological short-term memory. The test consists of 40 nonwords of increasing length (from 2 to 5 syllables). Items also differ in terms of phonological complexity and wordlikeness. The nonwords were played from a laptop computer (using the test CD) and children were asked to repeat them. The CNRep has been standardized in the UK on a sample of children aged 4;00 to 8;11. Responses for each of the 40 items were scored as correct or incorrect according to the manual instructions. Standardised and percentage accuracy scores are reported because some of the children were aged 9 years and above.

The blending subtask from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) was also employed. The test involves presentation of 20 strings of phonemes of increasing length (2-10 phonemes). The blending task was played from a laptop computer using the CD provided. Children were asked to blend the sounds to make a word. The CTOPP provides US standardization data for children and adult in the age range 5;00 to 24;11 years. Percentage of correct responses was calculated for each child because the

CTOPP was standardized in the USA and some discrepancies have been reported between the performance of TD UK children and the American standardization sample of Wagner et al. (1999) (Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007).

Two rapid naming tasks, of objects and of digits, from the Phonological Assessment Battery (PhAB; Frederickson, Frith, & Reason, 1997) were administered. Each task involves the presentation of 50 stimuli (a matrix of line drawings of common objects for the picture task and digits for the digit task) in random order. The time to name the objects or digits is recorded. The test has been standardized in the UK on a sample of children aged 6;00-14;11 and it provides a standard score (M = 100, SD = 15). In the present study, only children aged 6 and above were administered the rapid naming tests. Both standard score and raw score (in seconds) are reported.

IV.2.2.1.4.Single word reading and passage reading comprehension

Reading assessment in the current study was carried out with two tests, one assessing single word reading and one assessing text reading. For the former, a relatively new UK standardized reading assessment that allows for examination of the subcomponents of reading was employed, the Diagnostic Test of Word Reading Processes (DTWRP, Forum for Research in Language and Literacy Group, 2012). This comprises three subtasks involving nonwords, irregular words and regular words. According to Castles and Friedmann (2014) a test incorporating these three types of printed letter string allows for the detection of at least three types of dyslexia (surface, phonological and mixed).

The assessment of text reading was carried out with a test recently standardised in the UK, the YORK Assessment of Reading for Comprehension (Snowling, Stothard, Clarke, & Bowyer-Crane, 2009). This incorporates assessment of passage reading accuracy, rate, and comprehension. This test replaced and overcame some of the problems of The Neale Analysis of Reading Ability (Neale, 1989) (see for example Hurry & Doctor, 2007), in that dyslexic children were penalised in the Neale test by the discontinuation rules (they were likely to read fewer passages and, as a consequence, have the possibility to answer fewer comprehension questions). In the present study the results of the reading assessments were used for evaluation of the level of reading ability in the TD children and of the level of deficit in reading in the dyslexic children. They were also used for purposes of determining the reading age and chronological age matched control groups, and also for profiling the reading patterns in the dyslexic children.

In the DTWRP test children are asked to read items aloud (testing is individual) starting with nonwords, then exception words and finally regular words. There is a stopping rule for each subtest of five consecutive items incorrect. There are 30 items in each subtest and items become increasingly longer and orthographically complex throughout each subtest. In constructing the test the authors matched regular and irregular words for printed word frequency using the Children's printed word database (Masterson, Stuart, Dixon, Lovejoy, & Lovejoy, 2003). The nonwords were constructed by combining fragments of the regular and irregular words to ensure that orthographic familiarity was similar for words and nonwords (e.g., the nonword *wem* is a combination of the words *well* and *them*). The test provides an overall reading standard score, and stanine scores ($M = 5$, $SD = 2$) for the three subtests. According to the test manual, stanine scores equal to 4, 5 and 6 are in the average range, a stanine score of 3 is below average and of 7 is above average. The DTWRP was standardized in the UK on a sample of children aged 5;00 to 12;11.

In the assessment of text reading and reading comprehension with the YARC, children are first tested with the Single Word Reading Test (SWRT). The child's score in this is used to provide an evaluation of the starting point for the assessment of reading comprehension. The SWRT contains words of increasing difficulty (maximum score 60). It is untimed and is administered individually. On the basis of the SWRT score, two comprehension passages are selected and administered to each child. Testees are asked to read each passage aloud and the time taken is recorded. Children are given eight comprehension questions to answer after each passage is read. There is a discontinuation rule for reading accuracy, which varies according to the passage level. Also, in order to select the additional passage, a score of at least 5 out of 8 for comprehension should be met in order to administer the next passage at the higher level. With a score of 4 or less out of 8 for comprehension, a passage at a lower level is administered. The comprehension questions assess literal and inferential comprehension skills. The YARC test has been standardised in the UK on a sample of children aged 5;00 to 11;11 years.

IV.2.2.2. Experimental Tasks

Five new tasks were developed to evaluate picture naming, knowledge of the concepts depicted in the stimuli in the picture naming task (by means of a word-picture verification task), associative semantic knowledge, and speed of processing.

IV.2.2.2.1.Picture Naming

Materials

The pictures from the study of Funnell, Hughes and Woodcock (2006) were used. The list of items is provided in Appendix B. They consist of 72 black and white line drawings of objects from four categories of 18 items each. Two categories (Animals, Fruits/Vegetables) represent living things and two (Implements and Vehicles) represent artefacts. Line-drawn pictures were preferred to coloured pictures to avoid the issue that recognition latency varies between colours (Levelt, 2002). The items depicted in the pictures have only one basic level name and there are no superordinate items. Also, the items differ in age-of-acquisition (AoA) as assessed objectively by Funnell et al. in their study, so that floor and ceiling effects are unlikely to be found. Using this set of pictures meant that it was possible to use the actual age of acquisition values obtained by Funnell et al. in the present study. A total of 22 items (6 animals, 6 fruits/vegetables, 5 implements, and 5 vehicles) reached a probability of more than 50% of being correctly named at the earliest age level (i.e., before 43 months) and so they were given (by Funnell et al. 2006) an objective AoA value for naming of < 43 months. Seventeen items (5 animals, 6 fruits/vegetables, 3 implements and 3 vehicles) did not reach 50% level of probability of being named correctly at any age and were given an AoA objective value for naming of > 138 months. The objective age of acquisition values of the items in months are reported in Appendix B.

Items were presented in prototypical orientation and although the size of the image was not proportional to their actual size, no object was depicted in a larger size than it appears in reality (as in the study of Funnell et al., 2006).

Values for spoken word frequency, imageability, visual complexity, word length and number of phonological neighbours were collected for the pictures and their verbal labels for the purposes of carrying out item-based regression analyses in the present research. Three scales were devised to collect ratings for spoken frequency, imageability and visual complexity. The 7-point rating scales were uploaded to the

WOrd project[17] website (https://sites.google.com/site/wordfinding/). The link to the website was sent to students and staff at UCL and the UCL Institute of Education. Only ratings of participants with English as a main and first language were analysed. Rated spoken frequency was used as a measure of word frequency. Spoken word frequency is considered a more conceptually appropriate measure for use in analyses of picture naming responses (see Johnson, Paivio, & Clark, 1996). Also, results from Meschyan and Hernandez (2002) showed similarities between rated and objective word frequency. Rated frequency has been reported to be a better predictor of naming latencies than is objective frequency. Balota, Pilotti and Cortese (2001) suggested that rated frequency may retain more information over time than objective frequency measures. Spoken frequency ratings were obtained from 49 participants (12 males and 37 females) aged 18 to 72 years (M = 31.7; SD = 12.69). Participants were asked to rate how frequently the pictures' verbal labels (presented in printed format) are used in speech. Instructions asked participants to provide their rating on the 7-point Likert scale provided for each item, where 1 indicated words used very rarely and 7 words used most frequently.

Imageability ratings for the verbal labels were collected from 40 participants (13 males and 27 females) aged 19-72 years (M = 37.4; SD = 14.25). The instructions were adapted from Paivio, Yuille and Madigan (1968) and explicitly mentioned sensory experience in the form of mental pictures, sounds, tactile and olfactory images. The verbal labels were presented, as in the collection of the spoken frequency ratings, in printed form with a 7-point scale for each item (1 = words arousing images with the greatest difficulty, 7 = words arousing images most easily). Word length values in terms of number of phonemes of the verbal labels of the pictures were initially calculated since the interest was in spoken word production. To follow Swan and Goswami (1997), two other measures of word length, number of letters and number of syllables, were also calculated. In their analyses, Swan and Goswami used a joint measure of word length calculated as the arithmetic sum of word length in phonemes, syllables and letters for each picture. This measure was adopted in the analyses of the results from the present study.

[17] The WOrd (Word Retrieval and Developmental) project is a joint research project among three institutions: University College London, Birkbeck College and UCL Institute of Education.

Visual complexity ratings for the 72 pictures were collected from 38 participants (6 males and 32 females) aged 25-76 (*M* = 40.7; *SD* = 13.56). Instructions from Snodgrass and Vanderwart (1980) were used. Participants were asked to rate the complexity of the drawings, rather than the complexity of the real-life objects they represented, using a 7-point scale, where 1 indicated very simple and 7 very complex.

Number of phonological neighbours of the pictures' verbal labels was calculated using two procedures: the first (*Phonological Neighbours 1*) involved counting the number of words obtained by replacing each phoneme of the verbal label in turn with every other phoneme (Masterson et al., 2003). Proper nouns were excluded from the count. The second count (*Phonological Neighbours 2*) included, in addition, words that differ by one phoneme added to or deleted from the target and included also the plural form for singular nouns (Davis, 2005). The latter count was used in the analyses in the present study as no association of the former measure with performance was found.

Appendix C provides the values for spoken frequency, imageability, visual complexity, word length (phonemes, letters, syllables and the joint measure) and phonological neighbours for the 72 stimuli. A summary of the values is given in Table IV.5.

Table IV.5 Mean values for psycholinguistic variables for the 72 items used in the picture naming task (standard deviations and standard errors are in parentheses)

Variables	Mean (SD)	Skewness (SE)	Kurtosis (SE)	Min	Max
Spoken frequency	3.06 (1.33)	.52 (.28)	-.68 (.56)	1	6
Imageability	5.31 (.74)	-.57 (.28)	.22 (.56)	3	7
Word length in phonemes	5.51 (1.76)	.04 (.28)	-.56 (.56)	2	9
Word length in letters	6.70 (1.84)	.049 (.283)	-.814 (.559)	3	10
Word length in syllables	2.11 (.76)	.598 (.28)	.474 (.56)	1	4
Joint measure of word length	14.34 (4.08)	.051 (.28)	-.530 (.56)	6	23
Phonological Neighbours 1	1.94 (3.89)	2.72 (.28)	7.75 (.56)	0	20
Phonological Neighbours 2	3.22 (4.82)	2.99 (.28)	10.60 (.56)	0	28
Visual Complexity	3.36 (.97)	-.03 (.28)	-6.61 (.56)	1	5

Apparatus

The task was programmed using the experimental software package DMDX (Forster & Forster, 2003) running on a COMPAQ Presario V6000 laptop with an Intel Core Duo T2300 processor and a 15.4 inch screen. The spoken responses were recorded using an external microphone connected to the laptop. CheckVocal software (Protopapas, 2007) was used to extract naming latencies from the soundfiles. The software was used rather than a voice key interfaced with the computer as it allows for removal of responses involving accidental sounds, such as pre-verbalisations, coughs and verbal hesitations from the naming latencies. This results in a higher rate of useable naming latency data.

Procedure

The 72 pictures were presented in one session divided into three blocks of 24 items. The task lasted about 20 minutes. The session commenced with the calibration of the microphone, followed by instructions and a short practice session involving three pictures (*cat, banana* and *shoe*) not used in the main experiment. The instructions appeared on the screen of the computer and were read aloud by the researcher. Children were asked to speak as clearly as they could, to say the name of the pictures as fast as they could and to use a single word for each picture. In the event of an unknown/unfamiliar picture being presented, children were asked to try to find the name of the picture. Feedback was given after the practice items only. The children's verbal responses were noted by the researcher during testing and checked later using the audio recording.

Each trial began with the presentation of a fixation cross in the centre of the screen for 500 msecs. Then the picture appeared and stayed on the screen for a maximum of 5000 msecs. If no response was produced after 5000 msecs, a sound alerted the researcher to move to the next picture by pressing the left button on the mouse. If the children answered before the time out, the researcher terminated presentation of the picture by pressing the right mouse button on the mouse and moved to the next trial by pressing the left button. After the picture was named, there was an interval of 20 ticks (the measurement unit in DMDX which corresponds to circa 320 msecs) before the next trial was initiated. Four fixed randomized orders (A, B, C and D) were rotated across children during testing. No more than two objects from the same category appeared in succession. At the end of each block, a concluding sentence appeared indicating that the block had finished. Children were invited to rest before the researcher started the next block by pressing the left button on the mouse and a new introductory sentence indicating the block that was to follow appeared. Children were alerted by the researcher that a new block was about to begin.

IV.2.2.2.2.Word-Picture Verification Task (WPVT)

The WPVT was developed to assess children's knowledge of the items in the picture naming task. It involved presenting one picture at a time on the computer together with a pre-recorded spoken word. On one occasion the target picture was presented with its matching verbal label and on another, the picture was presented with a semantically related word. Children were asked to indicate whether the spoken word corresponded to the picture or not on each trial.

Materials

The items from the picture naming task together with seventy-two semantically related words were used to develop the WPVT. The semantically related words were selected from the same semantic categories as the target pictures: animals, fruits/vegetable, vehicles and implements, but were visually dissimilar (e.g., *bus*/*train*). The words were also as phonologically dissimilar as possible from the target words (e.g., there were no shared initial phonemes) (e.g., Kay & Ellis, 1987).

A pilot study was conducted with five adult participants in order to ascertain the appropriateness of the items chosen for the WPVT. As a result, the items *spade* and *beetroot* (associated with *trowel* and *radish*, respectively) were replaced with *shears* and *potato* respectively, leading to the following new pairs: *shears/trowel*; *potato/radish*; *beetroot/mushroom*. A second pilot study was carried out with ten children aged between 4 and 5 years old in order to investigate the feasibility of the assessment and the items chosen.

Ethical approval and parental consent were obtained before conducting the pilot study. The children, all from a day nursery in North London, were administered the full battery of standardised and experimental tasks. Since the results showed that children across all the ages named the picture of a *tapir* as "elephant" in the picture naming task, we decided to use the new pair *elephant/tapir*[18] for the WPVT.

The closeness of the semantic relationship of the target and semantically related distractor across pairs was examined to check whether the target pairs (e.g., *asparagus-leek*) were considered closely related relative to random pairings. Semantic similarity ratings were collected from 40 adult participants with a scale consisting of a mix of related pairs and non-related pairs from the same semantic category (i.e., randomly paired targets and distractors). The instructions asked respondents to rate 144 word pairs according to how closely related they were in meaning. A 7-point

[18] Some way into data collection it was noted that the spoken distractor "*taxi"* was paired with both the target pictures *caravan* and *milk-float* in the WPVT, instead of there being separate distractors for the two targets. This error was identified once most of the TD data had been collected. Since the items *caravan-taxi* and *milk float-taxi* occurred in different testing sessions, it was decided to keep the items in the analyses on the grounds that children would be unlikely to notice the repetition of the distractor given the time gap involved between successive presentations.

semantic relatedness scale (1= not at all related and 7= highly related) was used. Appendix D provides mean values for semantic relatedness for the stimuli. The non-related pairs (distractors) were devised by random pairing using the 72 verbal labels of the items in the picture naming task and the 72 semantically related words. Matlab software was used for the random pairings of the pictures and semantically related words.

Familiarity ratings were also collected for the 72 semantically related words used in the WPVT. Forty adult respondents were asked to rate familiarity of the printed words on a 7-point scale (1= very unfamiliar and 7= highly familiar). Instructions were adapted from Barry, Morrison and Ellis (1997). The mean ratings values are provided in Appendix E.

The 72 picture names and the semantically related words were recorded by a Speech and Language Therapist with a British-English accent in a recording room. The question recorded was “Is it (*item name*)?” (without using a determiner) for each picture name and semantically related word. The audio file was edited in order to obtain 144 audio files (wave files). 500 msecs of silence was added at the beginning and end of each file. The software used to trim each audio file was Audacity, downloaded from the web.

Apparatus

The experiment was programmed on a Windows laptop computer (COMPAQ Presario V6000) using the experimental software package DMDX (Forster & Forster, 2003).

Procedure

The WPVT was administered in two testing sessions separate from and following the session in which the picture naming task was presented. Each of the 72 pictures was shown twice, in one session the picture was shown with its verbal label, and in the other with the semantically related word. The 72 items in each of the two testing sessions were split into three blocks of 24 items, with a rest between blocks. The child was asked to press the Left Ctrl button for NO responses and the Right Ctrl button for YES responses.

Buttons were highlighted with stickers (smile signs). Following Breese and Hillis (2004) a response for an individual item was only considered correct if the child accepted the correct name on the match trial and rejected the semantically related word on the mismatch trial.

Each WPVT session began with an explanation of the task. Instructions were read aloud by the researcher followed by three practice trials (*cat*-dog; *banana*-banana; *shoe*-boot) initiated by pressing the left button on the mouse. Feedback was given for practice trials but not during the main testing session. Four fixed random presentation orders of the items were rotated across participants. Each trial began with the presentation of a fixation cross in the centre of the computer screen for 500 msecs. Limitations in the software meant that it was not possible to present the picture and the audio file and to record latencies at the same time. Therefore the task was programmed so that the picture presentation preceded the audio file by 16.62 msecs. At the end of each block a sentence indicating that the block had finished appeared. The next block commenced with an introductory sentence and children were alerted by the researcher that a new block was about to begin.

IV.2.2.2.3.Picture Judgement's Task (PJs)

The PJs task taps children's knowledge of associative semantic relationships. It was devised in collaboration with researchers on the WOrd project at University College of London (UCL)[19] in order to have a test of semantics that did not involve verbal production. As described on page 57 it was necessary to develop a new test to overcome the limitations of the previously available Squirrel-Nut Test of associative semantics for children (Pitchford & Eames, 1994). The computerized version permits collection of reaction times (RTs) as well as accuracy. Finally, the coloured images make the task more attractive and motivating for children.

Materials

Pictures of items in the published stimulus sets of Druks and Masterson (2000) and Funnell, Hughes and Woodcock (2006) were taken from the Shutterstock website (http://www.shutterstock.com/index.mhtml?language=it&gclid=COPfkqG8mqsCFZQOfAod82vzfw). The picture names are given in Appendix F. All pictures were of the same size, coloured, with a prototypical perspective and displayed on a white background except for *parachute*, *windsurf*, *library*, *picnic*, *garden* and *bell*. It seemed reasonable to use the proper blue background for *parachute* and *windsurf*. *Library* represents an interior. *Garden* and *picnic* are exterior pictures and *bell* is pictured on a handlebar of a bicycle. Sets of three items were devised – a target with

[19] The WOrd (Word Retrieval and Developmental) project is a joint research project among three institutions: University College London, UCL Institute of Education and Birkbeck College.

two pictures underneath. One of the two pictures presented in the lower part of the screen had an associative semantic relationship to the target, and the alternative item came from the same semantic category (e.g., target *pyjamas* presented with associate *bed* and distractor *chair*).

Apparatus

The experiment was programmed on a Windows laptop computer (COMPAQ Presario V6000) using Visual Basic software by IT staff at UCL, Division of Psychology and Language Sciences.

Procedure

There were three trials for practice and twenty in the main task. The task was administered in one session. The session commenced by explaining the instructions: children were asked to choose which of the two items in the lower part of the screen fitted best with the item at the top. Once instructions had been clearly understood, the task began. A fixation point appeared before each trial in the middle of the laptop screen. To select the picture on the left hand side, the child was asked to press the Z button, for the picture on the right, the M button. The two buttons were highlighted with stickers (smile signs). The researcher moved to the next trial by pressing the left button on the mouse. At the end of the practice and experimental session, a snowman and a jingle appeared in the middle of the screen indicating that the task had finished and children were praised for their effort.

IV.2.2.2.4.Simple and Choice Reaction Time

As a measure of general processing speed, two computerized tasks of simple and choice reaction time were adapted from Powell, Stainthorp, Stuart, Garwood and Quinlan (2007) and programmed using the DMDX experimental software (Forster & Forster, 2003). The simple reaction time task measured the time taken to make a key press response following the appearance of a target on the screen. The choice reaction time task required the children to identify which of two stimuli appeared on the computer screen, and to press the appropriate response key as quickly as possible. The tasks were included to evaluate individual variability in sensory-motor response times and whether the poor readers may have a general processing impairment (Snowling, 2008).

Materials

Six different coloured drawings of monsters were the target stimuli for the simple reaction time task. The stimuli and procedure were those described in Powell et al. (2007). Two dinosaur pictures (one green and one orange) from the Shutterstock website (http://www.shutterstock.com/index.mhtml?language=it&gclid=COPfkqG8mqsCFZQOfAod82vzfw) were used as stimuli for the choice reaction time task.

Procedure

In the simple reaction time task the six pictures of monsters and instructions appeared on the welcome screen. The instructions were always read aloud to ensure that children understood the task. Children were asked to make a key press response, using the space bar on the keyboard, as quickly as they could following the appearance of any one of the six targets on the screen. There were six items for practice followed by two blocks of 18 experimental trials each. Each trial started with the presentation of a fixation point (a black cross) in the centre of a white screen, followed by a lag and the appearance of the target stimulus. The duration of the lag varied, to prevent anticipatory responses, and was either, 300, 600 or 900 msecs. The different lags occurred in random order, as did each of the six target stimuli. The target remained on the screen for 1500 msecs.

In the choice reaction time task, children were asked to press the left Ctrl button as soon as the green dinosaur appeared, or the right Ctrl button if the orange dinosaur appeared. Green and orange stickers were placed on the corresponding buttons. As for the simple reaction time task, instructions were read aloud by the experimenter. A mouse press initiated the practice block of six items, with half containing the orange and half the green dinosaur. A black fixation cross appeared in the middle of the screen for 500 msecs followed by the target. Order of presentation of the different lag times was randomised, as was the order of appearance of the orange or green dinosaur. The lag times were 300, 600 or 900 msecs. The target stimulus remained on the screen for 1500 msecs. There were two blocks of 18 trials.

IV.2.3. Procedure

Ethical approval for the study was obtained from the Department of Psychology and Human Development at the UCL Institute of Education. Permission was obtained from the Head teachers of the schools and from individual parents/carers for each child to participate in the study (Information leaflets for parents and consent forms are in Appendix G). Children were tested individually in a quiet room at their school during normal school hours. The assessments were administered over four sessions for each child, each session lasting about 30 minutes. The tasks were administered in the same order for all the TD children and were balanced in terms of difficulty/effort required among the four sessions. All the sessions started with a computerized task, which children enjoyed. The order of task presentation is reported in Table IV.6.

The procedure for each testing session was made clear to the children before starting, and they were given the possibility to terminate the tasks at any time and to ask the researcher any questions they wished. They were reassured that this was not part of their school assessment and they were not expected to know the responses to all the questions. At the end of each session, children were praised for their efforts. The next section outlines the scores from the experimental tasks that were used in the analyses of the results.

Table IV.6 Order of administration of the tasks over testing sessions

Sessions	Task 1	Task 2	Task 3	Task 4
1	Simple reaction time	Picture naming	Single word reading from YARC	Vocabulary subtask from the WISC/WPPSI
2	Choice reaction	Picture-Judgment	Pattern construction from BAS	DTWRP reading
3	Word-Picture Verification 1	BPVS	Nonword repetition	Rapid naming objects and digits
4	Word-Picture Verification 2	Blending	YARC	

IV.2.4. Treatment of scores in the experimental tasks

Picture Naming

In the picture naming task, accuracy and latency of responses were recorded, and the transcription of the children's naming responses was used for qualitative analysis of the naming errors.

1. Accuracy and Latency

Responses were firstly classified as correct (including minor phonetic error, syllabification/stress errors, and acceptable alternatives[20]), incorrect (excluding modal responses) or incorrect modal responses (according to Funnell, Hughes, & Woodcock, 2006, modal responses are incorrect responses typical for that age, e.g., *yacht* > "boat"). When two or more responses were produced for a picture, only the first response was scored. Self-corrections were noted but only the first response was counted (Friedmann & Lukov, 2008). Common abbreviations such as *aeroplane* > "plane", elaborations such as *tank* > "army tank", British English words such as *can opener* > "tin opener" and American English words, such as *spanner* > "wrench",

[20] Acceptable alternative responses were: *rocket* > "space ship" or "space rocket"; *grater* > "cheese grater"; *yacht* > "sail boat"; *bus* > "double decker bus"; *plane* > "jet plane"; *caravan* > "camper van"; *parachute* > "man plus parachute"; *sledge* > "sled"; *ladle* > "scoop"; *barge* > "canal boat" or "narrow boat"; *motorbike* > "motorcycle".

were accepted as correct responses. Correct responses were scored as 1 (maximum score 72) while incorrect or modal responses were scored as 0. The proportion of correct responses was calculated for each child.

Naming latencies were recorded for correct trials. In the analysis of latencies, it was decided not to trim the data as it has been shown that this can lead to skewed distribution and there is not a general consensus for the appropriate method to use for children's latencies (Székely et al., 2003; Ulrich & Miller, 1994). The median score for each child was used rather than the mean, as the median is not influenced by extreme values and it is considered to be a robust measure.

2. Qualitative analysis of the naming errors

A scheme for classification of the naming errors was devised in collaboration with researchers (who are speech and language therapists and psychologists) on the WOrd project (https://sites.google.com/site/wordfinding/). The scheme was exhaustive and covered all the errors made by the children. The categories were based on those previously used by researchers studying language disorder in children and adults, and in particular, those found in the Test of Word Finding (German, 2000), in the Object and Action Naming Battery (Druks & Masterson, 2000) and in the study of Swan and Goswami (1997).

Five main categories (semantic, phonological, mixed, perceptual and other) were used to classify the errors, with sub-categories as follows. For the semantic errors sub-categories were: (1) coordinate (the response was from the same semantic class, e.g., *pear* > "apple"); (2) superordinate/general noun (e.g., *pineapple* > "fruit"); (3) subordinate (e.g., *dog* > "Dalmatian"); (4) functional (the response involved functional attributes/use of the target, e.g., *knife* > "cutter"); (5) locative (the response involved the location of the target, e.g., *flower* > "garden"); (6) compositional (the response involved material of the target, e.g., *fence* > "log"); (7) associative (the response co-occurs with the target, e.g., *switch* > "bulb"); (8) circumlocution (a multiword descriptive response); (9) visual attributes (the response involved similar physical features to the target, e.g., *web* > "net").

Errors were classified as phonological when the response shared at least 50% of the phonemes of the target word. Two sub-categories were used. The first was 'phonologically related nonword' involving (1) phoneme/morpheme exchange (phonemic approximation with transposition of a phoneme, e.g., *octopus* > "optucus" or morpheme, e.g., *seahorse* > "horsesea"); (2) phoneme/morpheme substitution (phonemic approximation with substitution of a phoneme, e.g., *octopus* > "octobus" or morpheme, e.g., *seahorse* > "seahouse"); (3) phoneme addition (phonemic approximation with added phoneme, e.g., *octopus* > "octgopus")[21]; (4) phoneme/morpheme omission (omission of a phoneme, e.g., *octopus* > "ocpus" or morpheme, e.g., *seahorse* > "sea"); (5) initial sound or syllable only (e.g., *octopus* > "oc"). The second sub-category of phonological error was 'phonologically related real words' (malapropism/formal error), involving a response semantically unrelated to the target but sharing at least 50% of the target phonemes (e.g., *octopus* > "octagon").

Naming errors that were both semantically and phonologically related to the target were classified as Mixed. Mixed errors were then sub-categorized as (1) semantic and phonological (e.g., *tractor* > "truck", *saw* > "sword"); (2) semantic then phonological (e.g., *tomato* > "ranish", *ruler* > "meas-rer") and (3) morphological/semantic/phonological (the response includes the target word morpheme, e.g., *telescope* > "telesomething", *whisk* > "whisker").

Perceptual errors were also sub-categorised as (1) perceptual visual misperception (e.g., *button* > "biscuit"); (2) perceptual part-whole (the error involved naming only part of the picture, e.g., *bicycle* > "wheel") and (3) named object in the picture but not the target (e.g., *parachute* > "man").

Other errors, which could not be included in the above mentioned categories, are: (1) metalinguistic and metacognitive comment (response showing knowledge of the target's phonological form, e.g., *thermometer* > "it's a long word", and response indicating a search for the target, e.g., "I know it, but I can't think of it"); (2) noun to verb (response where the associated verb was produced, e.g., *bell* > "rings"); (3) part of a compound (e.g., *milk-float* > "milk-van"); (4) unspecified noun (e.g., "thing, something, stuff"); (5) No response or Don't know response, and (6) Unrelated (no apparent relationship between the target and response).

Finally, qualitative information (recorded as a tag) about the child's behaviour was recorded for each response: (1) no tag; (2) an iconic gesture (mime of target word's function or an associated action); (3) gesture of frustration (miscellaneous, random or idiosyncratic gesture indicating awareness of retrieval difficulty); (3) perseveration (repetition of a response which the child had already produced; e.g., *radish* > "tomato" when tomato had already been given as a response) (4) self-

[21] There were no cases of morpheme addition.

correction (child produces the correct response after initially giving an incorrect response).

The categorisation scheme was found to produce good inter-rater reliability[22]. Percentage scores for each error category (calculated as a percentage of total error) were calculated for each child and were used in the analyses.

Word Picture Verification Task

Accuracy and latency data were recorded by the computer for the WPVT. A correct score (of 1) was given only if the correct name was accepted on the match trial <u>and</u> the semantically related word was rejected on the mismatch trial. Since the test consisted of match and mismatch trials for the 72 pictures (from the picture naming task), this led to a combined accuracy score maximum of 72. Percentage of combined correct responses and median key press response times for correct trials for each child were used in the analyses.

Picture Judgment (PJs) task

Accuracy and reaction times were recorded by the computer for the PJs task. Scores consisted of percentage of correct trials (out of a maximum 20) and median response times for correct responses.

Simple and Choice Reaction Time

The Simple and Choice reaction time tasks consisted of a total of 36 trials each. A cut-off time was imposed so that if no response had been made after 1500 msecs, the trial was terminated and the response was removed from the calculation of reaction times. In the Simple reaction time task, latency scores consisted of the median response time across responses. In the Choice reaction time task scores consisted of percent correct responses and median reaction time for correct responses.

[22] Inter-rater reliability was assessed using naming responses of 50 of the TD children (randomly selected to cover all the age ranges). The author and a UCL Institute of Education Psychology of Education MSc student independently classified the naming errors of the 50 children. The agreement was found to be 87% out of total errors.

IV.3. Results

IV.3.1. Introduction

The results are organised into the following sections. In the first, results for the experimental tasks of picture naming, word-picture verification, picture judgment, and simple and choice reaction time are reported. Subsidiary analyses are also reported in this section: a qualitative analysis of picture naming errors and item-based regression analyses investigating the effect of psycholinguistic variables on picture naming accuracy. In the second main section, the results from the standardised assessments of phonology and semantics are reported. In the third section reading performance in the subtasks of the DTWRP are reported[23]. For each of the three above-mentioned sections, descriptive statistics, plots examining potential developmental progression of scores, and intercorrelation analyses are presented. Intercorrelations among the measures for each of the sets of scores were examined in order to look for expected relationships (e.g., scores for measures tapping semantics would demonstrate significant correlations, as would scores for assessments of phonology), which would increase confidence in the validity of the measures, but also to look for unexpected results in order that this could be taken into consideration when examining the data from the dyslexic children. The final section of the *Results* presents correlation analyses where the sample of TD children were divided in two groups (younger and older), to examine the relations of semantics and phonology with naming, and of semantics, phonology and naming with reading.

Before conducting inferential statistics, exploratory data analyses were carried out and data distributions were examined for normality using the Kolmogorov Smirnov test of normality. Also, individual variables were checked for skewedness and for the presence of outliers. Parametric and nonparametric tests were carried out. Nonparametric analyses were conducted when assumption of parametric tests were violated. When the outcome did not change significantly, parametric analyses only are reported for brevity.

[23] Nonverbal ability standard and raw scores for the TD children are given in Appendix H.

IV.3.2. Experimental tasks: picture naming, word-picture verification, picture judgment, simple and choice reaction time

Before presenting the results for the experimental tasks it is necessary to note two issues that were taken into consideration regarding the picture naming data. It is well recognized that picture-naming errors may occur when the semantic representation of the items the children are asked to name is not fully established within the child's vocabulary. In light of this, in order to avoid a child's error profile including items that they did not know, in the analyses of the picture naming data that are reported, only those items the children were able to recognise, as ascertained by their responses in the word-picture verification task (WPVT), were included. The second issue regarding the picture naming data concerned compound words. The stimuli included 15 items whose verbal labels were compound nouns (e.g., *milk-float*). Swan and Goswami (1997) argued that, although other picture naming studies did include compounds (e.g., D'Amico, Devescovi, & Bates, 2001; Masterson, Druks, & Gallienne, 2008; Nation et al., 2001), it is possible that compound nouns could be represented as two separate nouns in the mental lexicon and this might be a matter of concern when attempting to control for word length. Therefore, in the present study the analyses were carried out twice, once with all the items included and once removing compound nouns and unfamiliar items (as ascertained by WPVT performance). It was decided that, in order to be in line with the previous most relevant picture naming studies (Katz, 1986; Swan & Goswami, 1997; Budd et al., 2011), the analyses with each child's naming profile adjusted by eliminating compound nouns and unfamiliar items would be presented. The mean percentage of types of naming errors made on the included items and the mean percentage of types of errors made on the excluded items are distributed fairly similarly, as observed by Budd et al. (2011). In particular, semantic errors (45.75% versus 45.69%), phonological errors (1.95% versus 1.91%), mixed errors (2.44% versus 2.48%), perceptual errors (1.72% versus 1.73%) and other naming errors (48.14% versus 48.18%). The results with all the items (i.e., compound nouns and unfamiliar items) included are given in Appendix I.

A summary is given in Table IV.7 of the scores for picture naming, in terms of (adjusted) percent accuracy and median latencies for correct responses (msecs), percent accuracy and median latencies (msecs) for the word-picture verification task (WPVT) and picture-judgment task (PJs), together with median latencies (msecs) for the simple and choice reaction time tasks, and percent accuracy for the choice reaction time task. Accuracy is not reported for the simple reaction time task, since there were no errors in this task. Exploratory data analyses (*EDA*) showed that all the variables were nonnormally distributed (Kolmogorov-Smirnov: all ps $< .01$). Standard z scores were calculated for each variable to check for outliers and it was found that for PJs latencies two cases had a z score more than or equal to 3 *SD*, and for PJs accuracy two cases had a z score more than 3 *SD*. The analyses were therefore conducted twice, once with the outliers in and once with them out. Since there was no substantial difference in results, the analyses with outliers included are reported. In spite of the nonnormal distributions, parametric correlations were carried out since the sample size was large enough according to the central limit theory ($N > 30$) and there were no serious outliers, except for the four cases in the PJs task.

Table IV.7 Summary of percentage accuracy and latencies (msecs) in the experimental tasks for the TD children according to school year group (standard deviations are in parentheses)

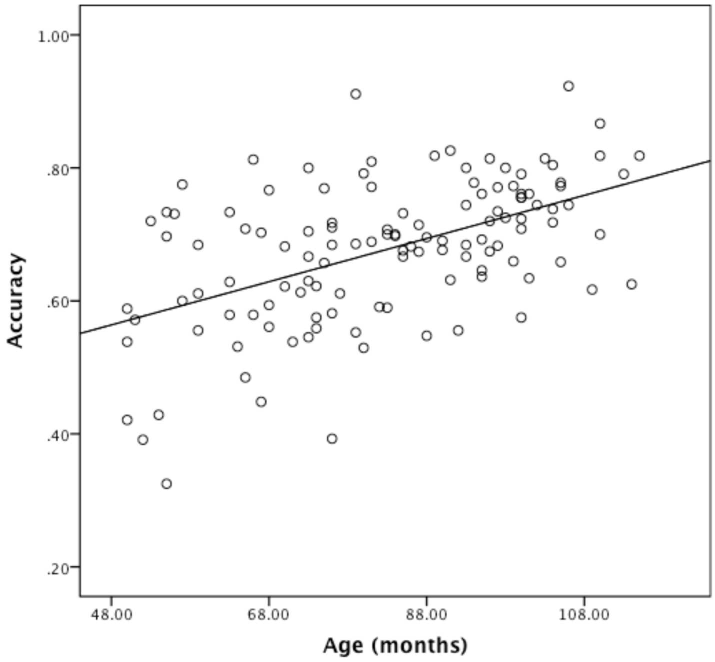
Measures	Nursery (N=11)	Reception (N=11)	Year 1 (N=30)	Year 2 (N=23)	Year 3 (N=38)	Year 4 (N=9)
Picture naming accuracy	54.98 (14.38)	65.20 (10.61)	65.06 (9.85)	67.40 (9.14)	72.92 (7.27)	74.42 (9.45)
Picture naming latency	1681 (221)	1485 (197)	1564 (380)	1434 (252)	1324 (233)	1230 (112)
WPVT accuracy	41.67 (12.01)	51.89 (13.46)	67.13 (8.35)	73.55 (8.81)	76.39 (6.30)	78.55 (2.96)
WPVT latency	2809 (626)	2786 (573)	2328 (309)	2340 (255)	2195 (240)	2219 (227)
PJs accuracy	79.09 (14.29)	84.09 (9.70)	87.67 (10.81)	92.61 (8.24)	95.79 (5.52)	98.33 (3.54)
PJs latency	7066 (2961)	5024 (1816)	3656 (1151)	3389 (694)	2876 (943)	3233 (636)
Simple reaction time latency	732 (227)	610 (166)	576 (214)	522 (134)	490 (134)	438 (104)
Choice reaction time accuracy	80.05 (.09)	89.14 (5.89)	94.12 (5.74)	94.08 (7.46)	97.81 (2.83)	98.15 (1.96)
Choice reaction time latency	689 (132)	624 (97)	576 (111)	597 (115)	518 (83)	480 (48)

Note: Percentage picture naming accuracy scores are adjusted to eliminate those items not recognised in the WPVT and compound nouns, as outlined in the text.

The data for accuracy and latency for picture naming, WPVT, PJs and choice reaction time tasks, as well as latencies for the simple reaction time task, were plotted against the children's ages in months. The resulting plots, together with regression lines, are depicted in Figure IV.1 to IV.5.

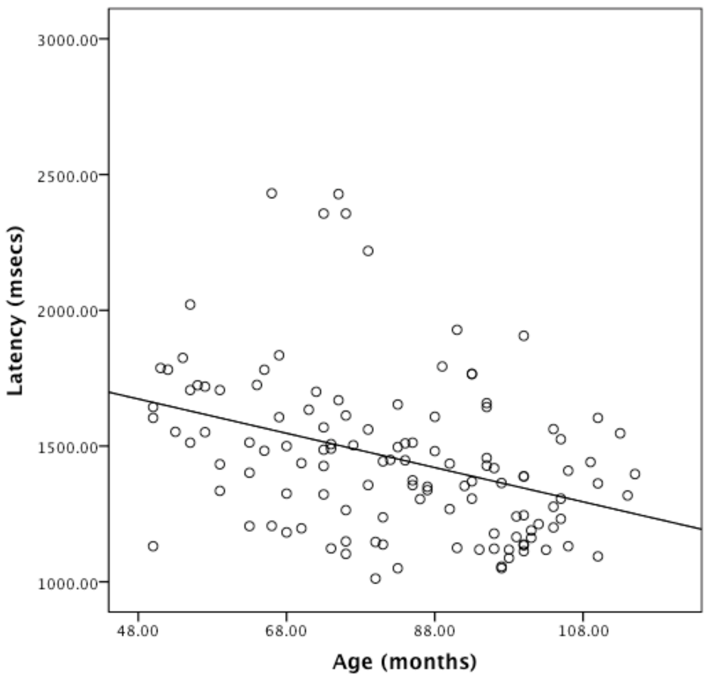
Figure IV.1 *Scatterplots showing a) accuracy and b) latencies (msecs) in the picture naming task as a function of chronological age in months for the TD children*

a)



y = .005x + .113, R^2 = .532, p < .0001

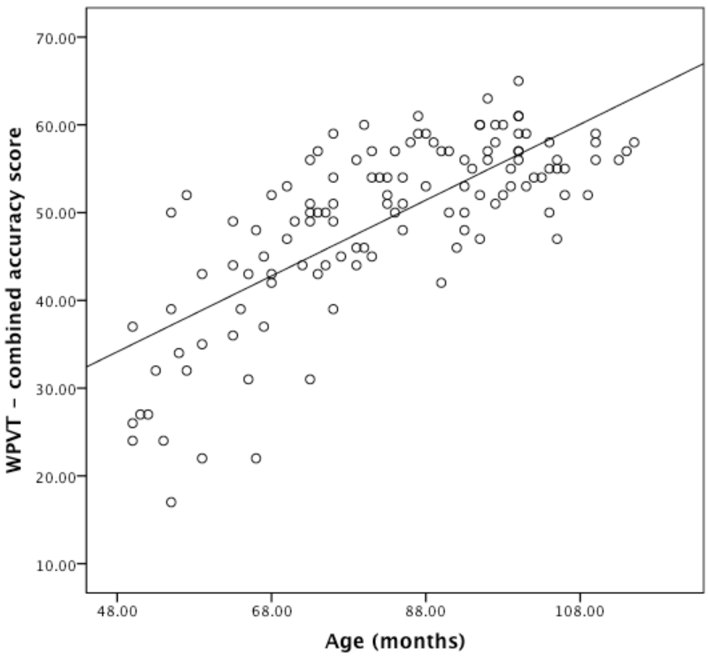
b)



y = -5.609x + 1917, R^2 = .111, p < .0001

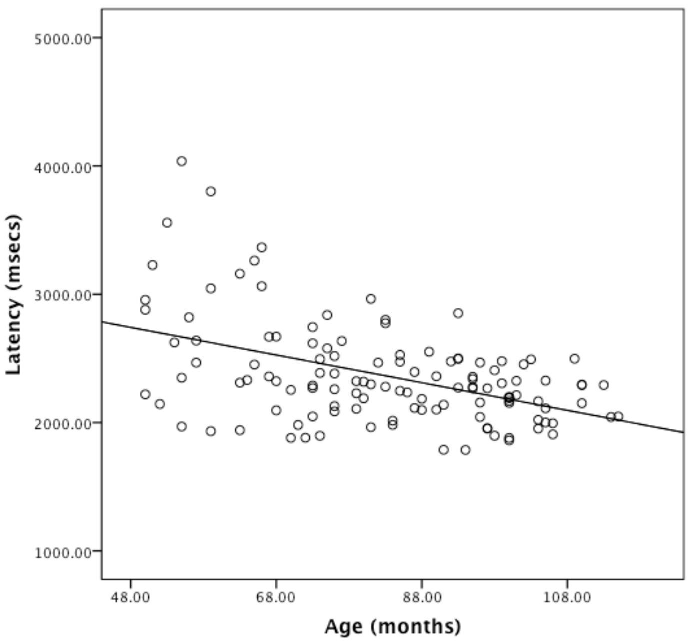
Figure IV.2 *Scatterplots showing a) accuracy and b) latencies (msecs) in the word picture verification task (WPVT) as a function of chronological age in months for the TD children*

a)



$y = .006x + .186$, $R^2 = .548$, $p < .0001$

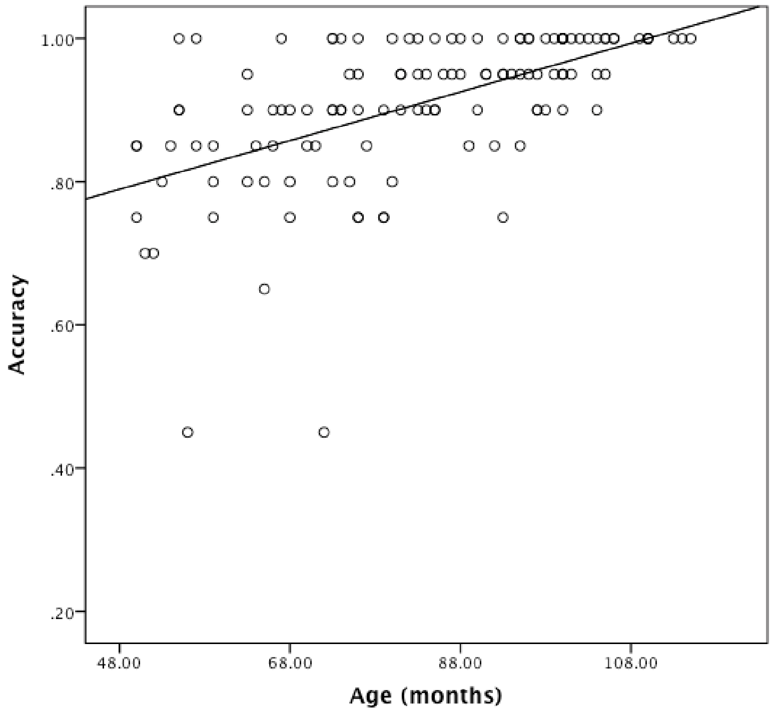
b)



$y = -10.78x + 3259$, $R^2 = .215$, $p < .0001$

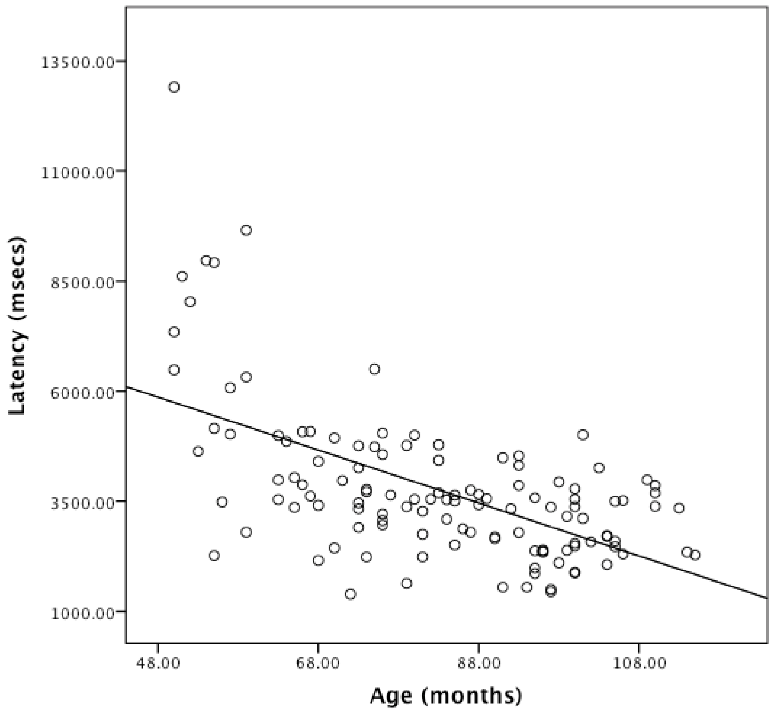
Figure IV.3 *Scatterplots showing a) accuracy and b) latencies (msecs) in the picture-judgment task (PJs) as a function of chronological age in months for the TD children*

a)



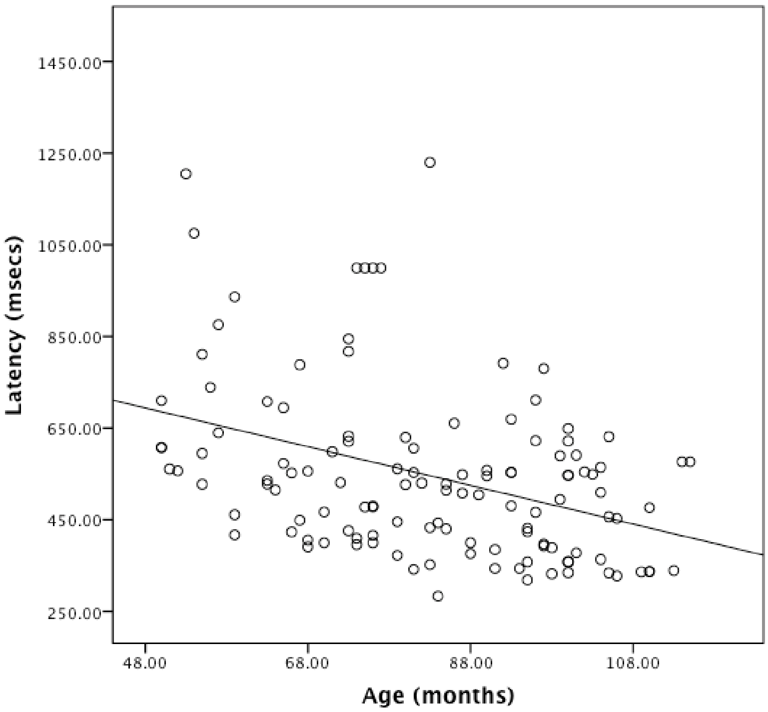
$y = .003x + .622$, $R^2 = .326$, $p < .0001$

b)



$y = -59.99x + 8731$, $R^2 = .338$, $p < .0001$

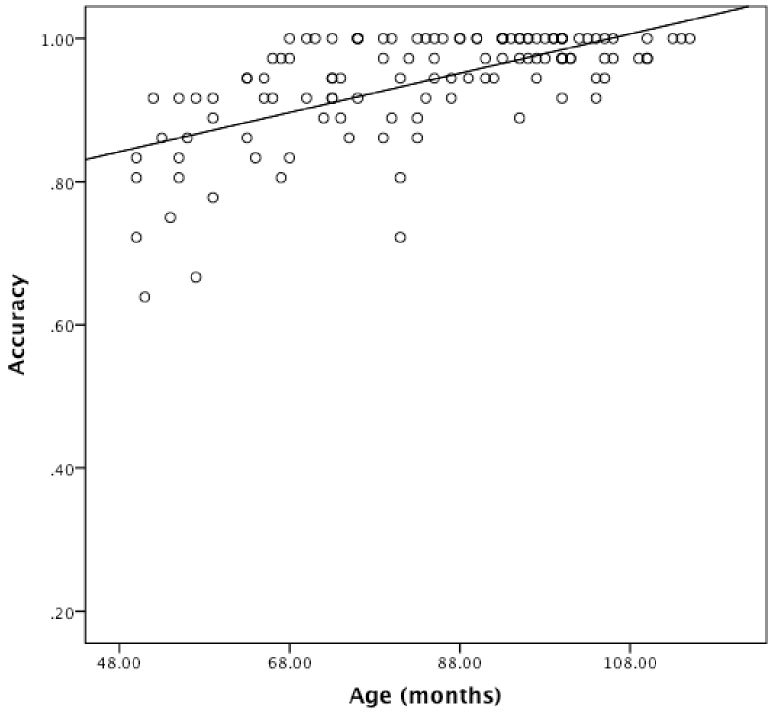
Figure IV.4 *Scatterplot showing latencies (msecs) in the simple reaction time task as a function of chronological age in months for the TD children*



$y = -4.153x + 890$, $R^2 = .148$, $p < .0001$

Figure IV.5 *Scatterplots showing a) accuracy and b) latencies (msecs) in the choice reaction time task as a function of chronological age in months for the TD children*

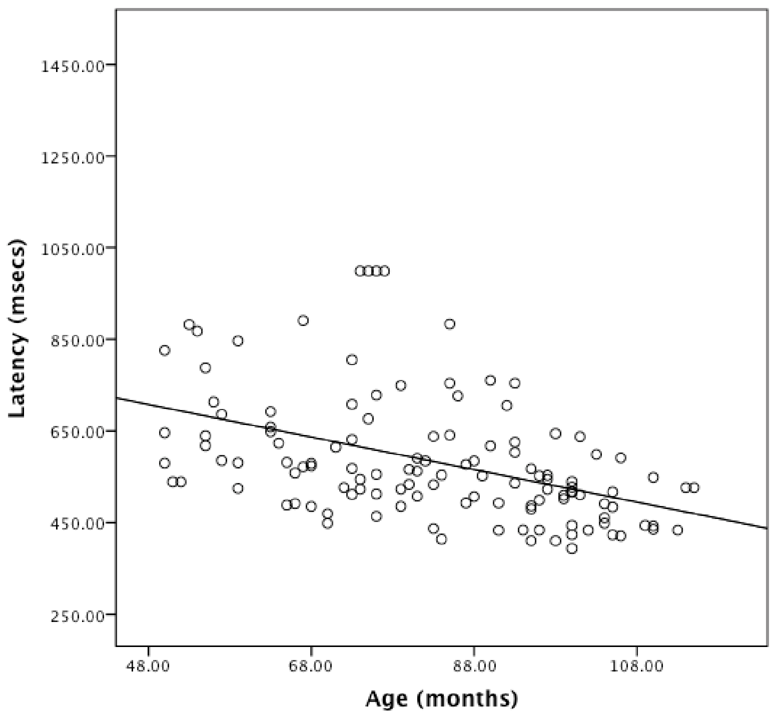
a)



y = -.723x +126,

$R^2 = .005$, $p = .436$

b)



y = -3.528x + 877,

$R^2 = .200$, $p < .0001$

There was a significant developmental progression in scores in all the experimental tasks except for choice reaction time task accuracy, where results were near ceiling at quite a young age.

Correlation analyses were carried out with picture naming accuracy scores and latencies, WPVT and PJs accuracy and latencies, together with latencies for the simple reaction time task and accuracy and latencies for the choice reaction time. The correlation table is given in Appendix J. The correlation matrix with outliers in the PJs task removed from the analyses is provided in Appendix K (the correlation tables are consigned to the appendix since results of correlation analyses that include all the data, i.e., from the experimental tasks, standardised tasks and reading measures, and where chronological age is controlled, are presented in the last section of the *Results*). There were strong positive correlations between accuracy scores for picture naming, and WPVT and PJs tasks. Choice reaction time accuracy correlated significantly with picture naming latency and simple reaction time latencies only. When PJs outliers were removed from the analyses, the results did not change substantially, except for choice reaction time accuracy that correlated significantly with all the other measures.

IV.3.2.1. Picture naming: Subsidiary analyses

Qualitative analysis of the naming errors

Analysis of the children's picture naming errors was undertaken to explore whether these were predominantly semantic, phonological, mixed, perceptual or other errors, and whether the pattern of errors differed with age. For each child, percentage of naming errors in each category was calculated. A summary of the results broken down according to school year group is given in Table IV.8.

Table IV.8 Mean number and percentage of picture naming errors in each error category for TD children according to school year group (standard deviations are in parentheses)

Type of naming error (number)	Nursery	Reception	Year 1	Year 2	Year 3	Year 4
Semantic	20.73	15.55	15.40	13.65	15.55	14.89
	(7.25)	(6.77)	(4.81)	(4.59)	(5.22)	(5.44)
Phonological	1.73	.64	1.17	.78	.37	0
	(2.05)	(1.03)	(1.78)	(1.13)	(.64)	
Mixed	1.73	.64	1.14	.91	.74	.23
	(1.42)	(1.03)	(1.43)	(1.12)	(1.00)	(.44)
Perceptual	1.64	1.09	.67	.65	.39	.23
	(1.75)	(1.14)	(.99)	(.83)	(.72)	(.67)
Other	22.36	23.55	19.87	17.39	13.45	11.56
	(9.44)	(8.91)	(5.76)	(8.06)	(6.40)	(7.40)
Type of naming error (%)	**Nursery**	**Reception**	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Semantic	43.37	37.79	40.91	42.13	52.00	56.47
	(15.41)	(15.80)	(12.69)	(15.33)	(18.44)	(21.55)
Phonological	3.49	1.42	2.70	2.31	1.20	0
	(4.00)	(2.32)	(3.85)	(3.50)	(2.08)	
Mixed	3.43	1.44	2.80	3.02	2.31	0.93
	(2.73)	(2.36)	(3.14)	(3.98)	(3.22)	(1.84)
Perceptual	3.42	2.62	1.71	1.92	1.08	0.93
	(3.59)	(2.85)	(2.50)	(2.32)	(1.89)	(2.78)
Other	46.29	56.73	51.89	50.50	43.47	41.68
	(18.49)	(18.43)	(11.10)	(18.83)	(18.08)	(22.23)

Inspection of the table reveals that the rate of semantic errors increased with age, while the rate of all other types of errors appeared to decrease with age.

Regression analyses to examine the effect of psycholinguistic variables

Item-based regression analyses to examine the effect of the psycholinguistic variables on the children's naming performance were carried out. For the purpose of these analyses, the TD children were divided into two groups on the basis of age, the younger group (novice readers) aged 4;02 to 6;11, and the older group 7;00 to 9;07. A summary of the participant characteristics for the groups is given in Table IV.9. The younger and older children did not differ significantly on nonverbal ability (Levene's test: $F = 3.336$, $p = .070$; $t(120) = 1.682$, $p = .095$; Cohen's $d = .30$).

Table IV.9 Participant characteristics for the younger and older TD groups (standard deviations are in parentheses)

Measures	Younger group	Older group
N	61	61
Gender	31F, 30M	30F, 31M
Chronological age (months)	68.41 (9.98)	97.51 (7.93)
Nonverbal ability (T score)	52.10 (6.63)	54.41 (8.45)
Nonverbal ability (raw score)	22.28 (10.39)	23.49 (5.58)

The data were inspected to see whether ceiling effects may be present, and therefore be problematic for the analyses. However, the older group did not reach a ceiling level of accuracy in the naming task. The rate of missing latency data was quite high (as noted earlier, latencies were only recorded for correct responses) and analyses were conducted only on naming accuracy percentage scores. Before conducting regression analyses, the relationship between the measures of spoken frequency, imageability, joint measure of word length (sum of word length in letters, syllables and phonemes), phonological neighbours, and visual complexity was examined using simple correlation.

The distribution of naming accuracy scores for both the younger and older groups was binomial as some items proved particularly easy (or difficult) to name. Inspection of the distribution of the variables prior to analyses led to spoken frequency and number of phonological neighbours being transformed using the formula ln (1+x). Transformed and untransformed values did not show substantial differences so untransformed data for spoken frequency and phonological neighbours were used in the present analyses (the correlation matrix with transformed values can be found in Appendix L). The results of the simple correlation between the psycholinguistic variables are shown in Table IV.10.

Table IV.10 Correlation matrix for the untransformed psycholinguistic variables

	1	2	3	4
1. Spoken Frequency	-			
2. Visual Complexity	-.371**	-		
3. Word length (joint measure)	-.244	.329*	-	
4. Phonological Neighbours	.094	-.177	-.693**	-
5. Imageability	.692**	-.229	-.140	.054

Note: * $p < .05$, ** $p < .01$.

Results indicated a significant correlation between imageability and spoken frequency. Also, significant correlations between visual complexity and spoken frequency, and between visual complexity and word length were found. Finally, there was a significant correlation between word length and phonological neighbours.

As a general condition, it has been suggested that predictors should not be included in the regression model where they correlate with one another at 0.70 or greater (DSS Princeton University). In order to examine for multicollinearity among the predictors, tolerance and variance inflation factor (VIF) were calculated. Menard (1995) suggested that a tolerance of less than 0.20 is a cause for concern; and a tolerance of less than 0.10 almost certainly indicates a serious collinearity problem. On the other hand, even if there is no formal cut-off value to use with VIF for determining presence of multicollinearity, values exceeding 10 are often regarded as indicating multicollinearity. The tolerance and VIF values for the five predictors used in the analyses are given in Table IV.11.

Table IV.11 Collinearity statistics for the predictors

Predictors	Tolerance	VIF
Spoken frequency	.463	2.158
Visual complexity	.800	1.251
Word length (joint measure)	.463	2.160
Phonological neighbour	.513	1.950
Imageability	.520	1.925

For these two models all VIF values are well below 10 and the tolerance statistics all above 0.2; therefore it can be concluded that there is no substantial evidence of collinearity within the data. According to a several sources (DSS Princeton University) the cases-to-Independent Variables ratio should ideally be 20:1, while others state between 5:1 and 15:1. In the present case, there are 57 items and five predictors, so the cases-to-Independent Variables ratio is 1:11. It was decided to use all the predictors because correlation analyses carried out individually for each child showed significant relationships between each of the psycholinguistic variables and picture naming accuracy.

Younger and older group picture naming accuracy scores were analysed using item-based regression analyses in which the dependent variable was accuracy (calculated across participants) in the picture naming task and the independent variables were untransformed values for spoken word frequency, visual complexity, word length (joint measure), phonological neighbours and imageability. All the variables were simultaneously entered. The results are given in Table IV.12.

Table IV.12 Summary of the multiple regression analysis for the younger and older TD groups with picture naming accuracy as the dependent variable and psycholinguistic variables as predictors

	B	SE(B)	β	*t*	Sig. (*p*)
Younger group					
Constant	-72.291	17.377		-4.390	.000
Spoken frequency	1.360	2.090	.079	.651	.518
Visual complexity	-.030	2.198	-.001	-.014	.989
Phono. Neighbour	.174	.514	.037	.338	.736
Word length	-.854	.668	-.153	-1.278	.206
Imageability	20.887	3.503	.681	5.963	.000
	B	SE(B)	β	*t*	Sig. (*p*)
Older group					
Constant	-80.193	19.027		-4.215	.000
Spoken frequency	-.931	2.288	-.052	-.407	.685
Visual complexity	-.904	2.407	-.037	-.376	.708
Phono. Neighbour	.573	.563	.116	1.018	.312
Word length	-.468	.731	-.080	-.640	.524
Imageability	24.892	3.883	.799	6.410	.000

Note: Younger TD model: R^2 = .608, ΔR^2 = .569. ANOVA: $F(5, 51) = 15.801$, $p < .0001$. Older TD model: R^2 = .589, ΔR^2 = .548. ANOVA: $F(5, 51) = 14.602$, $p < .0001$.

For the younger group, imageability was the only significant predictor ($p < .0001$). All the predictors together accounted for 61% of the variability in the dependent variable. When rated imageability was entered into the model in step 1 and all the other predictors in step 2 (Hierarchical regression analyses), imageability explained 57.1% of variability in the younger group’s naming accuracy, and spoken frequency, visual complexity, word length and phonological neighbours together explained the remaining 3.7% of the variance.

Similarly, for the older group, it was found that imageability was the only significant predictor ($p < .0001$). When imageability was entered into a hierarchical regression analysis in step 1, it explained 55.1% of the variance and all the other predictors (spoken frequency, visual complexity, word length and number of phonological neighbours) explained the remaining 3.8% of variance.

Interim summary of results

The findings revealed a developmental progression of scores in all the experimental tasks, with the exception of choice reaction time task accuracy. There were no ceiling or floor effects in the experimental tasks except in the case of PJs and choice reaction time accuracy, where performance reached high levels of accuracy at quite a young age. Scores in the experimental tasks were intercorrelated, apart from accuracy in the choice reaction time task. The results of the qualitative analysis of the rate of picture naming errors revealed that children in the older year groups made more semantic but less phonological and other types of errors in comparison to younger year groups. Finally, the results of the item-based regression analyses indicated that rated imageability was the only significant predictor of picture naming accuracy for both the younger and older children.

IV.3.3. Standardised assessments of phonology and semantics

A summary of the scores in the assessments of semantics and phonology according to school year group is given in Table IV.13. It needs to be noted that the group size differed according to the standardised test's age range. In particular, no standardisation data was available for children aged less than 6 years for rapid naming of objects and of digits, and blending was only assessed in children aged 5 and above. The nonword repetition test standard scores were available for children aged 4;00 to 8;11. In addition to this, as noted in section IV.2.2.1.2 (pp. 55-56), the assessment of expressive vocabulary was administered to 70 (57%) of the TD children. As a result of this, pairwise deletion was applied, in that for those children for whom no data were available (e.g., for rapid naming of objects and of digits in the case of children aged less than 6 years old), their data were excluded only for calculations involving the variable for which they had no score.

Table IV.13 Mean standard scores, and percentage correct/time taken for standardised assessment of semantics and phonology for the TD children according to school year group (standard deviations are in parentheses)

Measures	Nursery (N=11)	Reception (N=11)	Year 1 (N=30)	Year 2 (N=23)	Year 3 (N=38)	Year 4 (N=9)
Receptive vocabulary	103.27 (7.88)	103.45 (9.55)	96.00 (7.80)	98.04 (11.53)	103.89 (11.56)	96.78 (6.44)
Receptive vocabulary (%)	36.80 (4.70)	44.91 (4.08)	51.12 (6.38)	58.67 (9.14)	67.61 (7.49)	73.35 (6.25)
Expressive vocabulary	11.00 $^{\alpha}$ (1.55)	11.00 $^{\beta}$ (1.00)	10.00 $^{\gamma}$ (2.20)	8.13 $^{\gamma}$ (1.85)	10.62 $^{\delta}$ (2.08)	10.60 $^{\varepsilon}$ (1.14)
Expressive vocabulary (%)	36.17 $^{\alpha}$ (4.85)	42.55 $^{\beta}$ (3.68)	36.68 $^{\gamma}$ (13.02)	25.45 $^{\gamma}$ (5.11)	40.55 $^{\delta}$ (7.34)	45.00 $^{\varepsilon}$ (3.39)
Nonword repetition	91.09 (11.74)	107.09 (11.72)	102.17 (12.45)	101.87 (11.80)	97.32 (8.48)	93.00 $^{\zeta}$ (25.46)
Nonword repetition (%)	38.41 (11.20)	57.05 (8.28)	60.84 (12.38)	68.80 (10.64)	75.99 (7.55)	85.28 (7.75)
Blending	-	12.00 (1.67)	12.34 (1.54)	11.09 (1.81)	9.97 (1.65)	11.67 (.71)
Blending (%)	-	31.82 (10.55)	53.17 (11.48)	57.17 (12.14)	61.32 (12.61)	77.23 (3.63)
Rapid naming digits	-	-	99.35 $^{\eta}$ (10.21)	99.91 (11.37)	105.08 (9.59)	102.44 (7.07)
Rapid naming digits (seconds)	-	-	84.00 $^{\eta}$ (15.17)	76.26 (18.32)	60.89 (11.02)	56.11 (8.40)
Rapid naming objects	-	-	91.80 $^{\eta}$ (20.36)	96.43 (16.05)	102.37 (9.89)	95.11 (11.37)
Rapid naming objects (seconds)	-	-	140.52 $^{\eta}$ (37.56)	123.00 (26.85)	104.24 (13.52)	106.44 (19.78)

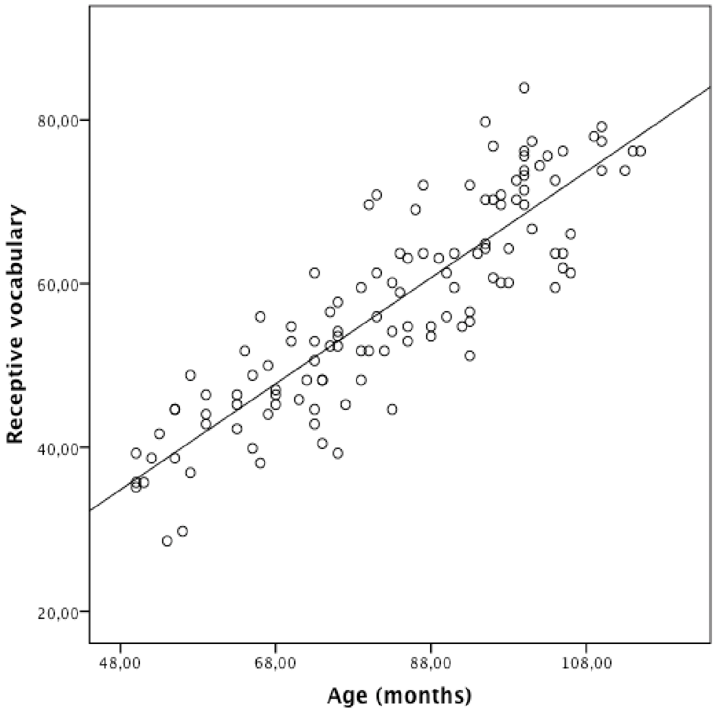
Note: $^{\alpha}$N = 6, $^{\beta}$N = 3, $^{\gamma}$N = 15, $^{\delta}$N = 26, $^{\varepsilon}$N = 5, $^{\zeta}$N = 2, $^{\eta}$N = 20. Standardised score are presented for receptive vocabulary, expressive vocabulary, nonword repetition, blending words, rapid naming of objects and of digits.

The *EDA* revealed nonnormal distributions (assessed using the Kolmogorov-Smirnov test) for nonword repetition percentage correct scores for Reception (p = .010) and Year 4 (p < .0001), blending percentage correct scores for Year 1 (p = .019), Year 2 (p = .030) and Year 4 (p < .0001), rapid naming of digits (time taken) for Year 3 (p = .007) and rapid naming of objects (time taken) for Year 2 (p = .050). Standard z-scores were calculated for all the variables to check for the presence of outliers. Results revealed a case of z score above 3 *SD* (z score = 3.58) for rapid naming of objects (time taken) and one (z score = 3.03) for rapid naming of digits (time taken).

Since the raw scores for the standardised assessments of semantics and phonology were used in the later analyses in order to have comparable measures with the experimental task scores, raw scores from the standardised assessments were plotted according to age, as in the case of the experimental task data. It was of course expected that there would be evidence of developmental progression of scores in these assessments, since they are standardised measures and developed with this purpose. However, the plots allowed for examination of any floor and ceiling effects and indication of any unexpected trends. Since a small number of children in nursery and reception classes were administered the expressive vocabulary task (N = 9), only results for children aged 6 to 9 were plotted. Raw scores in seconds were plotted for the rapid naming of digits and of objects. The resulting scatterplots, together with regression lines, are depicted in Figure IV.6 to IV.8. Results revealed that age was a strong predictor of scores for all measures, as expected.

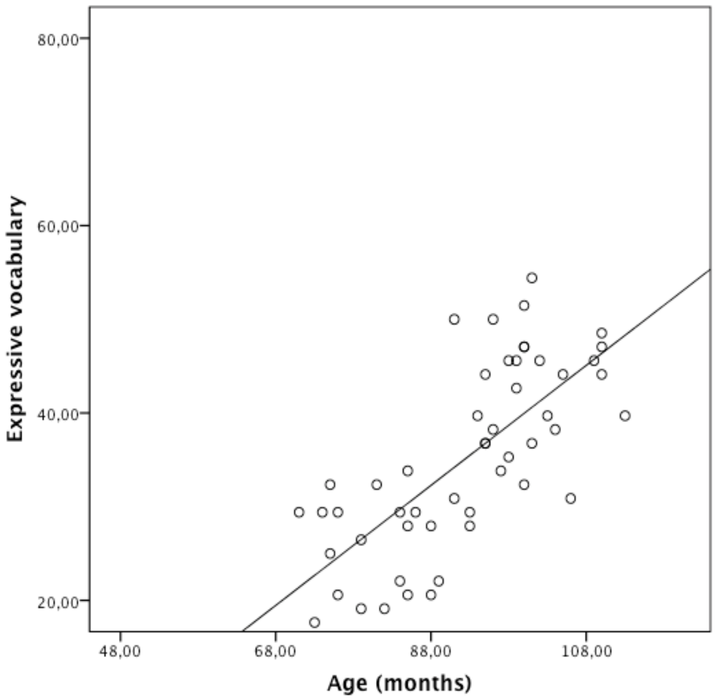
Figure IV.6 *Scatterplot showing a) receptive vocabulary and b) expressive vocabulary (percentage scores) as a function of chronological age in month for the TD children*

a)



$y = .647x + 3.771$, $R^2 = .759$, $p < .0001$

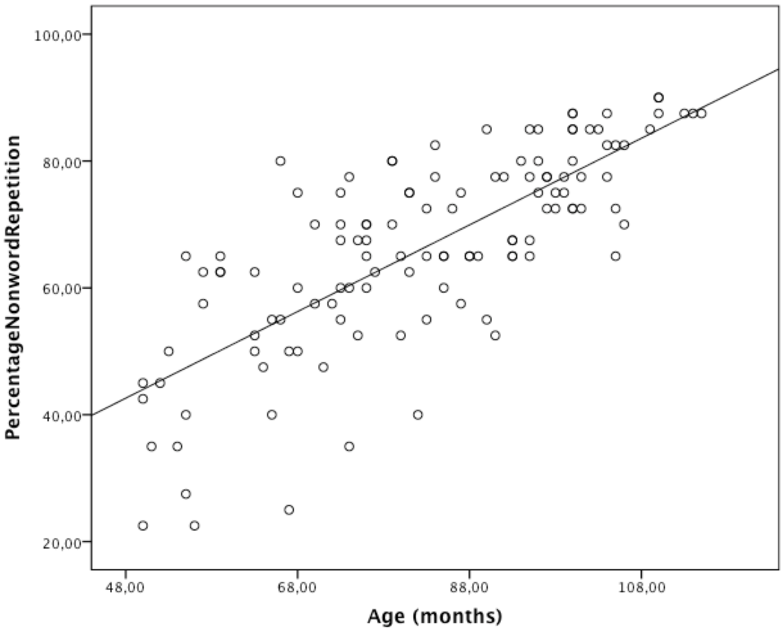
b)



$y = .310x + 8.66$, $R^2 = .123$, $p = .006$

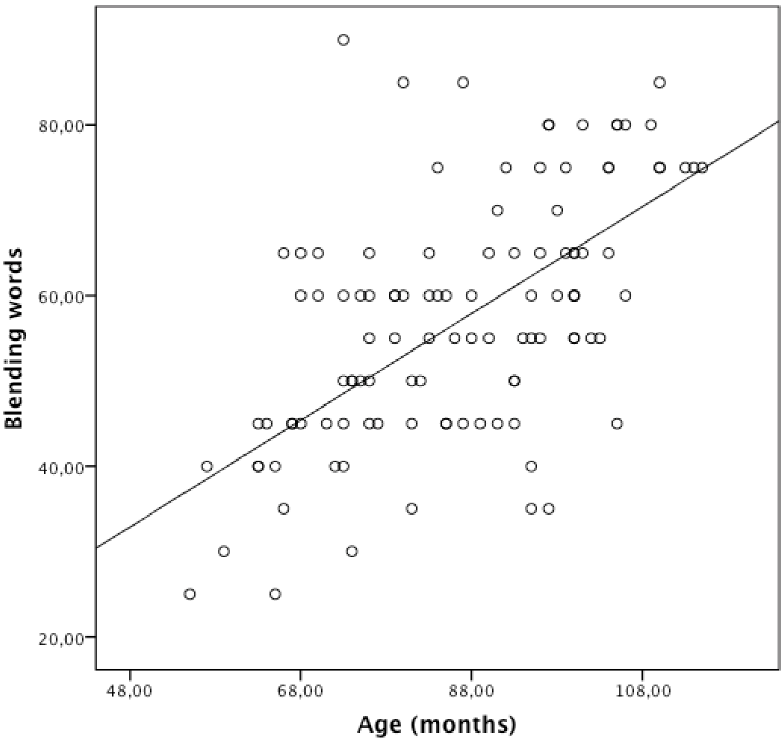
Figure IV.7 *Scatterplot showing a) nonword repetition and b) blending words (percentage scores) as a function of chronological age in months for the TD children*

a)



y = .683x + 9.84, $R^2 = .576$, $p < .0001$

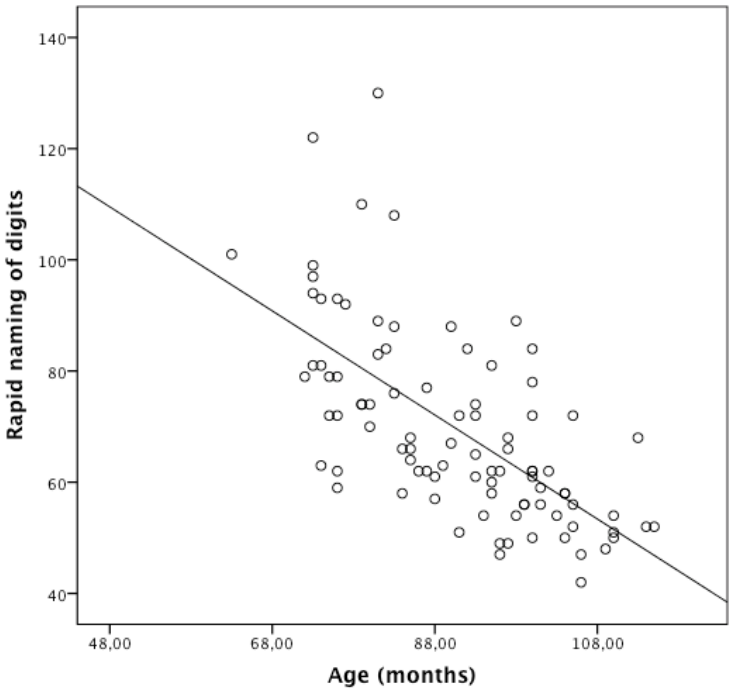
b)



y = .626x + 2.827, $R^2 = .372$, $p < .0001$

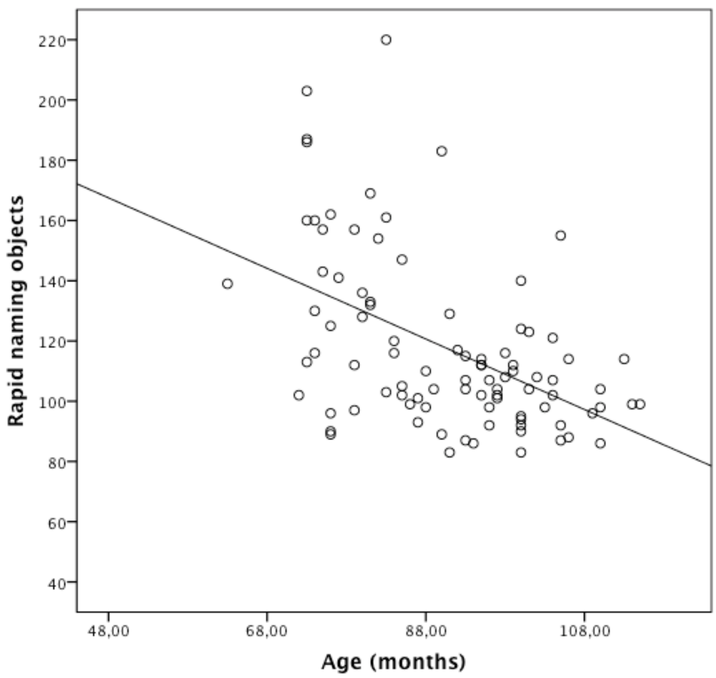
Figure IV.8 *Scatterplot showing a) rapid naming of digits and b) rapid naming of objects (sec) as a function of chronological age in months for the TD children*

a)



y = -.936x + 154.451,
R^2 = .425, p < .0001

b)



y = -.1.171x + 223.75,
R^2 = .244, p < .0001

Correlation analyses were conducted to examine the intercorrelation of scores in the assessment of semantics and phonology. The correlation matrix is given in Appendix M. Correlation analysis with the two outliers in the rapid naming of objects and digits taken out is given in Appendix N. When the two outliers were removed, results did not change substantially. Results revealed that all the variables were significantly intercorrelated. The association between receptive and expressive vocabulary was significantly higher than that of the phonological measures with vocabulary knowledge. Receptive and expressive vocabulary scores were significantly highly correlated with nonword repetition.

IV.3.4. Reading assessment

A summary of the scores in the DTWRP assessment of single word reading is given in Table IV.14. The *EDA* revealed that not all the data was normally distributed, however, when *z* scores were calculated no outliers (*z* score > ± 3SD) were identified for any of the eight reading variables[24]

[24] The results of the YARC single word reading standardised test and YARC reading passage accuracy, rate and comprehension scores are given in Appendix O.

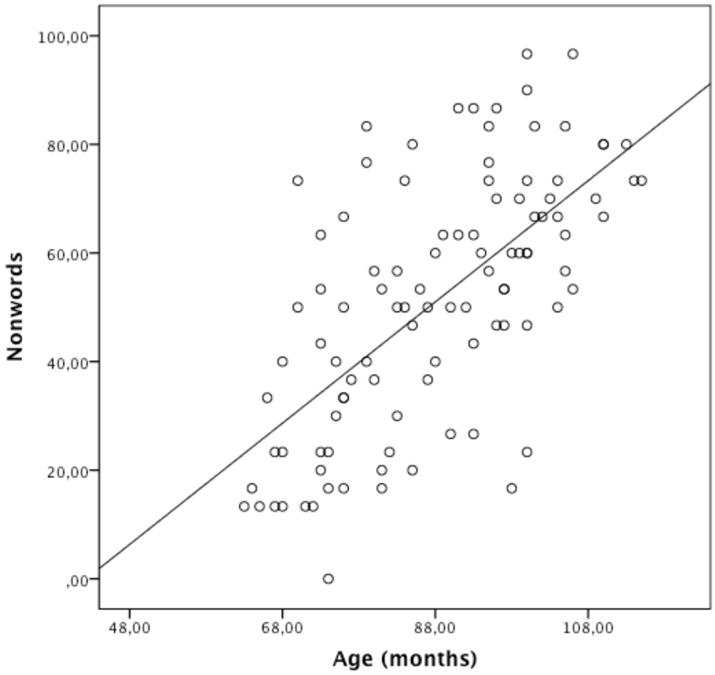
Table IV.14 Mean stanine and percentage correct score for nonword, irregular word, and regular word subtasks, and standard score and percentage correct for total reading score in the DTWRP for the TD children (standard deviations are in parentheses)

Measures	Year 1 (N=30)	Year 2 (N=23)	Year 3 (N=38)	Year 4 (N=9)
Nonword (stanine)	5.73 (1.76)	5.30 (1.64)	5.68 (1.68)	5.44 (.88)
Nonword (%)	35.12 (20.78)	48.12 (19.54)	63.25 (18.61)	72.96 (10.20)
Irregular words (stanine)	6.07 (2.29)	5.52 (1.28)	5.55 (1.37)	4.78 (.44)
Irregular words (%)	38.00 (21.42)	54.49 (18.33)	71.75 (9.95)	74.45 (4.41)
Regular words (stanine)	6.03 (1.90)	5.22 (1.57)	5.18 (1.39)	5.22 (.83)
Regular words (%)	47.00 (21.23)	63.48 (20.95)	78.07 (9.82)	85.19 (4.45)
Total (standard score)	107.97 (13.06)	102.74 (11.22)	104.63 (10.36)	101.56 (2.30)
Total (%)	39.70 (19.38)	55.36 (18.45)	71.02 (11.70)	77.04 (4.04)

Since percentage correct scores would be used in subsequent analyses, percentage correct subtask and total scores were plotted against children's chronological age to examine any floor and ceiling effects and unexpected trends. The resulting scatterplots, together with regression lines, are depicted in Figure IV.9 and IV.10. As expected, since these scores were from a standardised assessment, chronological age was a strong predictor of scores.

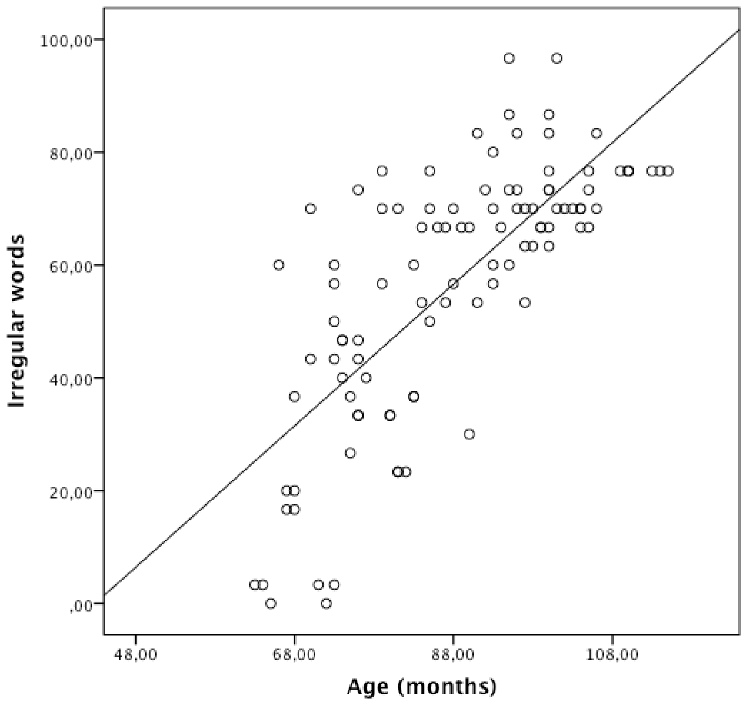
Figure IV.9 *Scatterplot showing a) nonword, b) irregular word, and c) regular word reading (percentage correct) as a function of chronological age in months for the TD children*

a)



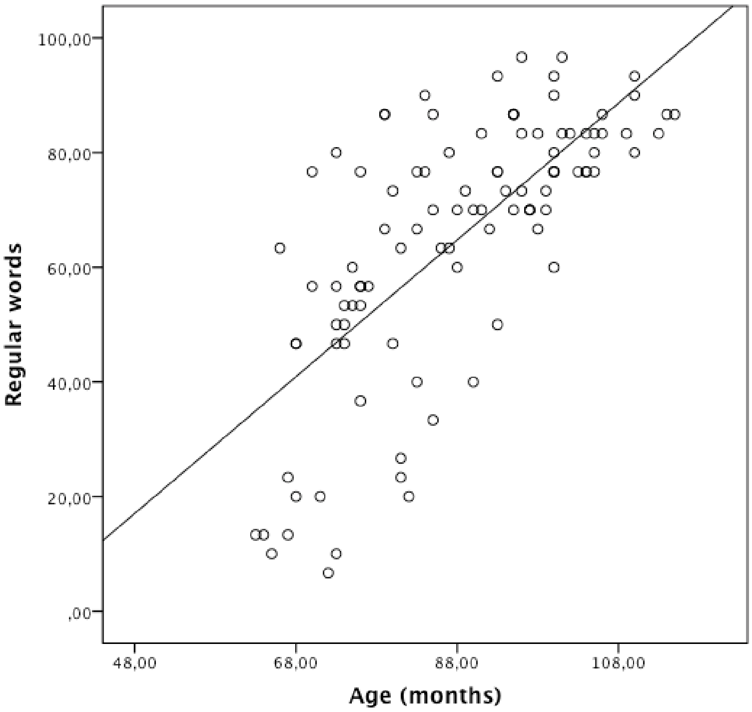
y = 1.12x - 47.24, $R^2 = .417$, $p < .0001$

b)



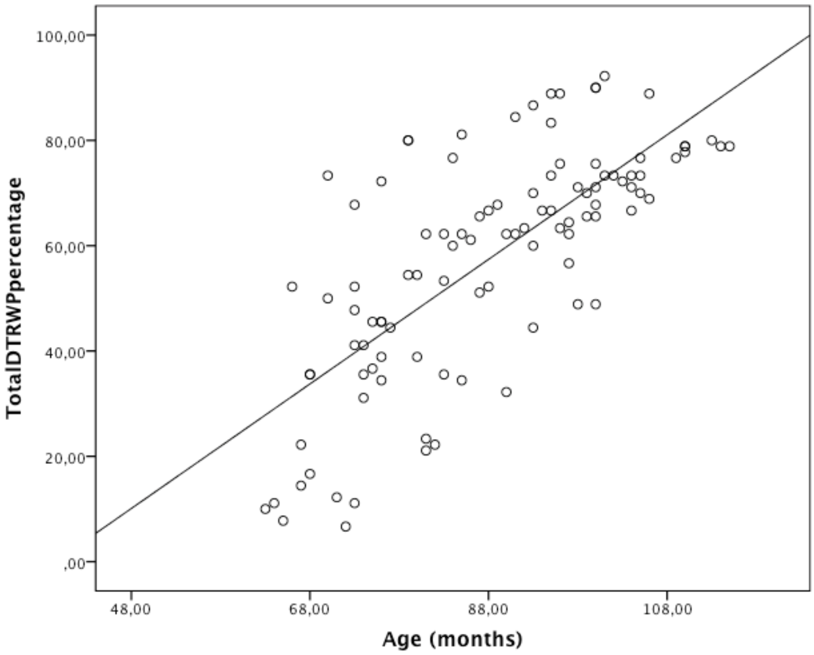
y = 1.26x - 53813, $R^2 = .547$, $p < .0001$

c)



$y = 1.19x – 40.20$, $R^2 = .500$, $p < .0001$

Figure IV.10 *Scatterplot showing total DTWRP items (percentage correct) as a function of chronological age in months for the TD children*



$y = 1.183x – 46.66$,
$R^2 = .531$, $p < .0001$

Correlation analysis looking at the relationships among the reading scores (the matrix is given in Appendix P) revealed strong correlations among all the variables (all *p*s < .001).

Interim summary of results from standardised assessments

Results have shown a developmental progression for all the semantic, phonological and reading variables. There was no ceiling or floor effect for any of the variables inspected. The next section aims to investigate the correlations between semantics, phonology and naming, and their associations to reading.

IV.3.5. Relationship of semantics and phonology to naming, and of these to reading

Correlations were carried out to investigate relationships in the scores for semantics, phonology, and naming. As we have seen at the end of Chapter II, the picture naming paradigm was employed in this study to investigate the link between semantics and phonology, since both these processes are involved in naming objects. In light of this, we would expect to find a significant correlation between the semantic and phonological variables with picture naming accuracy. The literature review also indicated the important role of both phonological and semantic processes in reading in young children. In particular, in Chapter II, we saw that there is an extensive literature regarding the contribution of phonology to reading. Nevertheless, there is evidence that semantics not only plays a key role in typical reading development, but it has also been demonstrated that it might be one of the possible source of reading difficulties for, at least, some types of dyslexia. Given these premises, we would expect to find significant correlations between phonology, semantics, naming and reading, that would vary according to age. Specifically, according to the Dual Route model, sublexical processes are required in order to read nonwords, in that they depend upon knowledge of letter-sound correspondence rules in order to be correctly read, while lexical processes are required to read irregular words and, as we have seen in Chapter II, there is evidence that oral vocabulary (a measure of semantics) is involved in irregular word reading in typically developing children. Therefore, we would expect to find stronger associations between nonword reading and phonological measures and between irregular word reading and semantic measures; this latter correlation should be stronger for older children than younger on the basis of recent research (Ricketts, Davies, Masterson, Stuart, & Duff, submitted) suggesting specific involvement of vocabulary in irregular word reading, as reading abilities develop.

Picture naming accuracy, latency and rate of phonological naming errors, as well as results from the standardised assessments of phonology and semantics, and irregular word and nonword reading were entered in the correlation analyses[25]. Due to evidence indicating that the process of learning to read results in alteration of phonological representations (e.g., Wagner et al., 1997), the analyses were conducted separately for younger and older children (the grouping according to age was as in section IV.3.2.1, p. 98). A summary of the standard score and percentage correct for all the variables for the younger and older children is given in Table IV.15.

[25] Scores for nonverbal ability (BAS), and simple and choice reaction time tasks were left out since they correlated with each other but not with the other measures.

Table IV.15 Mean percentage naming accuracy, latency and number of phonological errors, mean percentage PJs accuracy and latency and mean accuracy percentage and standard score of phonology and semantics for the younger and older groups (standard deviations are in parentheses)

Measure	Younger group (N=61)	Older group (N=61)
Picture naming accuracy (%)	63.13 (11.65)	72.36 (7.40)
Phonological naming errors (%)	2.70 (3.73)	1.13 (2.11)
Picture naming latency (msecs)	1538 (326)	1365 (215)
Receptive vocabulary (SS)	98.25 (9.54)	102.21 (10.83)
Receptive vocabulary (%)	47.79 (8.48)	67.15 (8.07)
Expressive vocabulary (SS)	10.08 [α] (2.15)	10.00 [β] (2.21)
Expressive vocabulary (%)	35.42 (11.09)	37. 83 (9.18)
Nonword repetition (SS)	101.72 (13.21)	97.54 [γ] (9.52)
Nonword repetition (%)	57.09 (14.61)	75.90 (9.33)
Blending words (SS)	12.16 [δ] (1.61)	10.23 (1.68)
Blending words (%)	51.78 [δ] (12.62)	62.79 (12.99)
Rapid naming digits (SS)	97.41 [ε] (11.21)	103.49 (11.23)
Rapid naming digits (secs)	85.93 (16.86)	61.62 (10.65)
Rapid naming objects (SS)	90.34 [ε] (18.83)	101.31 (11.20)
Rapid naming objects (secs)	140.03 (33.44)	106.52 (17.59)
PJs accuracy (%)	85.74 (11.65)	95.90 (5.21)
PJ latency (msecs)	4541	2985

	(2099)	(829)
Nonword reading (stanine)	5.63 (1.74)	5.56 (1.53)
Nonword reading (%)	34.96 (20.22)	62.08 (18.41)
Irregular word reading (stanine)	5.63 (2.33)	5.48 (1.26)
Irregular word reading (%)	36.99 (21.51)	70.11 (10.97)

Note: $^{\alpha}$ N = 30, $^{\beta}$ N = 40, $^{\gamma}$ N = 54, $^{\delta}$ N = 45, $^{\varepsilon}$ N = 30.

The correlation analyses were conducted with variance attributable to chronological age partialled out, on the grounds that age correlated significantly with all these variables[26]. Rate of phonological naming errors was nonnormally distributed and, for the presence of outliers, logarithmic transformations were applied. Results did not significantly change whether transformation was applied or not therefore results of the correlation analyses with untransformed data are given in Table IV.16. The correlation matrix with logarithm-transformed data is in Appendix Q. In order to facilitate interpretation of the results and make the presentation clear, results of the correlation analyses are discussed in the following order: correlations between semantics and phonology with naming, and correlations between naming, semantics, and phonology with reading.

[26] Expressive vocabulary was not used in the correlation for the younger TD as there were far fewer data for this. I looked at the correlations of expressive vocabulary for the older children as the N was higher here and it showed the same pattern of associations as receptive vocabulary.

Table IV.16 Correlations between experimental measures, standardised scores and reading scores for the TD children controlling for chronological age, results for the younger group are below the diagonal and those for the older group are above the diagonal

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Rec.Voc.	-	.634**	.033	.399**	.133	-.190	.378**	-.248	-.297*	.179	.155	.628**	-.305*
2. Exp.Voc	-	-	.090	.417**	-.070	-.168	.371*	-.422**	-.321*	.456**	.425**	.307	-.508**
3. Blending	.041	-	-	.214	-.007	.124	.146	-.003	-.380**	-.208	.057	.094	-.015
4. NWRep.	.280*	-	.063	-	-.110	-.493**	.189	-.264*	-.255*	.238	.138	.417**	-.318*
5. RAN dig.	-.199	-	.051	.148	-	.395**	-.229	.023	-.087	-.226	-.352**	.040	.055
6. RAN obj.	.011	-	.247	-.242	.498**	-	-.294*	.195	.124	-.203	.076	-.509**	.187
7. PJs acc.	.270*	-	.101	.080	.289	.408*	-	-.029	-.138	-.095	-.010	.268*	-.247
8. PJs time	-.128	-	.042	-.044	.021	.196	.042	-	-.029	-.206	-.068	-.255*	.578**
9. Phon.Err.	-.145	-	-.008	-.342**	.097	-.110	-.015	.136	-	.156	-.039	-.131	-.020
10. Irr. acc.	-.009	-	.321*	.443**	-.157	-.139	.054	.073	-.422**	-	.687**	.077	-.117
11. Nwd acc.	.198	-	.553**	.434**	-.070	-.039	.047	.069	-.374*	.696**	-	-.100	.131
12. Pic. acc.	.677**	-	.047	.407**	-.097	.047	.339**	.118	-.420**	.284	.309	-	-.273*
13. Pic. time	.004	-	-.076	.030	-.002	-.019	-.111	.156	.081	-.124	-.213	-.025	-

Note: $*p < .05$, $**p < .01$.

Intercorrelations between semantics, phonology and naming

Picture naming accuracy correlated significantly with receptive vocabulary ($p < .001$), nonword repetition ($p < .001$), and PJs accuracy ($p < .001$) for both age groups. For the younger group, naming accuracy was significantly negatively related to number of phonological errors and picture naming latency ($p < .01$). For the older group, significant negative correlations were found for picture naming accuracy and RAN objects ($p < .01$), and PJs latency ($p < .05$). A marginally significant correlation was found for picture naming accuracy and expressive vocabulary ($p = .057$).

Picture naming latency did not correlate with any variable in the younger group, while for the older group it was significantly negatively correlated with receptive vocabulary ($p < .05$), expressive vocabulary ($p < .01$), nonword repetition ($p < .05$), and picture naming accuracy ($p < .05$); and positively correlated with PJs latency ($p < .01$).

Rate of phonological errors correlated negatively with nonword repetition for both the younger ($p < .01$) and older ($p < .05$) group. For the older group, phonological errors were significantly negatively correlated with receptive vocabulary, blending, picture naming accuracy (all *p*s < .01), and expressive vocabulary ($p < .05$).

Intercorrelations between semantics, phonology, naming and reading

Regarding the relationship between semantics, phonology, and naming abilities with reading, results indicated that for the younger group, nonword reading accuracy correlated significantly with blending and nonword repetition ($p < .01$), irregular word reading accuracy ($p < .01$), and negatively with phonological errors in naming ($p < .05$). Irregular word reading accuracy correlated significantly with nonword repetition ($p < .01$) and blending ($p < .05$), and negatively with rate of phonological errors in picture naming ($p < .01$).

For the older group, nonword reading accuracy correlated negatively with RAN digits ($p < .01$) and positively with expressive vocabulary and irregular word accuracy (all *p*s < .01). Irregular word accuracy correlated significantly with expressive vocabulary ($p < .01$), and marginally with nonword repetition ($p = .067$), and RAN digits ($p = .082$).

IV.4. Discussion

The overall aim of this chapter was to investigate the relationships of semantics and phonology to naming, and of all three to reading ability, in order to provide a context for the analyses of the data for the dyslexic children. In order to achieve this, I first examined whether there was evidence of developmental progression in the tasks and whether any produced evidence of ceiling or floor effects.

Results revealed a near ceiling effect for accuracy in the picture judgment and choice reaction time tasks, for children in the older year groups in particular. Scores in all the experimental tasks were significantly related to chronological age. Older children were faster and more accurate than younger children.

IV.4.1. Picture naming: Subsidiary analyses

Qualitative analysis of the naming errors

Regarding the qualitative analysis of the picture naming errors, the rate of semantic errors (as a percentage of total error) was higher in the older children, while the rate of phonological errors decreased with age. This pattern did not differ whether naming scores were eliminated or not according to concept familiarity based on WPVT performance. As reviewed in Chapter III, Budd, Hanley and Griffiths (2011) assessed the naming abilities of 68 children aged 5-to-11 years with pictures from Nation et al. (2001) and they found that older children made less semantic errors than younger children. The discrepant results of the present study and those of Budd et al. may be due to a number of reasons. First, it is possible that it might be due to the different items used. In the Budd et al. study, the level of picture-naming accuracy was higher than in the current study. In Budd et al. mean naming accuracy ranges from 69% for children aged 5 to 84% for children aged 11. In the present study, accuracy ranges from 55% for children in nursery (aged 4/5 years) to 74% for children in Year 4 (aged 8/9 years). If we take into consideration the rate of semantic and phonological errors per age group, we see that in Budd et al. the percentage of semantic errors ranges from 16% for children aged 5 to 11% for children aged 11, while in the present study the rate ranges from 43% for children in nursery to 55% for children in Year 4. Similarly, in Budd et al. the proportion of phonological errors is stable (1%) across all age groups (from children aged 5 to children aged 11, with the exception of children aged 7 who did not make any phonological errors), while in the present study the proportion decreased with age from 4% in nursery to 0% in Year 4. It is possible that the difference in the percentages of the different types of error is due to use of different criteria for naming error classification (for example, Budd et al. included “circumlocution” in the “other errors” category, while in the present study circumlocution was included in the semantic error category).

Another possible explanation comes from the study by Shao, Roelofs, Acheson and Meyer (2014). They demonstrated that inhibition mechanisms are recruited by adult participants to solve competition during lexical decision tasks. Shao et al. showed that in linguistic tasks, such as the picture naming task, the competition derived from the activation of more than one *lemma*, hence the activation of several lexical concepts, is solved by selective inhibition (top-down processes), in that pictures with low agreement were named slower than those with high agreement. To support the behavioural findings, Shao et al. recorded the event-related brain potential (ERP) component, N2, which is found to be elicited after stimulus onset in tasks requiring response inhibition such as the Stroop task, also in lexical decision tasks.

In the present study items such as *chilli*, for example, might activate also “carrot”, “pepper” or “vegetable”, leading to errors classified as “semantic”. Since the children were asked in the picture naming task to try to find a name if an item was unfamiliar, older children might have produced more “guess” words as they have wider vocabularies to draw on. In Budd et al. (2011), participants were instructed to answer as quickly and clearly as possible, but there is no mention that children were asked to try to find a name for unfamiliar items. In conclusion, inhibition processes might not be sufficiently developed in the younger children (due to immature frontal lobe contribution to cognitive control (e.g., Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002) to inhibit the competition in lexical selection when several *lemmas* are activated. On the contrary, older children who would be expected to show a reduction in rate of semantic errors produced a high rate of these. It is suggested that this was due to wider vocabulary knowledge and the task instructions.

Regarding the investigation of which psycholinguistic variables influenced picture-naming accuracy, results revealed that the semantic variable imageability was a strong predictor of naming accuracy for both the younger and older TD children. Masterson et al. (2008) found that imageability was the most robust predictor of object picture naming accuracy for three-and five-year old children in their study. Bates, Burani, D’Amico and Barca (2001) found that imageability was also a strong predictor of object naming in adult participants. According to Levelt’s theory of lexical access (Levelt, 1992; 1999; 2001), spoken production consists of different stages from conceptualisation to articulation of the selected word. In particular, there are three main strata: the first node represents semantics or concepts, the second is represented by a *lemma* and the last stratum is dedicated to phonological retrieval. Semantics therefore is considered to play a crucial role in lexical activation (Bates et al., 2001) and so it is perhaps not surprising that imageability was found to have a strong effect on picture naming for the children in the present study. Masterson et al. (2008) interpreted the effect in terms of Funnell et al. (2006)'s demonstration of the importance of perceptual/sensory features in supporting early lexical representations for objects.

IV.4.2. Standardised assessments of phonology and semantics

With regard to the standardised assessment of phonology and semantics, results indicated developmental progression for receptive and expressive vocabulary, nonword repetition, blending words and rapid naming of objects and of digits.

Simple correlation analyses (not controlling for age) revealed significant correlations among all the variables. In particular, highly significant correlations between expressive and receptive vocabulary were found, and this association was stronger than the one with the phonological assessments, with the exception of nonword repetition which was highly correlated with receptive and expressive vocabulary.

IV.4.3. Relationship of semantics and phonology to naming, and of these to reading

The results of the correlation analyses between semantics, phonology, naming and reading, with the effect of age controlled for, are reported in this section. In the first sub-section the intercorrelations for naming, semantics and phonology are discussed, and in the second sub-section the results of intercorrelation of all three of these with reading are discussed. As noted earlier, it was important to control for age in these analyses because of the strong effect this variable had on the processes assessed.

Intercorrelations between semantics, phonology and naming

Regarding first the relationship between semantics and phonology, results indicated that receptive vocabulary significantly correlated with nonword repetition in both the younger readers and the older group. This finding is in line with the results of Gathercole and Baddeley (1989) who reported that nonword repetition scores were significantly associated with vocabulary scores in typically developing children aged 4, 6, and 8 (see also Gathercole & Willis, 1991; Gathercole, Willis, Emslie, & Baddeley, 1992; Gathercole, Hitch, Service, & Martin, 1997). Expressive vocabulary was also significantly correlated with nonword repetition in the older TD group (due to the small number of younger children tested with the expressive vocabulary assessment scores for this measure were not included in the analyses for the younger group). The relationship between nonword repetition and receptive vocabulary (for which data were available for the whole sample) is significantly stronger for the older than the younger group, and this supports the view that increase in vocabulary with age leads to improvement in nonword repetition. As vocabulary knowledge increases, the phonological representations become better specified and this would lead to more efficient phonological processing and, in turn, to better performance in tasks such as nonword repetition (e.g., Metsala, 1999; Bowey, 2001; Munson, Edwards, & Beckman, 2005). PJs accuracy was significantly correlated with receptive vocabulary in both the younger and older groups, indicating that both tap semantics. Both involve recognition of depicted objects, as well as knowledge of relationships between concepts.

Results revealed that scores for blending did not correlate significantly with any of the other variables assessing phonology or semantics. Blending, like nonword repetition, is considered to tap phonological processes and therefore we would have expected to find a significant relationship between these two. Conversely, blending has traditionally been used as a measure of phonological awareness, the ability to recognise and manipulate phonemes; while nonword repetition has been claimed by some to assess phonological short-term memory (e.g., Wagner & Muse, 2006; Kruk, Mayer, & Funk, 2014). On the grounds that different phonological processes might underlie blending and nonword repetition, Marshall, Christo and Davis (2013) examined the relation between the two in a study with 48 reading impaired children aged from 6 to 15 years. They found no significant correlation (r = -.034, p > .05) between scores from the blending words and nonword repetition subtasks from the CTOPP. Similarly, Passenger, Stuart and Terrell (2000) carried out a longitudinal study with 80 children aged 4 at Time 1, and assessed three times over an 18-month period. Phonological awareness was assessed by alliteration and rhyme tasks, and phonological memory was assessed through nonword repetition task and digit span. Factor analysis indicated that alliteration and nonword repetition loaded on two different factors, suggesting different underlying mechanisms for the two types of phonological processing.

With regard to the relationship between semantics and phonology to naming, results indicated a strong correlation between picture naming accuracy, receptive vocabulary, nonword repetition and PJs accuracy for both the younger and older groups. These findings are in line with what we expected, since picture naming involves both semantic and phonological processes. A marginally significant correlation was found between picture naming accuracy and expressive vocabulary, perhaps due to the relatively small number of older children assessed in expressive vocabulary. Less clear is why naming accuracy did not correlate with blending since the latter is a measure of phonological abilities. This result might be due to the nature of the blending task, in that it may be considered a pure measure of phonological awareness while nonword repetition is affected by several factors as reviewed in Chapter II, including lexical knowledge from long-term memory.

For both younger and older TD groups, the rate of phonological errors in picture naming was negatively associated with nonword repetition accuracy. In addition, in the older group, the rate of phonological errors in picture naming was found to be negatively correlated with receptive vocabulary, blending, and expressive vocabulary. This suggests, as indicated in the study of Ricketts, Davies, Masterson, Stuart and Duff (submitted) reviewed in Chapter II, that as children's vocabulary size increases and phonological abilities become more efficient, the likelihood of making phonological errors decreases significantly.

Intercorrelations between semantics, phonology, naming and reading

With regard to the relationship between semantics, phonology, and naming abilities to reading, it was found that for the younger TD group (novice readers), nonword reading was significantly associated with both nonword repetition and blending, and negatively with the rate of phonological errors in picture naming. This suggests that for the younger group phonological abilities are fundamental to support sublexical processes. Irregular word reading was also significantly associated with phonological abilities in the younger group, but not with any of the semantic measures. The results indicate that for the younger group, the contribution of phonology to reading all types of letter string is strong (in contrast to the results for the older group, see next).

For the older group, nonword reading accuracy correlated negatively with RAN digits and positively with expressive vocabulary. Irregular word reading correlated significantly with expressive vocabulary but not with any of the phonological measures. This is in line with the view that as GPCs become more consolidated with reading experience; a closer association between semantic knowledge (measured with vocabulary assessments in the present study) and irregular word reading emerges. Since expressive vocabulary correlated significantly with both nonword and irregular word reading, we may have expected to find the same significant association with receptive vocabulary as well. A possible explanation for the failure to find a significant association might be the anomaly in the receptive vocabulary data distribution: although the statistical test did not detect a non-normal distribution and outliers were absent, a plot of the data reveals low frequency scores in the middle of the distribution, resembling a binomial distribution.

As noted above, rapid naming of digits significantly correlated with nonword reading in the older group (N = 61). As we have seen in Chapter II, it is not yet well understood which cognitive processes underlie the association between RAN and reading. If RAN is conceived as part of the phonological tasks (e.g., Ramus et al. 2013), this result might suggest that both phonology and semantics are involved in nonword reading in the older group. Similar findings were reported by Zoccolotti, De Luca and Marinelli (2014), who found a significant correlation between rapid naming of digits and nonword reading (r = .38, p < .003) in a sample of 43 typically developing Italian children aged 11. In the present study, the lack of association of RAN and reading in the younger children might be explained by the small sample of younger group (N = 30 compared to N = 61 for the older group) assessed with rapid naming tasks.

In conclusion, results for the TD sample indicated a developmental progression in all the experimental and standardised tasks, with the exception of choice reaction time and PJs accuracy tasks. In light of this, results of analyses with these two assessments are treated with caution. Regarding the relationship between picture naming, semantics and phonology, results indicated that naming accuracy was significantly associated with receptive vocabulary, PJs accuracy and nonword repetition in both the younger and older TD group. Rate of phonological errors in picture naming was significantly associated with nonword repetition accuracy in both age groups. Finally, the relationship between semantics, phonology and naming to reading indicated that phonology, assessed by nonword repetition and blending, correlated with nonword and irregular word reading in the younger group. For the older group, expressive vocabulary correlated with nonword and irregular word reading, and RAN digits correlated significantly with nonword reading. For the younger children the results highlight the important role of phonology in early reading performance. The result showing the association of RAN digits with nonword reading for the older TD group likely reflects the role of speed in phonological assembly for decoding, once GPCs have been acquired. The result showing an association of irregular word reading with expressive vocabulary confirms earlier research showing an increasing role for vocabulary knowledge/semantics with increase in reading skill. The association with nonword reading in the older group was unexpected. It may be due to the wordlike nature of the nonwords included in the DTWRP assessment that was used in this study. The manual informs that the nonword items were constructed from segments of regular words in order to ensure the words and nonwords were matched for orthographic familiarity. With highly wordlike items (e.g., WEM, GOUSE, WILDERDOTE), children may well rely on existing vocabulary/lexical items to support decoding. If this explanation is correct then those children with wider levels of vocabulary knowledge (as well as good sublexical skills) will be at an advantage.

Having explored the results for the TD children, it was necessary to bear all the issues (above summarised) in mind when the results for the dyslexic children were analysed. The findings are presented next.

CHAPTER V. Methods and Results for Dyslexic Children

V.1. Introduction

The overarching aims of the thesis were to revisit the phonological naming deficit hypothesis of dyslexia and to explore whether a naming deficit might be specific to different reading profile. In Chapter IV the naming abilities of TD children were investigated in order to provide a framework to understand how naming skills develop in both the TD children and those with reading difficulties. This chapter outlines how the research aims were addressed with data collection conducted with a sample of dyslexic children. The methodology used to investigate the semantic, phonological, naming and reading skills of the dyslexic children was the same of that employed for the TD children, and is presented in the previous chapter. Additional measures that were collected with the dyslexic children only are reported in this chapter. They were parental questionnaires that provided details of case history, as well as assessments of speech articulation and verbal short-term memory. In the next section, I summarise the analyses that were carried out with the dyslexic children's data to address the research aims, and the experimental hypotheses are outlined. The methods and results are presented after this.

Semantics, phonology, and picture naming: The naming deficit in dyslexia revisited

In Chapter IV, the results were presented for the TD children in the experimental and standardised tasks, and developmental progression in the scores was examined. In the present chapter the results for the dyslexic children are presented in the tasks of semantics, phonology and naming. The review of the research on naming in dyslexic children presented in Chapter III revealed that although a naming deficit in dyslexic children has been ascribed to phonological processing deficiencies, there are no studies of picture naming in dyslexics that included independent assessments of phonological abilities. It was therefore considered important to include this in the data collection. As noted in Chapter II, examination of semantics (as assessed by receptive and expressive vocabulary tasks) was also included in the present study, since a) semantic processing is specified as critical in models of naming, b) it has been not examined in any study investigating naming deficits in dyslexic children, and c) if there are different underlying causes of dyslexia, semantics might be the locus of impairment in reading and in naming for some of the dyslexic children.

Control groups were constituted in order to address the aim of looking into a possible naming deficit in the dyslexic children. From the sample of TD children (whose results are presented in the previous chapter), a group was selected who were the same chronological age as the dyslexic children, constituting a chronological age (CA) control group. A further group of TD children was selected who were younger but of the same reading age as the dyslexic children, constituting a reading age (RA) control group[27]. The performance of the dyslexic children and controls was compared in the standardized and experimental tasks, and in particular, in the picture naming task. Mixed factor ANOVAs were used, with accuracy and latency (where applicable) as the dependent variables and group the between-subjects factor.

Subsidiary analyses with the picture naming data were conducted, as with the data from the TD children reported in the previous chapter. These involved looking at the types of errors made in naming, and at which of five psycholinguistic variables would affect naming accuracy. With regard to naming errors, it was reported in Chapter IV that for the TD children the rate of semantic errors increased with age while the rate of phonological and other-type errors decreased with age. In the analyses reported in the present chapter I examined whether the same pattern would be found for the dyslexic children. With regard to examining the effect of the psycholinguistic variables on picture naming, this was carried out using regression analyses with the same five psycholinguistic variables as in the analyses in the previous chapter (spoken frequency, imageability, visual complexity, phonological neighbourhood size and word length).

Relationship of naming and phonology and semantics, and of all three to reading in dyslexic children

With the data for the TD children, correlation analyses were reported looking at relationships between naming, phonology, semantics and reading in the younger and older TD children separately. The results of these indicated that, for the young readers, measures of phonological ability were significantly associated with both nonword and irregular word reading, while for the older children, irregular word reading was

[27] Although the debate about employing CA and RA controls as mentioned on page 24, these two control groups were selected to ascertain whether the dyslexic children would perform accordingly. As already stated on page 61-62, comparing the picture naming abilities of the dyslexic children to those of the younger children of the same reading age and to children of the same chronological age means to verify whether the naming abilities of dyslexic children are deviant or delayed.

significantly associated with expressive vocabulary but nonword reading was associated with phonological measures. These results confirm earlier research indicating the important role of phonological skills for early reading, and an association of semantics with lexical skills as reading experience increases. In the present chapter, the pattern of association between picture naming, phonological and semantic abilities and nonword and irregular word reading is reported for the dyslexic children and CA and RA controls.

Is the naming deficit specific to subtypes of dyslexia?

To address this research question, dyslexic children were classified in terms of reading profile according to different criteria, and association with performance in naming, phonology and semantics was examined. In Chapter II, I discussed the absence of standard criteria for identifying dyslexic subtypes. Therefore, different classification schemes were adopted: one involved a continuous measure and one involved discrete measures. The continuous measure was calculated on the basis of the relative difference in accuracy in scores in the nonword and irregular word subtasks from the *Diagnostic Test of Word Reading Processes*, on the grounds that irregular word reading and nonword reading are considered to be “pure” measures of lexical and sublexical skill respectively. The continuous measure calculated as a difference between nonword and irregular word reading provides a measure of sublexical ability. The continuous measure has been advocated by some researchers (e.g., Griffiths & Snowling, 2002) as it allows for the examination of correlation with measures of interest (in this case naming, semantics and phonological ability), so that all the variance in variables is captured in the analyses.

In addition to this, a discrete measure was used to classify the dyslexic children into subtypes. This involved calculating *z* scores for irregular word and nonword reading accuracy on the basis of the scores of CA control children. Three dyslexic subtypes were identified: dyslexic children with impairment to sublexical processes (the phonological subtype), those with impairment of lexical processes (the surface subtype) and dyslexic children with impairment of both processes (the mixed subtype). Individual dyslexic children were matched to controls for chronological age. Independent *t*-tests were then carried out to look at the dyslexics’ naming, phonological and semantic skills in relation to the different patterns of reading on the basis of the Dual Route account.

Experimental hypotheses

The experimental hypotheses were as follows. The first research aim of revisiting the naming deficit in dyslexia was addressed by comparing the performance of the dyslexic children and the CA and RA controls in the semantic, phonological and naming assessments. It was possible to investigate whether a) dyslexic children performed similarly to controls, and b) whether a naming deficit in the dyslexics, as described in the literature, was due to a phonological impairment. In particular, as we saw in Chapter IV (pp. 61-62), if the picture naming abilities of the dyslexic children in the present research were similar to those of the younger controls of the same reading age, then this would support the view that dyslexics' naming abilities resemble those of younger children (Snowling et al., 1988). However, if the naming abilities of the dyslexic children were found to be worse than those of younger children of the same reading age, then this would support the view of a notable impairment in this group, unrelated to reading skill, at least for the sample of children in this study. In addition, if the naming deficit in dyslexic children is due to a phonological impairment, as claimed by Swan and Goswami (1997) and Nation et al. (2001), then I would expect to find the dyslexic children's scores on those tasks tapping phonology to be worse than those of the RA controls. Finally, if semantics plays an important role in reading acquisition, and is a possible locus of impairment in dyslexic children (and this should be associated with a deficit in lexical processes, according to the evidence reviewed in Chapter II and III), then I would expect to find dyslexics' scores on the tasks tapping semantics (receptive and expressive vocabulary) to be impaired (as reviewed in Chapter II, p. 36-40).

Regarding the subsidiary analyses of the picture naming data, according to the literature reviewed in Chapter III, I would expect the dyslexic children to produce a higher rate of phonological errors in naming, relative to controls. In particular, as we have seen above, if dyslexics suffer from a naming deficit due to phonological impairment, they should produce a higher rate of phonological errors than the RA control group. With regards to the psycholinguistic variables, according to Swan and Goswami (1997) and Nation et al. (2001), I would expect to find the dyslexic children's naming to be affected by word length, since this is considered to be a marker of a phonological deficit.

With regards to exploration of the relationship of naming, semantics and phonology, I expected that, as for TD children, the results for tasks traditionally argued to tap phonological processes (blending, nonword repetition, rapid naming) should be associated, and those for the tasks tapping semantics (vocabulary, PJs) should be also, and that picture naming would be related to both sets of processes. Regarding the relationship between semantics and phonology, in the TD data reported in the last chapter there was indication of developmental change in that, for example, nonword repetition was more strongly associated to receptive vocabulary in the older than the younger group. If the dyslexics' difficulty is phonological in nature, I would expect to find the pattern of association of the dyslexic children to resemble the one of the older TD group (increase in vocabulary knowledge should lead to improvements in nonword repetition, e.g., Metsala, 1999), but with weaker association with phonological abilities.

Second, regarding the association between naming, semantics, phonology and of these three to reading, Griffiths and Snowling (2002) reported different patterns of correlation of reading with other variables (e.g., phoneme deletion, rhyme) for their dyslexic group and reading-age controls. On the grounds of this evidence, I hypothesised that if dyslexic children present with a phonological deficit, then, as noted earlier, the pattern of association between naming, phonology, semantics and reading skills should resemble that of the older TD children but with weaker association of reading and phonology, in that dyslexic children should rely less on sublexical processes, which are thought to be impaired.

Finally, regarding the question of whether a naming deficit is specific to subtypes of dyslexia, on the basis of the findings of Friedmann and Lukov (2008) and Truman and Hennessey (2006), I predicted that children with a reading profile consistent with phonological dyslexia would present with a picture naming deficit, characterised by inaccurate naming performance and phonological naming errors. On the other hand, children with a reading profile consistent with surface dyslexia should not exhibit a naming deficit; rather their deficit might be a semantic one.

In summary, the aim of the thesis was addressed by exploring the naming deficit of dyslexic children with assessments taking into account phonology and semantics. Analyses were carried out to investigate picture naming accuracy and latencies, followed by examination of errors in picture naming and the influence of psycholinguistic variables. The results of the dyslexic children were compared to those of two control groups selected from the sample of typically developing children described in Chapter IV. Patterns of association of naming, phonology and semantics with reading were examined for group differences. Finally, dyslexic children were classified according to their reading profile to explore whether naming deficits might be specific to subtypes of dyslexia.

The next section outlines the methods used to collect the data with the dyslexic children and to compare their results with those of CA and RA controls. The *Participants* section gives the background characteristics for the dyslexics as well as the CA and RA control children. A description of the assessments given to the dyslexic children only is presented in the *Materials* section (all the tasks described in Chapter IV were administered to dyslexics as well as TD children and will not be repeated in the present chapter).

V.2. Method

V.2.1. Participants

V.2.1.1. Dyslexic children

Sixty-six children were referred to the researcher by Special Educational Needs Co-ordinators (SENCOs) and teachers. Children with either a diagnosis of dyslexia or with specific reading difficulty were recruited to overcome the problem that in some London boroughs and bordering area dyslexia is not recognised as a condition and therefore assessments are not carried out. Only children with English as their first and main language were included. Children were recruited from Year 3 and Year 4 classes because this is the stage at which literacy difficulties are often clearly established. Neurological, behavioural and sensory impairments were criteria for exclusion, together with general learning difficulty, low socioeconomic background and irregular reading instruction (i.e., low level of school attendance)[28].

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[28] Although the sample of children with reading difficulties consisted of children with a formal diagnosis of dyslexia and children who met the criteria to be included in this project (that is, no evidence of neurological, behavioural and sensory impairments, general learning difficulty, low socioeconomic background and irregular reading instruction), the label *dyslexic* will be used to indicate all these children. According to Siegel (1992) there is not any significant difference between individuals with a diagnosis of dyslexia and poor readers on measures of reading, spelling, and phonological processing. Siegel (1992) demonstrated that poor readers and dyslexic children differed in domains less related to reading (e.g., a simple measure of syntax). It seems therefore appropriate to use the label “dyslexic” for children with a formal diagnosis of dyslexia and poor readers who met the criteria to participate in the present study.

The children were recruited from eleven primary schools in London boroughs (Barnet, Barking & Dagenham, Camden, Croydon, Islington, Lewisham, and Newham), four primary schools in Surrey, Essex, Windsor and Hertfordshire, and one Literacy Centre in south London. The children were recruited by contacting private specialist support, the British Dyslexia Association, and Dyslexia Action Plus, as well as several affiliated associations. Schools for children with special educational needs were also contacted. SENCOs and Educational Psychologists were contacted via the UK SENCO Forum, Special Education Needs UK website group and through the London Councils government webpage. Professionals in schools and literacy centres were asked to refer children who were experiencing a specific reading difficulty unexplained by any of the factors mentioned above (that is, by neurological, behavioural and sensory impairments, general learning difficulty, low socioeconomic background and irregular reading instruction).

Six children with English as an additional language were excluded from the sample. All the children in the study were administered the Pattern Construction subtest of the British Ability Scales (Elliot, Smith, & McCullouch, 1997) in order to ensure that participants did not have generally low cognitive ability. Three of the poor readers were excluded due to a low score in the Pattern Construction subtask (percentile below 7). The children were also all administered two standardised reading tests to assess current reading level. These assessed single word reading and reading comprehension: the Diagnostic Test of Word Reading Processes (DTWRP, FRLL, 2012) and the York Assessment of Reading for Comprehension (YARC) Passage Reading (Snowling et al., 2009). Twelve children were excluded when they were found to have a reading score within the average range in the DTWRP. Three additional children were excluded due to neurological problems (brain tumor, autism spectrum disorder, and meningitis in the first three years of life), and six children were excluded for low socio-economic background[29] or documented behavioural

[29] Although the socioeconomic status of the children was not quantified, teachers/SENCos/Head teachers were asked whether the reading difficulty of the children referred might have been attributed to family socioeconomic background. This information, and the status of "free school meal" (a widely used index of low income, see for example Duff et al., 2008) were used as index of low socioeconomic background. In some of the primary schools recruited in fact the status of free school meal alone did not constitute an index of financial hardship: some of the schools adopted the policy of free school meals for all their pupils in order not to make distinctions, even before the 2014 government scheme,

problems. One child was excluded because of documented recent speech and language problems (as reported in the Child History questionnaire which the parents were asked to fill in, and which is described in *Materials*).

After these exclusions, the final sample of poor readers consisted of 35 children (13 were girls). There were 27 Year 3 and 8 Year 4 children. One child had corrected to normal vision and she wore her prescribed glasses during all the assessment sessions. Those children in the sample with no formal diagnosis of dyslexia had a reading age equivalent score in the DTWRP that was at least 18 months below their chronological age and a standardised reading score below 85 in the DTWRP. Two children diagnosed as dyslexic by an Educational Psychologist had reading age equivalent scores of 13 and 10 months below their chronological age. Their standard scores were 90 and 91 in the DTWRP and 90 and 92 in the YARC single word reading test. Both children have spelling problems and they were attending a structured intervention programme for spelling and reading difficulties at the time of the assessment. They were included in the sample on the grounds of having a recent history of documented dyslexia. A summary of the participant characteristics of the group of dyslexic children is given in Table V.1 (a description of the groups of chronological age and reading age control children that appear in the table is given in the following section). Table V.1 reports the standardised single word and reading passage scores, as well as the percentage of correct nonword and irregular word reading, in the DTWRP (FRLL, 2012) [30].

All the dyslexic children were either attending a reading training in their school or a structured intervention programme in a literacy centre (43% of the sample). The intervention programmes varied in terms of intensity, from a few

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stating that all Reception to Year 2 children in state-funded schools in England were entitled to free lunches.

[30] Standardised scores have been included to show the reading ability of the dyslexic children in comparison to their chronological age and reading age controls. In Chapter III (page 53-54), I stated that the standard score is considered to be the most accurate normative score for interpreting performance on standardised tests, and the DTWRP may overcome some of the issues highlighted in previous picture naming studies with dyslexic children. Nonword and irregular word stanine, as well as percentage correct scores, are also reported because these are the two critical reading subtasks which will be used later to identify dyslexic children with primary lexical and sublexical impairment.

minutes every day (15/20 minutes) to three hours per week, and in terms of duration, lasting from a number of months to years.

Table V.1. Mean chronological age and standard scores in background measures for dyslexic children and chronological age (CA) and reading age (RA) control children (standard deviations in parentheses)

Measures	Dyslexics (*N*=35)	CA controls (*N*=35)	RA controls (*N*=24)	T-tests
Chronological age (months)	101.89 (6.85)	101.57 (6.51)	77.42 (7.12)	D vs RA $t(57)=13.27$, $p<.001$
Nonverbal ability (T score)	52.86 (10.33)	52.91 (6.34)	53.50 (7.44)	
DTWRP total score (SS)	80.60 (5.97)	101.49 (3.03)	103.33 (4.04)	D vs CA $t(51)=18.45$, $p<.001$* D vs RA $t(57)=16.25$, $p<.001$
Nonword reading (stanine)	2.83 (.92)	5.37 (.88)	5.00 (1.18)	
Nonword reading (%)	26.57 (9.95)	63.90 (10.43)	33.06 (15.88)	
Irregular word reading (stanine)	2.46 (.82)	5.00 (.73)	5.58 (.97)	
Irregular word reading (%)	40.86 (12.48)	70.48 (5.55)	40.97 (16.90)	
YARC single word reading (SS)	78.51 (6.81)	98.57 (4.96)	104.50 (7.41)	D vs CA $t(62)=14.08$, $p<.001$* D vs RA $t(57)=13.88$, $p<.001$
YARC passage accuracy (SS)	86.43 (4.94)	102.26 (5.18)	108.50 (6.20)	D vs CA $t(68)=13.09$, $p<.001$ D vs RA $t(57)=15.19$, $p<.001$
YARC passage rate (SS)	86.66 $^{\alpha}$ (9.55)	101.26 (6.47)	108.55 $^{\beta}$ (6.18)	D vs CA $t(65)=7.38$, $p<.001$ D vs RA $t(50)=9.11$, $p<.001$
YARC comprehension (SS)	95.40 (10.34)	102.34 (4.82)	105.50 (9.42)	D vs CA $t(48)=3.60$, $p<.01$* D vs RA $t(57)=3.82$, $p<.001$

Note: $^{\alpha}$ N = 32, $^{\beta}$ N = 20, * Welch-Satterthwaite correction.

The dyslexic children were given the digit span subtask from WISC UK IV (Wechsler, 2004) and the articulation test (Goldman & Fristoe, 2000) to assess for any verbal memory or articulation difficulties (details of both assessments are provided in the *Materials* section[31]). The mean standard score in the articulation test was 104.29 (*SD* = 2.31; range = 100-108). The results indicated that the dyslexic children did not have articulation difficulties. In the digit span task the mean scaled score was 7.60

[31] Regarding the reason why dyslexics were given tests of working memory and articulation, see page 47.

(*SD* = 1.85, range = 3-12). There was variability within the scores, with one child performing well below the average range (*z* score = -2.61). The scores for digit span are included in the analyses carried out of the dyslexic children's data reported in section V.2.5.2 (p. 159).

Parents/carers of the dyslexic children were asked to complete questionnaires regarding their child's development and also the Strengths and Difficulties Questionnaire (SDQ, Goodman, 1997). Twenty-five (71%) questionnaires and 23 (66%) SDQs were returned. Regarding the child development questionnaire, responses for the children revealed that 64% had a family member with dyslexia and/or learning difficulties. Twenty-four percent of the children were also described as "late talkers" (2-3 word phrases at 18 months or later)[32]. Eight percent suffered from illness in the first 3 years of life and 12% had ear infections/hearing problems. None of the participating dyslexic children in this study had a diagnosis of other developmental disorders (e.g., ADHD) or behavioural disorders.

The results from the SDQ are given in Table V.2. The mean score for each behavioural trait was compared to the British normative score for children aged 5-10 years old (as reported in the last column of Table V.2). The SDQ categorised the dyslexic children as in the normal range on the majority of subscales and just falling into the borderline category for emotional symptoms.

[32] All children were monolingual English speakers.

Table V.2 Means and ranges of the SDQ behavioural traits for 23 of the dyslexic children (standard deviations are in parentheses)

Behavioural trait	Maximum score	Mean (*SD*)	Range	Normative sample children aged 5-10*
Emotional symptoms	10	3.61 (3.16)	0.00-9.00	1.9 (2.0)
Conduct problems	10	1.87 (1.74)	0.00-5.00	1.6 (1.7)
Hyperactivity	10	5.74 (2.56)	2.00-10.00	3.6 (2.7)
Peer problems	10	1.65 (1.99)	0.00-8.00	1.4 (1.7)
Prosocial behaviour	10	8.26 (1.36)	6.00-10.00	8.6 (1.6)

Note: * = British means and standard deviations for Parent SDQ (Meltzer, Gatward, Goodman, & Ford, 2000).

V.2.1.2. Chronological age and reading age matched controls

Chronological age and reading age control groups were formed by selecting children from the TD sample described in Chapter IV. All the children in the control groups were average readers according to their scores in the DTWRP (FRLL, 2012) and YARC tests (Snowling et al. 2009) and they had reading ages between 6 months below and 12 months above their chronological ages.

To constitute a group matched for chronological age to the dyslexic group (CA controls), 35 children (17 girls and 18 boys) were selected from the Year 3 and 4 TD sample. A summary of the chronological ages and scores of the dyslexics and CA controls in the DTWRP and YARC, together with scores in the nonverbal ability Pattern Construction subtest (Elliot et al., 1997) is given in Table V.1.

To constitute a reading age matched control group (RA controls), 24 TD children (11 girls and 13 boys) were selected from the Year 1 and Year 2 TD children on the basis of reading age in the DTWRP (total score) (RA M = 78.54, SD = 7.34; Dyslexics M = 76.37, SD = 5.51) and YARC passage accuracy (RA M = 87.54; SD = 10.84; Dyslexics M = 84.74, SD = 7.13). Independent sample t-tests were used to examine whether the reading age of the RA controls and dyslexics differed in the following: DTWRP total score *t*(57) = age of the RA controls and dyslexics differed in the following: DTWRP total score *t*(57) = 1.297, *p* = .200; YARC passage accuracy *t*(57) = 1.198, *p* = .236; YARC passage reading rate *t*(50) = .038, *p* = .970; YARC comprehension *t*(57) = 1.90, *p* = .062. Levene's test indicated homogeneity of variance (DTWRP total score: *F* = 2.414; *p* = .126; YARC passage accuracy: *F* = 2.133; *p* = .150; YARC passage reading rate: *F* = 1.412, *p* = .240; YARC comprehension: *F* = 1.656, *p* = .203). A summary of the scores of the RA control group is reported in Table V.1.

Independent sample t-tests were used to compare the dyslexics and control groups on the background measures: chronological age in months, BAS Pattern Construction T score, DTWRP and YARC single word reading, and YARC reading passage accuracy, rate and comprehension standard scores (SS). Levene's test was used to inspect for equality of variance between the RA and dyslexic groups (chronological age: *F* = .265, *p* = .609; BAS Pattern Construction T score: *F* = .932, *p* = .339; DTWRP (SS): *F* = 2.523, *p* = .118; YARC single word accuracy (SS): *F* = .176, *p* = .677; YARC passage accuracy (SS): *F* = .994, *p* = .323; YARC passage reading rate (SS): *F* = 1.494, *p* = .227; YARC comprehension (SS): *F* = .804, *p* = .374). When the Levene's test for equality of variance was applied for the dyslexics and CA controls, in four of the eight comparisons the variance differed (BAS Pattern Construction *T* scores: *F* = 9.932, *p* < .01, DTWRP (SS): *F* = 11.89, *p* < .01, YARC single word (SS): *F* = 8.39, *p* < .01 and YARC comprehension (SS): *F* = 16.30, *p* < .001). In these cases, violation of equality of variance was corrected using the Welch-Satterthwaite equation. In the other comparisons, variances did not differ significantly between the CA controls and dyslexics (chronological age: *F* = .961, *p* = .330; YARC reading passage accuracy (SS): *F* = .075, *p* = .785; YARC reading passage rate (SS): *F* = .882, *p* = .351).

Significant differences and those approaching significance are reported in Table V.1. A table with all the t-test results (significant and non-significant) is given in Appendix R.

V.2.2. Materials

As outlined in the Introduction to this chapter, all the experimental and standardised tests described in Chapter IV were also administered to the sample of dyslexic children. In addition to the standardised and experimental tasks employed for the assessment of the TD children, dyslexics were administered a standardised assessment of working memory and articulation. Additionally, parents/carers of the poor readers were asked to complete questionnaires regarding the developmental history of their child.

In order to assess working memory, the Digit Span (Forwards and Backwards) subtest from WISC UK IV (Wechsler, 2004) was used. The test consists of verbally presented sequences of numbers of progressing length to be repeated in the same order as presented (Forwards) and in the reverse order (Backwards). Each digit span task, Forwards and Backwards, comprises 8 items consisting of two trials each. A score is given to each trial with a maximum total score of 32. Both digit span forwards and backwards have a discontinuation rule consisting of a score of 0 on both trials of at a particular string length.

To assess articulation problems the Sounds-in-Words and Sounds-in-Sentences subtasks from the Goldman Fristoe 2 Test of Articulation (Goldman & Fristoe, 2000) were used. The test is available for children aged two years onwards. The Sounds-in-Words subtask consists of 34 coloured pictures depicting actions and objects familiar to children. Children are asked to name pictures or to reply to questions about the pictures for a total of 53 single word responses, which include 77 consonants and consonant clusters in different positions (initial, medial and final). The Sounds-in-Sentences subtask consists of two picture-based stories read aloud by the examiner. Children are asked to retell the story using the picture plates that illustrate the gist and target words. The Sounds-in-Sentences task provides information on the articulation of the consonant sounds in a content-controlled sample of speech and it represents an approximation of spontaneous conversational speech (Goldman & Fristoe, 2000).

The parents/carers of the dyslexic children were asked to complete two questionnaires. The first was a child history questionnaire, developed by the author for a previous study. It consisted of nine questions, requiring yes/no answers, regarding the child’s birth, psychomotor development (learning to walk and learning to talk), the occurrence of any illness or hearing problems during the first years of life, incidence of learning difficulties in the child’s immediate family, whether the child had attended speech and language therapy and whether the child had any formal diagnosis. The questionnaire is included in Appendix S. The second questionnaire was the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which explores children's behavioural, emotional and attentional regulation. A copy of this can be found at Appendix T. The SDQ comprises five subscales, each consisting of five items, both negative and positive attributes regarding emotional symptoms; conduct problems, hyperactivity/inattention, peer problems, and prosocial behaviour. It is scored on a 3-point Likert scale (0 = not true, 1 = somewhat true, 2 = absolutely true). The SDQ is suitable for children aged 3-16 years, and has been found to have good internal reliability and validity (Goodman, 1997).

V.2.3. Procedure

The same procedure adopted for the typically developing children and described in Chapter IV (p. 80-81), was also followed for the dyslexic children. Ethical approval for the study was obtained from the Department of Psychology and Human Development at the UCL Institute of Education. Permission was obtained for data collection from Head teachers of the schools and from individual parents/carers for each child (Information leaflet for parents of dyslexic children is in Appendix U, while the consent form was the same used for the TD children and given in Appendix G). Once consent had been obtained, dyslexic children were tested individually in a quiet room at their school/literacy centre during normal school hours.

Dyslexic children were tested over 1-2 sessions in consecutive weeks for about 30 minutes each session. This was due to SENCo/teacher requests that the dyslexic children would not suffer fatigue as they were already attending training for their reading difficulties. The tasks were administered in the same order as for the TD children and were balanced in terms of difficulty/effort required among the four sessions. The digit span and articulation tasks were added at the end of the second and fourth sessions, respectively. As for the TD children, the procedure for each testing session was made clear to the dyslexic children before starting the assessments. They were given the possibility to terminate the session at any time and to ask the researcher any questions they wished. They were reassured that this was not part of the school assessment and they were not expected to know the responses to all the questions. At the end of each session, the children were praised for their efforts.

Results are reported in three separate sections. In the first section analyses conducted to address the aim of revisiting the naming deficit hypothesis are reported. I compared first the dyslexics' and controls' performance on the scores in the semantic and phonological standardised assessments, followed by comparisons on the experimental tasks (picture naming, word picture verification (WPVT), picture judgment (PJs) and simple and choice reaction time). Mixed factor ANOVAs were carried out, comparing the results of dyslexics to those of the chronological age (CA) and reading age (RA) control children. Subsidiary analyses were then conducted examining a) the types of errors made in picture naming and whether this differed between the dyslexic children and controls and b) the effect of the psycholinguistic variables on picture naming in the dyslexics and the control groups.

The second section concerns the correlations examining the relationship of naming, semantics and phonology to single word reading in the dyslexic children, CA and RA controls. The final section is dedicated to addressing the issue of whether naming deficits might be restricted to specific dyslexic profiles. As outlined earlier, continuous and discrete criteria were used to delineate the profiles. The continuous criterion was calculated as a proportion following Masterson et al. (1992): difference between correct responses for nonwords words and irregular words divided by the total number of correct responses on both irregular words and nonwords. The discrete criterion involved calculating irregular word and nonword reading z scores on the basis of the performance of chronological age control children in the reading subtasks. In light of the findings reported by McArthur et al. (2013), and reviewed in Chapter I, regarding outcomes with different discrete classification schemes, their classification scheme 1 was selected. This was on the grounds of a) a balance in the number of children found with a primary lexical or sublexical impairment using this scheme, and b) the possibility of obtaining large enough numbers of children in the different subgroups for statistical comparison using this scheme. The naming, semantic and phonological skills of the children in the three ensuing subtypes were then examined.

V.2.4. The naming deficit in dyslexia revisited

Standardised and experimental task scores for the dyslexics and CA and RA controls were entered in a series of ANOVAs with group as the between-subjects factor. The significance level was set at $p < 0.05$ and Bonferroni post-hoc comparisons were used. All comparisons involve two-tailed probabilities. Skewed data were addressed by applying logarithmic transformations. For the sake of brevity, where the effect of group was significant, the post-hoc (Bonferroni) tests are reported in a separate table. Full description of results is given in appendixes.

V.3. Results

V.3.1. Standardised assessments of semantics and phonology

A summary of standard scores, percentage correct scores and time taken for rapid naming tasks in the standardised assessments[33] for the dyslexic children and the CA and RA controls is reported in Table V.3.

[33] It should be noted that the sample size of CA and RA controls was reduced for the expressive vocabulary and rapid naming of digits and of objects. As described in the previous chapter, expressive vocabulary was introduced as additional semantic measure later once the TD assessment had begun. Regarding the RAN of digits and objects, no standardisation data is available for children aged less than 6 years.

Table V.3 Mean standardised scores, and percentage correct/time taken for assessments of semantics and phonology for the dyslexic children and the CA, and RA control groups (standard deviations are in parentheses)

Measures	Dyslexics	CA controls	RA controls
Receptive vocabulary (SS)	86.86 (12.06)	101.43 (9.04)	93.83 (10.21)
Receptive vocabulary (%)	59.93 (7.90)	69.20 (8.45)	51.93 (8.71)
Expressive vocabulary (SS)	7.71 (1.77)	10.29 $^{\alpha}$ (1.63)	8.67 $^{\beta}$ (2.19)
Expressive vocabulary (%)	31.64 (7.09)	40.56 $^{\alpha}$ (5.90)	24.02 $^{\beta}$ (4.35)
Nonword repetition (SS)	81.70 $^{\gamma}$ (17.56)	96.61 $^{\delta}$ (9.40)	99.46 (12.28)
Nonword repetition (%)	67.21 (12.71)	78.36 (8.45)	61.77 (13.82)
Blending (SS)	10.08 (7.08)	10.51 (1.69)	11.62 (1.50)
Blending (%)	55.57 (12.11)	66.57 (12.94)	52.29 (11.03)
Rapid naming digits (SS)	91.91 (13.15)	103.77 (12.61)	101.50 $^{\varepsilon}$ (9.86)
Rapid naming digits (seconds)	121.60 (34.71)	104.97 (15.62)	119.10 $^{\varepsilon}$ (21.87)
Rapid naming objects (SS)	92.63 (13.92)	100.80 (10.30)	101.25 $^{\varepsilon}$ (14.14)
Rapid naming objects (seconds)	76.29 (20.55)	59.63 (11.52)	78.10 $^{\varepsilon}$ (15.92)

Note: $^{\alpha}$ N = 24, $^{\beta}$ N = 9, $^{\gamma}$ N = 27, $^{\delta}$ N = 28, $^{\varepsilon}$ N = 20.

Exploratory data analysis (*EDA*) revealed that data distributions for the three groups of children resembled a normal shape (Kolmogorov Smirnov test: $p > .05$) except for blending for the CA and RA controls ($p < .05$), rapid naming of objects for the dyslexics ($p < .05$), and rapid naming of digits for the CA controls ($p = .020$). The ANOVAs were conducted twice, once with logarithmic transformation of blending, rapid naming of objects and of digits and once with untransformed data. Results did not change significantly whether transformation was applied or not, therefore results with untransformed data are presented next while those with transformed data are consigned to Appendix V. Levene's test indicated that homogeneity of variance was met for receptive vocabulary ($F(2, 91) = .217$, $p = .805$), expressive vocabulary ($F(2, 65) = 1.274$, $p = .287$) and blending ($F(2, 91) = .786$, $p = .459$). Welch's F test correction was applied for nonword repetition ($F(2, 91) = 3.873$, $p = .024$), rapid naming of digits ($F(2, 88) = 6.016$, $p = .004$) and rapid naming of objects ($F(2, 88) = 3.641$, $p = .030$).

The analysis yielded a significant effect of group for receptive vocabulary ($F(2, 91) = 34.853$, $p < .0001$). There was also a significant effect of group for expressive vocabulary ($F(2, 65) = 25.918$, $p < .0001$). Regarding the phonological assessments, the analysis yielded a main effect of group for blending ($F(2, 91) = 12.303$, $p < .0001$). Results of the ANOVAs with Welch's correction[34] yielded a significant effect of group for nonword repetition ($F(2, 51) = 18.347$, $p < .0001$). Results of the ANOVAs with Welch's correction[35] also yielded a significant effect of group for rapid naming of digits ($F(2, 45) = 20.618$, $p < .0001$). Finally, there was a significant main effect of group for rapid naming of objects ($F(2, 45) = 6.438$, $p = .003$). Post-hoc (Bonferroni) tests are reported in Table V.4. Appendix W gives the full description of results.

[34] Results did not change if Welch's correction was not applied: ($F(2, 91) = 16.040$, $p < .0001$).

[35] Results did not change if Welch's correction was not applied: rapid naming of objects ($F(2, 88) = 4.554$, $p = .013$) and rapid naming of digits ($F(2, 88) = 14.894$, $p < .0001$).

Table V.4 Post-hoc (Bonferroni) tests in the standardised assessment of semantics and phonology for the dyslexics and CA, and RA controls

Measures	Comparisons	Mean difference	*SE*	*p*
Receptive vocabulary	D vs CA*	-14.914	3.096	.000
	D vs RA*	13.436	3.433	.001
	CA vs RA*	28.350	3.43	.000
Expressive vocabulary	D vs CA*	-6.069	1.153	.000
	D vs RA*	5.181	1.626	.007
	CA vs RA*	11.250	1.701	.000
Nonword repetition	D vs CA*	-4.457	1.112	.000
	D vs RA	2.177	1.233	.242
	CA vs RA*	6.635	1.233	.000
Blending	D vs CA*	-2.200	.570	.001
	D vs RA	.656	.632	.906
	CA vs RA*	2.856	.632	.000
RAN objects	D vs CA*	17.457	6.114	.016
	D vs RA	2.505	7.060	1.00
	CA vs RA	-14.952	7.060	.111
RAN digits	D vs CA*	18.086	3.825	.000
	D vs RA	-1.810	4.417	1.00
	CA vs RA*	-19.895	4.417	.000

Note: * significant result

Interim summary of results for the standardised assessment of phonology and semantics

In summary, results of the analyses indicated that dyslexics' scores were significantly lower than those of CA controls in all the standardised semantic and phonological tasks. In comparison to RA controls, dyslexics had significantly higher scores than those of RA controls in the two vocabulary measures. Regarding the phonological measures, dyslexics performed as well as RA controls in all the phonological tasks (i.e., blending, nonword repetition, and rapid naming of objects and of digits).

V.3.2. Experimental tasks of picture naming, word-picture verification tasks, picture judgment, and simple and choice reaction time

A summary of the scores in the experimental tasks for accuracy and latency for the dyslexics and the two control groups is given in Table V.5. The data were entered in a 3 (Group) X 2 (Measures) univariate ANOVA with group as a between-subjects factor. Significant main effect of group is reported next while, as for the results described in the previous section, post-hoc (Bonferroni) comparisons are given in Table V.6. Appendix X gives the full description of results.

Table V.5 Summary of percentage accuracy and latencies (msecs) in the experimental tasks for the dyslexic children, and the CA, and RA control groups (standard deviations are in parentheses)

Measures	Dyslexics	CA controls	RA controls
Picture naming accuracy	65.43 (8.70)	73.66 (7.64)	63.09 (8.88)
Picture naming latency	1302 (207)	1298 (224)	1485 (321)
WPVT accuracy	70.95 (7.73)	75.83 (4.80)	69.16 (9.66)
WPVT latency	2190 (215)	2201 (193)	2319 (245)
PJs accuracy	95.43 (4.75)	97.57 (3.71)	89.79 (9.03)
PJs latency	3160 (933)	3078 (864)	3883 (956)
Simple reaction time latency	492 (125)	479 (130)	504 (114)
Choice reaction time accuracy	96.19 (3.63)	98.09 (2.31)	92.86 (6.55)
Choice reaction time latency	527 (92)	513 (70)	613 (130)

Note: Percentage picture naming accuracy scores are adjusted eliminating those items not recognised in the WPVT and compound nouns.

Picture naming task

The following analyses involved adjusted picture naming scores (i.e., unfamiliar and compound nouns were removed). Median naming latency and percentage of correct naming responses were the dependent variables. Since the distribution of latency scores was slightly positively skewed for all three groups, log transformation was used. However, it did not produce different results, thus the analyses for untransformed data are reported (the analysis with transformed data is in Appendix Y). Levene's test indicated homogeneity of variances (picture naming accuracy: F = .113, *p* = .893; latency: *F* = 1.383, *p* = .256). The analysis yielded a main effect of group for picture naming accuracy (*F*(2, 91) = 13.769, *p* < .0001). The effect of group was also significant for latency (*F*(2, 91) = 4.162, *p* = .019).

Word picture verification task (WPVT)

According to the Kolmogorov-Smirnov test, accuracy data were normally distributed for dyslexic children and RA controls (both *p*s = .200) but not for the CA controls (*p* = .008). Nevertheless, the absence of outliers motivated the choice of a parametric test. The distribution of the latency was normal one for the dyslexics and CA and RA controls (all *p*s = .200). Levene's F test indicated that variances for accuracy differed significantly between groups (*F*(2, 91) = 7.418, *p* = .001) while the assumption of homogeneity was met for latencies (*F*(2, 91) = .846, *p* = .432). To overcome the violation of the assumption of homogeneity of variance for the accuracy data, the more conservative Welch's F test was used. The analysis yielded a main effect of group for accuracy[36] (*F*(2, 49) = 8.167, *p* = .001). No significant main effect was found for latencies (*F*(2, 91) = 2.982, *p* = .056).

Picture judgment task (PJs)

There was a near ceiling effect for PJs accuracy scores, especially for the CA controls. The Kolmogorov-Smirnov test indicated that the assumption of normality was not met for PJs accuracy for the CA controls and dyslexics (*p* < .0001) while data distribution for the RA controls resembled marginally a normal shape (*p* = .053). Regarding the latency data distribution, the assumption of normality was not met for the RA controls (*p* = .005) or the dyslexics (*p* = .034) while the distribution of data for the CA controls was normal (*p* = .200). This led to transformation of the data using logarithm transformation. Since the outcome did not change whether transformation was applied or not, results with untransformed data are reported next, while the results with transformed data are consigned to Appendix Z.

Levene's F test indicated that homogeneity of variance was met for the PJs latency score (*F*(2, 91) = .019, *p* = .981) but not for accuracy (*F*(2, 91) = 13.127, *p* < .0001), therefore Welch's F test was applied. Results revealed a main effect of

[36] Results did not change if Welch's correction was not applied: (*F*(2, 91) = 6.769, *p* = .002).

group for accuracy[37] ($F(2, 48) = 8.758$, $p = .001$). There was also a significant effect of group for latencies ($F(2, 91) = 6.318$, $p < .0001$).

Simple and choice reaction time tasks

This analysis aimed to address the issue (Chapter IV, p. 79) of whether dyslexics may suffer from processing speed impairment. Choice reaction time task accuracy was not entered into the analyses due to the near ceiling scores for all three groups of children. Exploratory data analyses revealed that the distribution of simple reaction time latencies was normal for the dyslexics and CA and RA controls (Kolmogorov-Smirnov test: all *p*s > .05). The distribution of choice reaction time latencies was normal for the dyslexics and CA controls (Kolmogorov- Smirnov test: both *p*s > .05), but not for the RA controls (Kolmogorov- Smirnov test: $p = .043$). Inspection of the data distribution revealed the presence of an outlier in the RA control group. Analyses were repeated twice with the outlier in and out of the analyses. Homogeneity of variance was assessed with Levene's test (simple reaction RT latencies: $F = .423$, $p = .656$, choice reaction time latencies $F = 5.116$, $p = .008$). The one-way ANOVA yielded a main effect of group for choice reaction time latencies ($F(2, 91) = 7.904$, $p = .001$). There was no significant effect of group for simple reaction time latencies ($F(2, 91) = .287$, $p = .751$).

[37] Results did not change if Welch's correction was not applied: ($F(2, 91) = 12.938$, $p < .0001$).

Table V.6 Post-hoc (Bonferroni) tests in the experimental tasks for the dyslexics and CA, and RA controls

Measures	Comparisons	Mean difference	*SE*	*p*
Picture naming accuracy	D vs CA*	-.082	.020	.000
	D vs RA	.023	.022	.879
	CA vs RA*	.106	.022	.000
Picture naming latency	D vs CA	-54.67	58.99	1.00
	D vs RA*	-186.81	65.40	.016
	CA vs RA*	-132.14	65.40	.021
WPVT accuracy	D vs CA*	-3.51	1.27	.021
	D vs RA	1.29	1.41	1.00
	CA vs RA*	4.81	1.41	.003
PJs accuracy	D vs CA	-.021	.014	.386
	D vs RA*	.056	.016	.001
	CA vs RA*	.078	.016	.000
PJs latency	D vs CA	81.24	218.49	.927
	D vs RA*	-723.72	242.24	.010
	CA vs RA*	-804.96	242.24	.004
Choice reaction time latency	D vs CA	14.22	22.67	1.00
	D vs RA*	-85.51	26.17	.005
	CA vs RA*	-99.73	26.17	.003

Note: * significant result

Interim summary of results for the experimental tasks

Results revealed that dyslexic children named significantly less pictures accurately than the CA controls, while there was no significant difference between dyslexics and RA controls. CA controls named significantly more pictures accurately than RA controls. There was no significant difference between dyslexics and CA controls in picture naming latencies, while both dyslexics and CA controls were faster than RA controls.

With regard to the WPVT, dyslexics recognised significantly less pictures than CA controls and there was no significant difference between dyslexics and RA controls. Conversely, CA controls recognised significantly more pictures than RA controls.

There was no significant difference between dyslexics and CA controls in picture judgment (PJs) task accuracy, while both dyslexics and CA controls were significantly more accurate than RA controls. Regarding PJs latencies, no difference between dyslexics and CA controls was found, while both dyslexics and CA controls were faster than RA controls. It needs to be acknowledged that results from the PJs task should be treated with caution given the near ceiling effect for PJs accuracy.

Finally, no significant difference between the dyslexics and the CA controls in choice reaction time latencies was found, while both dyslexics and CA controls were faster than the RA controls.

V.3.2.1. Picture naming: Subsidiary analyses

Qualitative analysis of picture naming errors

A summary of the different types of errors made in picture naming, expressed as number as well as percentage of total error, for the dyslexic children and the CA and RA controls is reported in Table V.7.

Table V.7 Mean number and mean percentage, and significant differences in naming error category for the dyslexic children and CA controls, and RA controls (standard deviations are in parentheses)

Type of naming error (number)	Dyslexics	CA controls	RA controls	Type of naming error (%)	Dyslexics	CA controls	RA controls	Significant differences
Semantic errors	5.49 (2.36)	5.69 (2.43)	5.13 (.61)	Semantic errors	41.03 (16.42)	52.63 (23.24)	37.08 (21.56)	D vs CA *p*=.060 CA vs RA *p*=.016
Phonological errors	.89 (.90)	.11 (.32)	.58 (.88)	Phonological errors	6.64 (6.64)	1.01 (2.90)	3.69 (5.54)	D vs CA *U*=07.00, *Z*=-4.19, *p*=.000 D vs RA *U*=306.50, *Z*=-1.87, *p*=.062 CA vs RA *U*=312.50, *Z*=-2.29, *p*=.022
Mixed errors	.89 (1.08)	.26 (.66)	.50 (.78)	Mixed errors	6.71 (7.94)	2.27 (5.53)	3.45 (5.38)	D vs CA *U*=406.50, *Z*=-2.86, *p*=.004
Perceptual errors	.09 (.28)	.11 (.32)	.08 (.28)	Perceptual errors	0.53 (1.81)	0.78 (2.20)	0.64 (2.17)	
Other errors	6.23 (3.28)	5.00 (3.27)	7.63 (2.89)	Other errors	45.09 (20.23)	43.30 (22.38)	55.13 (20.56)	

Analyses were carried out using percentages of naming errors. Nonparametric Mann-Whitney tests were used to investigate group differences in the rate of phonological, mixed and perceptual errors because of the nonnormal distribution and the presence of outliers. One-way ANOVAs were used to analyse group differences in the rate of semantic and other errors. Levene's test verified the equality of variances for the semantic (F = 1.931, p = .151) and other naming errors (F = .084, p = .920).

To improve readability, significant results (and those approaching significance) from the post-hoc (Bonferroni) tests and Mann Whitney tests are given in Table V.7. There was a significant main effect of group for semantic errors (F(2,91) = 4.828, p = .010). Post-hoc revealed no significant difference between dyslexics and RA controls (p = 1.00, Cohen's d = .21). There was no effect of group for the category of other errors (F(2,91) = 2.453, p = .092). The difference between dyslexics and CA controls in rate of perceptual errors was not significant (U = 594.50, Z = -.406, p = .685, Cohen's d = .12).

With regard to the comparison between dyslexics and RA controls, the results revealed that the percentage of mixed errors (U = 324.00, Z = -1.62, p = .106, Cohen's d = .48) and perceptual errors (U = 419.00, Z = -.032, p = .975, Cohen's d = .06) was no significant.

Finally, the difference between CA and RA controls in the rate of mixed (U = 346.00, Z = -1.49, p = .136, Cohen's d = .22) and perceptual errors (U = 411.00, Z = -.265, p = .791, Cohen's d = .06) was not significant.

Regression analyses to examine the effect of psycholinguistic variables in the dyslexic children and the CA, and RA controls.

Item-based regression analyses were carried out to examine the effect of the psycholinguistic variables on picture naming in the dyslexic children and CA and RA controls. The dependent variable was accuracy (calculated across participants and separately for each of the three groups) in the picture naming task and the independent variables were values for spoken word frequency, visual complexity, word length (joint measure), phonological neighbours and imageability.

In line with the analyses of the results from the TD children, it was decided to use all five predictors in the regression analyses because analyses carried out individually for the dyslexic children showed significant relationships between each of the psycholinguistic variables and picture naming accuracy.

The relationship between the measures of spoken frequency, imageability, joint measure of word length, phonological neighbours, and visual complexity was reported in the previous chapter, therefore it will not be included here.

The distribution of naming accuracy scores for all the three groups resembled a binomial distribution and since the distributions of spoken frequency and number of phonological neighbour were non-normal, analyses were carried out with log transformed and untransformed spoken frequency and phonological neighbour values. All the variables were simultaneously entered. Untransformed data for spoken frequency and phonological neighbours were used in the analyses reported here and results are given in Table V.8. A summary of results of regression analyses with transformed values is given in Appendix A1. Results did not show substantial differences whether transformed or untransformed data were used. The only difference was that, using transformed data, apart from the significant effect of imageability, number of phonological neighbours was also a significant predictor in the case of the CA and RA controls.

Table V.8 Summary of the multiple regression analyses for the dyslexic children, CA and RA controls with picture naming accuracy as the dependent variable and psycholinguistic variables as predictors

	B	SE(B)	β	*t*	Sig. (*p*)
Dyslexics					
Constant	-46.177	11.710		-3.943	.000
Spoken frequency	-.285	1.204	-.032	-.237	.814
Visual complexity	.153	1.298	.012	.118	.907
Phono. Neighbour	.229	.292	.100	.785	.436
Word length	-.291	.421	-.092	-.692	.492
Imageability	12.442	2.102	.747	5.920	.000
	B	SE(B)	β	*t*	Sig. (*p*)
CA controls					
Constant	-59.943	13.098		-4.576	.000
Spoken frequency	-.903	1.346	-.090	-.671	.505
Visual complexity	.533	1.452	.039	.381	.705
Phono. Neighbour	.423	.327	.165	1.296	.201
Word length	-.009	.471	-.002	-.018	.986
Imageability	14.930	2.351	.801	6.351	.000
	B	SE(B)	β	*t*	Sig. (*p*)
RA controls					
Constant	-35.653	8.034		-4.438	.000
Spoken frequency	-.251	.826	-.039	-.304	.762
Visual complexity	-.098	.891	-.011	-.110	.913
Phono. Neighbour	.268	.200	.164	1.336	.187
Word length	-.107	.289	-.048	-.371	.712
Imageability	9.006	1.442	.761	6.245	.000

Note: Dyslexics model: $R^2 = .578$, $\Delta R^2 = .537$. ANOVA: $F(5, 51) = 13.975$, $p < .0001$. CA controls: $R^2 = .760$, $\Delta R^2 = .578$. ANOVA: $F(5, 51) = 13.971$, $p < .0001$. RA controls: $R^2 = .779$, $\Delta R^2 = .606$. ANOVA: $F(5, 51) = 15.693$, $p < .0001$.

For all the three groups, imageability was the only significant predictor of naming accuracy ($p < .0001$). This was in line with results presented for the TD children in the previous chapter.

Interim summary of results of the picture naming subsidiary analyses

The results of the qualitative analysis of the picture naming errors revealed that dyslexic children had a significantly higher rate of phonological and mixed errors in comparison to chronological age controls, while no significant difference in naming errors between dyslexics and RA controls was found. The results of the item-based regression analyses indicated that rated imageability was the only significant predictor of picture naming accuracy for all the three groups (dyslexics, CA and RA controls).

Summary of results

Results of the analyses carried out with the scores from the standardized assessments of semantics and phonology revealed that the dyslexic children performed significantly worse than CA controls in all the tasks. In comparison to RA controls, dyslexics were significantly more accurate than RA controls in the vocabulary tasks. No difference between dyslexics and RA controls in the phonological assessments was found.

Regarding the experimental tasks of WPVT, PJs and simple and choice reaction time, results revealed that the dyslexic children recognised significantly fewer pictures than CA controls in the WPVT, while there was no significant difference between dyslexics and RA controls. A near ceiling effect for PJs accuracy for the dyslexic children was found; therefore results from this task should be considered with caution. There was no difference between dyslexics and CA controls in PJs accuracy and latency, while dyslexics and CA controls were significantly faster and more accurate than RA controls. Finally, in choice reaction time latencies no significant difference was found between dyslexics and the CA controls for accuracy, while dyslexics and CA controls were significantly faster than RA controls. No significant group effect was found in the simple reaction time latencies.

Finally, regarding the picture naming task, results indicated that the CA controls correctly named significantly more pictures than dyslexics and RA controls, while there was no significant difference for dyslexics and RA controls. Dyslexics' naming latencies were similar to those obtained by CA controls, while dyslexics and

CA controls were significantly faster than RA controls. Subsidiary analyses indicated that there was a significantly higher preponderance of phonological errors in the incorrect responses of dyslexics than CA controls, while the difference between dyslexics and RA controls in the rate of phonological errors was marginally significant. Dyslexics' errors contained a higher proportion of mixed errors than CA controls, while no difference between dyslexics and RA controls in the rate of mixed errors was found. Rate of semantic errors for the CA controls was significantly higher than that of the RA controls, and the difference between dyslexics and CA controls was marginally significant. With regard to the second subsidiary analysis of the picture naming data, results revealed a significant effect of imageability on naming accuracy for the dyslexics and CA, and RA controls.

V.3.3. Relationship of semantics and phonology to naming, and of these to reading

Picture naming accuracy, latency and rate of phonological naming errors, as well as results from the experimental and standardised assessments of phonology and semantics, and irregular word and nonword reading accuracy were entered in correlation analyses, for RA and CA controls, and dyslexics. Correlation analysis was carried out with age partialled out, as in the analyses with the data for the TD children reported in the previous chapter. Results are described in separate sections for the RA and CA controls, and dyslexics.

V.3.3.1. Reading age and chronological age control groups

Regarding the scores for RA controls, exploratory data analysis revealed that the distributions for blending and rate of phonological naming errors were not normal (Kolmogorov-Smirnov test: $p < .05$). Therefore logarithmic transformations were applied. Since results were not substantially different whether transformations were applied or not, it was decided to present the analyses of the untransformed data in Table V.9. Results with transformed data are given in Appendix B1. Expressive vocabulary was not entered into the correlation analysis for the RA controls due to the small number (N = 9) of children who were administered the vocabulary subtask from WISC IV (see Chapter IV, pp. 67-68).

Table V.9 Correlations between experimental measures, standardised assessments and reading scores for the CA and RA controls controlling for chronological age, results for the RA controls are below the diagonal and those for the CA controls are above the diagonal

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Rec.Voc.	-	.820***	.143	.470**	.190	-.149	.351*	-.225	-.143	.371*	.258	.672***	-.187
2. Exp.Voc	-	-	.340	.612**	.074	-.249	.218	-.345**	-.512*	.618***	.508*	.605**	-.135
3. Blending	.382	-	-	.166	.094	.030	.209	-.099	-.485**	-.242	.118	.233	-.062
4. NWRep.	.442*	-	.302	-	.056	-.641***	.363*	-.325*	-.416*	.129	-.008	.592***	-.230
5. RAN dig.	-.366	-	-.164	.104	-	.324	-.156	-.128	-.089	-.142	-.279	.294	.072
6. RAN obj.	-.031	-	.305	-.350	.252	-	-.339*	.145	.297	.012	.212	-.377*	.240
7. PJs acc.	.222	-	-.019	-.205	.091	.291	-	-.017	-.252	-.012	.098	.377*	-.181
8. PJs time	-.176	-	.097	-.203	.182	-.002	-.439	-	-.096	-.325	-.101	-.275	.535**
9. Phon.Err.	-.207	-	-.125	-.437*	-.123	-.063	-.037	-.021	-	.082	-.151	-.262	-.290
10. Irr. acc.	-.298	-	-.431*	.203	-.103	-.137	-.270	-.217	-.254	-	.686**	.128	-.071
11. Nwd acc.	.178	-	.659**	.430*	.294	.250	.153	-.015	-.296	-.393	-	-.013	.275
12. Pic. acc.	.653**	-	.305	.163	-.208	-.019	.440*	-.167	-.229	-.184	.156	-	-.341*
13. Pic. time	-.067	-	-.225	.031	.103	-.504*	-.328	.467*	-.138	.211	-.269	.119	-

Note: $*p < .05$, $**p < .01$, $***p <. 001$.

RA controls

With regard to the correlation between semantics and phonology, results revealed a marginally significant correlation between blending and receptive vocabulary ($p = .072$). A significant correlation was found between receptive vocabulary and nonword repetition ($p < .05$).

With regard to the relation between semantics, phonology and naming, the results indicated that picture naming accuracy correlated significantly with receptive vocabulary ($p < .01$), and PJs accuracy ($p < .05$). Picture naming latency was significantly negatively correlated to RAN objects ($p < .05$), and positively with PJs latency ($p < .05$). The rate of phonological errors was significantly negatively associated with nonword repetition ($p < .05$).

Finally, concerning the relationship between semantics, phonology, naming and reading, results revealed that nonword reading correlated significantly with blending ($p < .01$), nonword repetition ($p < .05$) and, marginally, with irregular word reading ($p = .063$). Irregular word reading was significantly negatively correlated with blending ($p < .05$).

CA controls

Regarding the association between the semantic and phonological assessments, results revealed that scores for receptive and expressive vocabulary were highly correlated ($p < .0001$). Nonword repetition was significantly associated with receptive and expressive vocabulary ($p < .01$). Blending did not correlate significantly with any other phonological or semantic measure. Rapid naming (RAN) of objects was significantly negatively correlated with nonword repetition ($p < .0001$), picture naming accuracy, and PJs accuracy (all ps < .05). There was a marginally significant association between RAN digits and RAN objects ($p = .061$).

With regard to the relation between semantics, phonology and naming, the results revealed that picture naming accuracy correlated significantly with receptive vocabulary ($p < .001$), expressive vocabulary ($p < .01$), nonword repetition ($p < .001$). Picture naming latency correlated with PJs latency ($p < .01$) and negatively with picture naming accuracy ($p < .05$). Rate of phonological errors in picture naming correlated negatively with expressive vocabulary ($p < .05$), blending ($p < .01$), and nonword repetition ($p < .05$).

Finally, regarding the relationship between semantics, phonology, naming and reading, results revealed that nonword reading correlated significantly with expressive vocabulary ($p < .05$) and with irregular word reading ($p < .01$). Irregular word reading correlated significantly with receptive ($p < .05$) and expressive vocabulary ($p < .01$).

V.3.3.2. Dyslexic children

In addition to the variables in the correlation analyses described in the previous section, digit span scores were entered into the correlation analyses for the dyslexic children.

The distributions of rate of phonological naming errors, picture naming latency, and PJs accuracy were non-normal for the dyslexic children and so correlation analysis was carried out twice, once with untransformed data and once with log-transformed data. Results did not change substantially, therefore a summary of results of the analysis with untransformed data is given in Table V.10, while the results with transformed data are in Appendix C1.

Table V.10 Correlations between experimental measures, standardised assessments and reading scores for the dyslexic children controlling for chronological age

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Rec.Voc.	-												
2. Exp.Voc	.617***	-											
3. Blending	.542**	.312	-										
4. NWRep.	.449**	.480**	.425*	-									
5. RAN dig.	.045	-.049	.051	.017	-								
6. RAN obj.	-.191	-.223	-.177	-.259	.654***	-							
7. PJs acc.	.037	-.117	.239	.340*	.024	.025	-						
8. PJs time	-.134	.064	-.122	-.019	.040	.384*	-.010	-					
9. Phon. Err.	.394*	.507**	.019	.145	.238	-.129	-.104	-.286	-				
10. Irr. acc.	.078	.228	.182	.249	-.247	.070	-.058	.033	-.052	-			
11. Nwd acc.	-.129	-.046	.402*	.170	-.178	-.024	.105	.153	-.234	.495**	-		
12. Pic. acc.	.565***	.220	.452**	.388*	.128	-.196	.223	-.202	.103	-.117	-.103	-	
13. Pic. time	-.513**	-.261	-.430*	-.288	.071	.352*	.143	.122	-.221	-.122	-.032	-.265	-
14. Digit span	-.232	-.049	-.084	.020	.073	-.099	-.058	.191	.078	-.323	.048	-.131	.165

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

Regarding the association between the semantic and phonological assessments, receptive and expressive vocabulary scores were highly correlated ($p < .0001$), and there was a significant correlation between blending and receptive vocabulary ($p < .01$). Nonword repetition was significantly associated with receptive vocabulary ($p < .01$) and expressive vocabulary ($p < .01$) as found also in the CA controls. A significant association was found between nonword repetition and blending ($p < .05$), while rapid naming of objects and of digits correlated significantly with each other only ($p < .0001$).

With regard to the relation between semantics, phonology and naming, the results of the correlation analyses indicated that picture naming accuracy correlated significantly with receptive vocabulary ($p < .001$), blending ($p < .01$) and nonword repetition ($p < .05$). Picture naming latency correlated negatively with receptive vocabulary ($p < .01$), blending ($p < .05$), and positively with rapid naming for objects ($p < .05$). Rate of phonological errors in picture naming correlated significantly with receptive ($p < .05$) and expressive vocabulary ($p < .01$).

Regarding the relationship between semantics, phonology, naming and reading, results revealed that nonword reading correlated significantly with blending ($p < .05$) and with irregular word reading ($p < .01$). Irregular word reading did not correlate significantly with any measure. There was a marginally significant correlation between digit span and irregular word reading ($p = .063$).

Interim summary of results

Results are summarised first for the dyslexic children, followed by the RA controls and lastly for the CA controls.

Results indicated that picture naming accuracy correlated significantly with receptive vocabulary and nonword repetition in the dyslexic children. Differently to the younger and older TD groups, in the dyslexic children blending correlated significantly with picture naming accuracy and the rate of phonological naming errors correlated with vocabulary knowledge, in that dyslexics with poorer vocabulary knowledge had a lower rate of phonological naming errors. Regarding the dyslexics' reading skills, results revealed that nonword reading correlated significantly with blending, while irregular word reading seemed to be marginally significantly associated to digit span only.

Looking at the associations in the RA control group, results revealed that picture naming accuracy correlated significantly with receptive vocabulary and PJs accuracy. The rate of phonological errors was negatively correlated with nonword repetition. Regarding the association of reading with semantics and phonology, nonword reading was significantly correlated with blending and nonword repetition, while irregular word reading was significantly negatively associated with blending.

Finally, in the CA controls, picture naming correlated significantly with receptive and expressive vocabulary, nonword repetition, and negatively with RAN objects. Contrarily to dyslexics, the rate of phonological errors was negatively correlated with expressive vocabulary, blending and nonword repetition. Finally, nonword reading was significantly associated with expressive vocabulary and irregular word reading was significantly correlated with receptive and expressive vocabulary.

V.3.4. Is naming deficit found for all children with dyslexia?

As described in the Introduction section, two different classification criteria were adopted: one continuous and one discrete. The continuous criterion (Griffiths & Snowling, 2002) was devised as a measure of relative strength of sublexical skills. Following Masterson, Laxon and Stuart (1992), the proportional difference between correct responses on nonwords and irregular words divided by the total number of correct responses on both irregular words and nonwords was calculated. The formula used was "(%NW-%IRRW)/(%NW+%IRRW)", in which NW stands for nonword, and IRRW for irregular words. Correlation analysis was carried out between the continuous measure and the scores in the assessments of naming, phonology and semantics.

The discrete criterion was used to assign the dyslexic children to subgroups according to their reading profile. As stated in the Introduction, this involved calculating irregular and nonword reading *z* scores on the basis of the performance of CA control children in the reading subtasks. Lexical processes were indexed by the irregular word reading subtask and sublexical processes by the nonword reading subtask. In light of the findings relating to different classification schemes of McArthur et al. (2013) (described in Chapter I, pp. 26-29), classification scheme 1 was selected on the grounds of a) a balance of relative lexical and sublexical primary impairment, and b) generating large enough numbers of children in the different subgroups for statistical comparison.

V.3.4.1. Continuous criterion

Scores for the continuous measure calculated for individual dyslexic children are given in Table V.11.

Table V.11 Percentage correct nonword, regular word and irregular word reading in the DTWRP and relative sublexical strength values for individual dyslexic children

Case number	Nonword reading	Irregular word reading	Regular word reading	Relative sublexical strenght
1	43.33	43.33	60.00	0.00
2	23.33	30.00	33.33	-0.13
3	23.33	23.33	16.67	0.00
4	36.67	43.33	46.67	-0.08
5	10.00	20.00	16.67	-0.33
6	36.67	53.33	56.67	-0.19
7	23.33	53.33	40.00	-0.39
8	16.67	46.67	53.33	-0.47
9	20.00	56.67	60.00	-0.48
10	36.67	43.33	63.33	-0.08
11	36.67	56.67	46.67	-0.21
12	46.67	70.00	80.00	-0.20
13	46.67	50.00	66.67	-0.03
14	30.00	26.67	26.67	0.06
15	10.00	30.00	33.33	-0.50
16	23.33	36.67	50.00	-0.22
17	30.00	56.67	60.00	-0.31
18	20.00	23.33	30.00	-0.08
19	16.67	26.67	33.33	-0.23
20	23.33	36.67	30.00	-0.22
21	43.33	40.00	63.33	0.04
22	20.00	33.33	43.33	-0.25

23	26.67	43.33	50.00	-0.24
24	26.67	46.67	63.33	-0.27
25	20.00	50.00	43.33	-0.43
26	26.67	23.33	26.67	0.07
27	13.33	46.67	43.33	-0.56
28	16.67	50.00	40.00	-0.50
29	40.00	63.33	63.33	-0.23
30	16.67	33.33	36.67	-0.33
31	23.33	43.33	46.67	-0.30
32	30.00	36.67	43.33	-0.10
33	23.33	26.67	30.00	-0.07
34	23.33	30.00	23.33	-0.13
35	26.27	36.67	60.00	-0.16

The continuous measure was included in a correlation matrix together with naming, semantic and phonological scores. A summary of results is given in Table V.12. *EDA* indicated that the relative continuous measure was normally distributed (Kolmogorov-Smirnov test: $p = .200$).

Table V.12 Correlations between the relative measure of sublexical strength and scores for semantics, phonology and naming

Measures	Relative sublexical strength
1. Receptive vocabulary	-.211
2. Expressive vocabulary	-.317
3. Blending	.346*
4. Nonword repetition	-.096
5. RAN digits	-.047
6. RAN objects	-.142
7. Phonological naming errors	-.372*
8. Picture naming accuracy	-.153
9. Picture naming latency	-.017
10. Digit span	.272

Results indicated that the relative measure of sublexical strength correlated significantly with blending (p = .042) and negatively with rate of phonological errors in picture naming (p = .028). A marginally negative significant association between the sublexical measure and expressive vocabulary scores (p = .064) was also found.

Interim summary of results

Results of correlation analyses revealed significant associations between the relative measure of sublexical strength with blending and the rate of phonological errors in picture naming. This suggests that those dyslexic children who are better at using sublexical phonology are less likely to have phonological problems, and they exhibited weaker vocabulary knowledge, as indicated by the negative marginally significant association with expressive vocabulary scores.

V.3.4.2. Discrete criterion

Nonword and irregular word reading z scores for the dyslexic children were calculated on the basis of the CA controls nonword and irregular word reading subtask scores (FRLL, 2012). Following the classification of McArthur et al. (2013a), described in detail in Chapter I, dyslexics were categorised according to five different schemes. The classification of each child according to the five schemes is given in

Table V.13. Three groups of dyslexic children, those with a relative impairment of sublexical versus lexical processes, those with relative impairment of lexical versus sublexical processes, and dyslexic children with impairment to both lexical and sublexical processes were identified.

Table V.13 Nonword and irregular word *z* scores and classification of individual dyslexic children according to the five-classification schemes following McArthur et al. (2013)

Case number	Nonword z score	Irregular word z score	Schema 1	Schema 2	Schema 3	Schema 4	Schema 5
1	-1.17	-2.81	L	M	M	L	M
2	-2.46	-3.07	M	M	M	L	M
3	-2.85	-3.70	M	M	M	L	M
4	-1.51	-2.81	L	M	M	L	M
5	-3.65	-3.01	M	M	M	L	M
6	-1.51	-1.86	L	M	M	M	M
7	-2.18	-1.86	M	M	M	M	M
8	-2.51	-2.49	M	M	M	M	M
9	-2.35	-1.55	S	M	M	S	M
10	-1.51	-2.81	L	M	M	L	M
11	-1.51	-1.55	N	M	N	N	M
12	-1.68	-0.29	S	S	S	S	S
13	-1.00	-2.18	L	L	L	L	L
14	-1.86	-2.38	M	M	M	L	M
15	-2.85	-3.37	M	M	M	L	M
16	-3.18	-2.44	M	M	M	L	M
17	-1.84	-1.55	S	M	M	M	M
18	-2.35	-3.70	M	M	M	L	M
19	-2.51	-3.38	M	M	M	L	M
20	-2.18	-3.44	M	M	M	L	M
21	-1.17	-3.12	L	M	M	L	M
22	-2.35	-3.75	M	M	M	L	M
23	-3.01	-2.41	M	M	M	L	M
24	-2.01	-2.49	M	M	M	M	M
25	-2.35	-2.18	M	M	M	M	M
26	-2.01	-2.70	M	M	M	L	M
27	-2.68	-2.49	M	M	M	M	M

28	-2.51	-2.18	M	M	M	M	M
29	-1.66	-0.92	S	S	S	S	S
30	-2.51	-3.75	M	M	M	L	M
31	-2.18	-2.81	M	M	M	L	M
32	-2.84	-3.44	M	M	M	L	M
33	-2.18	-3.38	M	M	M	L	M
34	-2.48	-3.07	M	M	M	L	M
35	-2.81	-3.44	M	M	M	L	M

Note: L = lexical dyslexia subtype, M = mixed dyslexia subtype, S = sublexical dyslexia subtype

The percentage of children classified as having a primary sublexical impairment, primary lexical impairment, or mixed impairment was calculated for each of the five classification schemes. The results are presented in Table V.14.

Table V.14 Summary of distribution of children in the dyslexia subtypes according to the five classification schemes

	Classification schema									
	1 Castles & Coltheart (1993)		2 Sprenger-Charolles et al. (2000)		3 Castles & Coltheart (1993)		4 Edwards & Hogben (1999)		5 McArthur et al. (2013)	
Profile	N	%	N	%	N	%	N	%	N	%
Sublexical	4	11	2	6	2	6	3	9	2	6
Lexical	6	17	1	3	1	3	23	66	1	3
Mixed	24	69	32	91	30	86	8	23	31	89
Unclassified	1	3	0	0	2	6	1	3	1	3

Note: Percentage scores have been rounded

As outlined in the previous section, Classification 1, originally used in the study of Castles and Coltheart (1993), was used for the present analyses. This defined primary sublexical impairment as a nonword reading *z* score equal to -1.64 or lower, and irregular word reading *z* score better than -1.64, and primary lexical impairment by the reverse criteria. A summary of the mean *z* scores for the three subtypes of dyslexia is given in Table V.15.

Table V.15 Mean z scores for dyslexic children in the sublexical, lexical and mixed dyslexia subtypes according to Classification scheme 1 (standard deviations are in parentheses)

Classification 1	Sublexical	Lexical	Mixed
Nonword reading (*z* score)	-1.88	-1.31	-2.52
	(.32)	(.22)	(.41)
Irregular word reading (*z*	-1.08	-2.60	-2.96
score)	(.60)	(.47)	(.58)

Within-subjects tests were used to test for difference in reading scores for the subtypes. The sublexical group was characterised by a greater impairment in nonword than irregular word reading (Z = -1.83, p = .048). The lexical subgroup was significantly better at reading nonwords than irregular words (Z = -2.21, p = .027). No statistically significant difference between nonword and irregular word reading was found in the mixed dyslexic subgroup (Z = -1.406, p = .160).

The following sections give the results of analyses comparing the scores for each of the subgroups with those of age matched controls[38]. The first section presents results for the background variables of chronological age, nonverbal ability and single word and passage reading. The second section presents the results for the standardised assessments of semantics and phonology and the third section presents results for the experimental tasks.

V.3.4.2.1.Background variables

A summary of standard scores in the assessment of articulation and in the digit span task for the three subgroups of dyslexic children is given in Table V.16. The three

[38] It was not possible to constitute a reading age control groups with enough children for statistical group comparisons. There is an issue in the literature about whether it is preferable to use reading-matched (e.g., Manis et al., 1996) or age-matched controls (McDougall, Borowsky, MacKinnon, & Hymel, 2005) when investigating primary lexical and sublexical impairment. As outlined in Chapter I, Wybrow and Hanley (2015) (see also McArthur et al. 2013; Peterson, Pennington, & Olson, 2013) have recently demonstrated that using a reading age controls matched on real-word reading test biases group comparisons, in that it reduces the incidence of surface dyslexia. This issue will be examined further in the Discussion section.

groups were compared with each other since these two measures were not administered to the typically developing children.

Questionnaires were available for three out of the four children with primary sublexical impairment and five of the six children with primary lexical impairment. The child developmental questionnaire revealed that two children in the sublexical group, of which one attended speech and language therapy in the past, were described as "late talkers" by their parents. The third one had familiarity for dyslexia. Regarding the lexical group, five out of six children had familiarity for dyslexia, and none were described as "late talkers".

Table V.16 Mean standard scores in the standardised articulation and digit span assessments for dyslexic children in the sublexical, lexical and mixed subtype groups (standard deviations are in parentheses)

	Sublexical	Lexical	Mixed	Sublexical vs Lexical	Sublexical vs Mixed	Lexical vs Mixed
Articulation	103.00	105.00	103.21	U=6.00, Z=-1.38, p=.181	U=43.00, Z=-.334, p=.738	U=50.50, Z=-1.13, p=.257
	(2.45)	(1.67)	(3.50)			
Digit span	7.00	8.33	7.54	U=8.00, Z=-1.23, p=.221	U=38.00, Z=-.680, p=.496	U=60.00, Z=-.64, p=.522
	(0)	(2.07)	(1.98)			

Mann-Whitney *U* tests revealed that there were no significant differences in the articulation and digit span tasks between the three dyslexic subtypes (all *p*s > .05).

The three subgroups of dyslexic children were matched on the basis of chronological age (in months) to children from the TD sample. Controls for the sublexical group were 13 children, of whom 6 were girls, those for the lexical group were 17 children (10 girls), and those for the mixed group were 24 children (11 girls). A summary of chronological ages and scores for assessments of nonverbal ability, single word reading, passage reading accuracy, rate and comprehension for the subgroups of dyslexic children and controls is given in Table V.17.

Table V.17 Means and standard deviations in the background assessments for dyslexic children in the sublexical, lexical and mixed subtype groups and their age-matched controls

Measures	Sublexical	Lexical	Mixed	Sublexical vs Control	Lexical vs Control	Mixed vs Control
Age	108.50 (3.32)	102.34 (4.88)	100.54 (7.26)	*U*=21.00, *Z*=-.574, *p*=.624	*U*=40.50, *Z*=-.742, *p*=.458	*t*(46)=.032, *p*=.975
Controls	107.77 (3.42)	101.00 (4.76)	100.61 (7.20)			
Nonverbal ability	53.50 (5.17)	53.83 (7.73)	52.58 (10.86)	*U*=23.00, *Z*=-.341, *p*=.733	*U*=36.50, *Z*=-1.02, *p*=.308	*t*(46)=.802, *p*=.427
Controls	50.77 (4.90)	50.88 (4.99)	54.91 (8.90)			
DTWRP total score (SS)	86.50 (6.14)	86.00 (4.15)	78.17 (4.90)	*U*=1.00, *Z*=-2.84, *p*=.002	*U*=.00, *Z*=-3.58, *p*<.0001	[1]*t*(29)=122.522, *p*<.0001
Controls	101.77 (5.93)	101.47 (5.52)	107.26 (11.66)			
Nonword reading (stanine score)	2.25 (.50)	3.75 (.50)	2.42 (.72)	*U*=.00, *Z*=-3.03, *p*=.002	*U*=12.50, *Z*=-2.89, *p*=.004	*U*= 23.50, *Z*=-5.48, *p*<.0001
Controls	5.38 (.87)	4.62 (.51)	6.13 (1.07)			
Irregular word reading (stanine score)	3.83 (.41)	2.50 (.55)	2.21 (.78)	*U*=7.50, *Z*=-2.35, *p*=.019	*U*=.00, Z=-3.70, *p*<.0001	*U*=.00, *Z*=-5.95, *p*<.0001
Controls	4.94 (.75)	4.82 (.73)	5.65 (.91)			

YARC single word reading (SS)	79.00 (4.76)	85.17 (7.57)	76.54 (6.02)	$U=.00, Z=-2.95, p=.001$	$U=4.50, Z=-3.27, p<.0001$	[2]$t(33)=101.245, p<.0001$
Controls	99.54 (8.31)	97.12 (5.37)	103.22 (11.27)			
YARC passage accuracy (SS)	89.50 (5.00)	88.17 (6.18)	85.54 (4.61)	$U=.000, Z=-3.00, p=.003$	$U=2.00, Z=-3.42, p=.001$	$U=.50, Z=-5.87, p<.0001$
Controls	103.38 (7.47)	102.50 (5.96)	110.13 (11.76)			
YARC passage rate (SS)	110.25 (11.27)	87.83 (5.98)	85.19 (10.20) N=21	$U=14.50, Z=-1.30, p=.192$	$U=5.00, Z=-3.17, p=.001$	$U=33.00, Z=-4.91, p<.0001$
Controls	102.08 (6.10)	101.75 (7.37)	107.17 (12.44)			
YARC comprehension (SS)	94.50 (8.38)	92.67 (10.31)	93.88 (8.60)	$U=17.00, Z=-1.02, p=.307$	$U=21.00, Z=-2.00, p=.046$	$t(46)=5.223, p< .0001$
Controls	100.31 (9.11)	101.94 (4.98)	106.57 (8.03)			

Note: [1,2]Results did not change if Welch's correction was not applied: [1]$t(46) = 126.313, p < .0001$; [2] $t(46) = 103.723, p < .0001$.

There were no significant differences between the subgroups and respective controls on chronological age or nonverbal ability (please see table for results of statistical comparisons). The comparisons between the sublexical and lexical group with their respective control groups were carried out using the Mann-Whitney *U* nonparametric test. This choice was motivated by the group sizes. The results for the mixed group were compared to those of controls using parametric *t*–tests since the this group was larger, however, where the distributions were non-normal, comparisons were carried out using nonparametric tests for the mixed group as well. The analyses employed an alpha set at the 5% level, two-tail test.

For the sublexical group, results revealed that there was a significant difference in single word reading between dyslexics and controls (both *p*s $< .01$ in the DTWRP and YARC single word). There was also a significant difference for YARC passage reading accuracy ($p < .01$), while there was no significant difference for YARC reading rate ($p = .192$) or reading comprehension ($p = .307$).

With regard to the lexical group, results revealed that there was a significant difference in single word reading (both *p*s $< .0001$ in the DTWRP and YARC single word), in YARC passage reading accuracy ($p < .01$) and reading rate ($p < .01$). The difference for YARC reading comprehension approached significance ($p = .046$).

Finally, for the mixed group, the Kolmogorov-Smirnov test for normality indicated that the YARC reading comprehension score distribution did not deviate significantly from a normal distribution ($p = .200$) while the distributions for accuracy and rate were non-normal. Therefore, Mann-Whitney *U* tests were used to compare the performance of the mixed subgroup and controls on YARC passage reading accuracy and rate, while an independent samples t-test was used for reading comprehension. Levene's test was used to check homogeneity of variance in reading comprehension scores ($F = .392$, $p = .534$). The results for group differences revealed that the mixed group performed significantly worse than controls in the two measures of single word reading (both *p*s $< .0001$ in the DTWRP and YARC single word reading) and in all the YARC passage reading measures (all *p*s $< .0001$).

V.3.4.2.2.Standardised assessments of phonology and semantics

A summary of the standardised scores in the semantic and phonological assessments is given in Table V.18. A summary of the scores in the same assessments for the dyslexic children in the three subgroups and their relative controls is given in Table V.19.

Analyses comparing the results of the dyslexic children and their relative controls were conducted on the percentage correct scores (and on time taken in the case of the rapid naming task scores). This was in order that the results of the comparisons would be comparable with those for the experimental task results.

Table V.18 Mean standard scores in the semantic and phonological assessments for the sublexical, lexical and mixed dyslexic subtypes and their relative age-matched controls (standard deviations are in parentheses)

Measures	Sublexical	Lexical	Mixed
Receptive vocabulary	90.50 (5.45)	79.33 (9.69)	89.58 (12.46)
Controls	94.38 (8.24)	97.88 (9.92)	100.70 (13.66)
Expressive vocabulary	9.25 (1.50)	7.67 (1.97)	7.58 (1.67)
Controls	10.14$^{\alpha}$ (1.68)	10.22$^{\beta}$ (1.93)	10.64$^{\gamma}$ (2.30)
Nonword repetition	82.50$^{\delta}$ (34.65)	84.50 (21.98)	81.06$^{\eta}$ (15.90)
Controls	93.86$^{\varepsilon}$ (12.80)	94.63$^{\zeta}$ (9.63)	96.61$^{\eta}$ (11.82)
Blending	8.75 (.96)	9.17 (1.17)	8.83 (1.58)
Controls	12.33 (1.97)	10.18 (1.97)	10.43 (1.80)

Rapid naming digits	97.00 (17.26)	99.50 (15.25)	90.13 (10.98)
Controls	102.00 (17.96)	105.47 (16.11)	105.09 (9.57)
Rapid naming objects	86.25 (7.18)	93.50 (11.04)	94.50 (14.69)
Controls	98.00 (12.05)	97.94 (9.80)	100.30 (10.33)

Note: $^{\alpha}$N = 7, $^{\beta}$N = 9, $^{\gamma}$N = 14, $^{\delta}$N = 2, $^{\varepsilon}$N = 7, $^{\zeta}$N = 16, $^{\eta}$N= 18

Table V.19 Mean percentage correct in the semantic and phonological assessments for the sublexical, lexical and mixed dyslexic subtypes and their relative age-matched controls (scores for the rapid naming assessments are time to complete the task in seconds, standard deviations are in parentheses)

Measures	Sublexical	Lexical	Mixed	Sublexical vs Controls	Lexical vs Controls	Mixed vs Controls
Receptive vocabulary	64.30 (8.39)	55.85 (4.57)	60.37 (8.37)	U=12.50, Z=-1.53, p=.125	U=4.00, Z=-3.30, p=.001	$t(46)$=12.303, p=.001
Controls	70.05 (7.38)	67.02 (6.23)	69.00 (8.49)			
Expressive vocabulary	37.85 (7.12)	29.40 (7.27)	28.99 (5.81)	U=11.50, Z=-.478, p=.633	U=7.50, Z=-2.31, p=.021	$t(21)$=16.755, p=.001
Controls	40.48 $^{\alpha}$ (5.64)	37.96 $^{\beta}$ (5.15)	39.19 $^{\gamma}$ (8.19)			
Nonword repetition	73.13 (13.13)	68.33 (15.14)	66.04 (12.60)	U=13.00, Z=-1.48, p=.138	U=38.50, Z=-.881, p=.379	$t(46)$=12.052, p=.001
Controls	81.92 (8.18)	75.88 (7.12)	77.61 (10.04)			
Blending	52.50 (10.41)	58.34 (10.33)	53.96 (13.19)	U=4.50, Z=-2.48, p=.013	U=36.50, Z=-1.03, p=.305	$t(46)$=7.365, p=.009
Controls	73.08 (10.71)	63.24 (14.25)	65.00 (14.69)			
Rapid naming digits	64.75 (21.70)	66.17 (17.99)	78.08 (16.20)	U=15.00, Z=-1.249, p=.212	U=33.50, Z=-1.24, p=.220	$t(46)$=19.656, p<.0001

Controls	53.85 (8.26)	55.00 (6.96)	59.61 (11.95)			
Rapid naming objects	121.50 (11.12)	114.83 (15.75)	117.29 (27.79)	*U*=8.00, *Z*=-2.04, *p*=.041	*U*=29.50, *Z*=-1.51, *p*=.131	*t*(37)=3.360, *p*=.075
Controls	104.69 (18.78)	108.12 (15.26)	105.26 (15.82)			

Note: $^{\alpha}$N = 7, $^{\beta}$N = 9, $^{\gamma}$N = 14.

For the sublexical group, results for the semantic assessments revealed that there were no significant differences between the dyslexics and controls (both receptive and expressive vocabulary: $p > .05$). Regarding the phonological measures, there was no significant difference for nonword repetition ($p > .05$), while there was a significant difference for blending: the sublexical group was significantly less accurate than controls ($p < .05$). The sublexical group was also significantly worse than controls in rapid naming of objects ($p < .05$), while there was no significant difference for rapid naming of digits ($p > .05$).

With regard to the lexical group, results revealed that they performed significantly worse than controls in both receptive vocabulary ($p < .01$) and expressive vocabulary ($p < .05$). With regard to the phonological assessments, there was no significant difference for nonword repetition, blending, rapid naming of digits or rapid naming of objects (all *p*s > .05).

Finally, regarding the mixed group, homogeneity of variance was assessed through Levene's test (receptive vocabulary: $F = .409$, $p = 526$; expressive vocabulary: $F = 4.942$, $p = .033$; nonword repetition: $F = 1.818$, $p = .184$; blending: $F = .529$, $p = .471$; rapid naming of objects: $F = 4.202$, $p = .046$; rapid naming of digits: $F = 1.234$, $p = .273$). Violation of equality of variance was corrected using the Welch-Satterthwaite equation. Results revealed that the mixed group performed significantly worse than controls in the semantic assessments of receptive vocabulary and expressive vocabulary (both *p*s < .01). In the phonological assessments they performed significantly worse than controls in nonword repetition ($p < .01$), blending ($p < .01$) and rapid naming of digits ($p < .0001$), but not rapid naming of objects ($p = .075$).

Interim summary of results of the standardised assessment of semantics and phonology

Results revealed that the sublexical group performed significantly worse than controls in the assessments of blending and rapid naming of objects. The lexical group performed significantly worse than controls in receptive and expressive vocabulary. Finally, the mixed group performed significantly worse than the age-matched controls in both the semantic and phonological assessments, with the exception of rapid naming of objects where the difference was marginally significant.

V.3.4.2.3.Experimental tasks

A summary of the picture naming, word-picture verification task, picture judgement task accuracy and latencies and the simple and choice reaction times latencies for the three dyslexic subgroups and their relative controls is given in Table V.20. Choice reaction time accuracy was not included in the analyses due to the ceiling effect in the dyslexics and CA controls as reported in the previous section (p. 148).

Table V.20 Mean percentage accuracy and latency (msecs) in the experimental tasks for the sublexical, lexical and mixed dyslexic subgroups and their controls (standard deviations are in parentheses)

	Sublexical	Lexical	Mixed	Sublexical vs Controls	Lexical vs Controls	Mixed vs Controls
Picture naming accuracy	66.68 (6.09)	61.64 (11.17)	66.27 (8.37)	*U*=7.00, *Z*=-2.15, *p*=.031	*U*=27.00, *Z*=-1.68, *p*=.093	*t*(46)=3.087, *p*=.003
Controls	77.39 (8.31)	70.43 (6.37)	73.92 (8.66)			
Picture naming latency	1413 (256)	1264 (74)	1286 (249)	*U*=22.00, *Z*=.453, *p*=.650	*U*=39.00, *Z*=-.840, *p*=.401	*t*(46)=1.760, *p*=.085
Controls	1391 (147)	1362 (217)	1415 (254)			
WPVT accuracy	69.74 (4.39)	67.82 (7.48)	72.05 (8.33)	*U*=14.00, *Z*=-1.37, *p*=.171	*U*=19.50, *Z*=-2.22, *p*=.027	*t*(46)=6.730, *p*=.013
Controls	73.82 (5.62)	74.67 (4.23)	77.68 (6.36)			
WPVT latency	2233 (266)	2316 (189)	2134 (192)	*U*=24.00, *Z*=-.227, *p*=.820	*U*=39.00, *Z*=-.840, *p*=.401	*t*(46)=1.566, *p*=.217
Controls	2175 (169)	2268 (241)	2213 (240)			
PJs accuracy	95.00 (4.08)	95.83 (3.76)	95.42 (5.30)	*U*=14.00, *Z*=-1.36, *p*=.174	*U*=43.50, *Z*=-.570,*p*=.568	*U*=240.00, *Z*=-.839, *p*=.401
Controls	98.46 (3.15)	95.88 (6.43)	96.09 (6.40)			
PJs latency	2609 (600)	3557 (739)	3117 (998)	*U*=12.50, *Z*=-1.80, *p*=.071	*U*=34.00, *Z*=-1.19, *p*=.234	*U*=256.00, *Z*=-.426, *p*=.670
Controls	3108	3109	2965			

	(602)	(690)	(884)			
Simple reaction time latency	499 (165)	456 (131)	492 (119)	*U*=19.00, *Z*=-.79, *p*=.428	*U*=43.00, *Z*=-.560, *p*=.575	*t*(45)=.549, *p*=.586
Controls	421 (104)	490 (129)	471 (139)			
Choice reaction time latency	500 (98)	540 (77)	524 (96)	*U*=22.00, *Z*=-.453, *p*=.651	*U*=43.00, *Z*=-.560, *p*=.575	*t*(45)=.181, *p*=.858
Controls	475 (54)	526 (83)	519 (97)			

For the sublexical group, results revealed that the dyslexics were significantly less accurate at picture naming than controls ($p < .05$). No significant difference was found for picture naming latency or any other experimental tasks? (all *p*s > .05).

Regarding the lexical group, it was found that they performed as well as controls in the picture naming task and there was no significant difference in latencies (all *p*s > .05). Regarding the other experimental tasks, the lexical subgroup recognized significantly less pictures than controls in the WPVT ($p < .05$), while there was no difference for WPVT latency ($p > .05$). There was no significant difference for PJs accuracy, PJs latency, simple reaction time latency and choice reaction time latency (all *p*s > .05).

Finally, parametric t-tests were used to compare the mixed group and controls. Homogeneity of variance was assessed through Levene's test (naming accuracy: $F = .490$, $p = 487$; naming latency: $F = 127$, $p = .723$; WPVT accuracy: $F = 1.248$, $p = .270$; WPVT latency: $F = 1.676$, $p = .202$; simple RT latency: $F = .054$, $p = .817$; choice RT latency: $F = 1.257$, $p = .268$). The mixed group performed significantly worse than controls in picture naming accuracy ($p < .01$), while there was no significant difference in picture naming latencies ($p > .05$). The mixed group recognised significantly less pictures than controls in the WPVT ($p < .05$), while there was no significant difference for WPVT latency or any of the other experimental tasks (all *p*s > .05).

V.3.4.2.3.1. Picture naming: Subsidiary analyses

Qualitative analysis of the picture naming errors

A summary of the different types of errors made in picture naming, expressed as number as well as percentage of total error, for the sublexical, lexical and mixed dyslexic groups and their controls is reported in Table V.21. Analyses for group differences (presented below) were carried out using percentages of naming errors.

Table V.21 Mean number and percentage of picture naming errors for the sublexical, lexical and mixed dyslexic subgroups and their controls (standard deviations are in parentheses)

Type of naming error (number)	Sublexical	Controls	Lexical	Controls	Mixed	Controls
Semantic	4.75	4.38	5.67	5.35	5.46	5.22
	(2.06)	(2.53)	(1.86)	(1.62)	(2.55)	(2.98)
Phonological	1.00	.08	.50	.18	.96	.17
	(1.15)	(.28)	(.84)	(.39)	(.91)	(.39)
Mixed	.25	.23	.84	.35	1.04	.30
	(.50)	(.44)	(.75)	(.79)	(1.20)	(.47)
Perceptual	0	0	.34	.24	.04	.17
			(.52)	(.56)	(.20)	(.49)
Other	12.75	8.00	7.17	6.35	5.88	5.30
	(2.99)	(3.67)	(3.60)	(3.27)	(2.97)	(3.34)
Type of naming error (%)	**Sublexical**	**Controls**	**Lexical**	**Controls**	**Mixed**	**Controls**
Semantic	38.67	46.43	39.48	44.88	41.03	47.26
	(23.37)	(23.13)	(6.25)	(15.07)	(17.02)	(24.49)
Phonological	8.57	.64	3.90	1.43	7.10	1.54
	(5.17)	(2.31)	(6.25)	(3.19)	(6.33)	(3.48)
Mixed	1.79	2.88	6.46	2.88	7.87	3.13
	(3.57)	(5.48)	(5.85)	(6.08)	(8.75)	(5.02)
Perceptual	0	0	1.98	1.48	0.28	1.16
			(3.26)	(3.46)	(1.36)	(3.15)
Other	50.97	50.04	48.15	49.33	43.72	46.92
	(34.16)	(23.77)	(16.48)	(15.99)	(19.59)	(23.20)

The sublexical group produced a significantly higher percentage of phonological errors than controls (*U* = 14.00, *Z* = -2.04, *p* = .041), while no difference was found for semantic (*U* = 20.00, *Z* = -.681, *p* = .496), mixed (*U* = 25.00, *Z* = -.153, *p* = .879), perceptual (*p* = 1.00) or others errors (*U* = 25.00, *Z* = -.113, *p* = .910).

Regarding the lexical group, it was found that they did not significantly differ from controls in rate of semantic errors (*U* = 40.00, *Z* = -.771, *p* = .441), phonological (*U* = 40.00, *Z* = -1.07, *p* = .286), mixed (*U* = 30.05, *Z* = -1.69, *p* = .091), perceptual (*U* = 44.00, *Z* = -.679, *p* = .497) or other errors (*U* = 50.50, *Z* = -.035, *p* = .972).

Finally, parametric *t*-tests were used to compare semantic and other naming errors of the mixed group and controls. Homogeneity of variance was assessed through Levene's test (semantic errors: *F* = 2.70, *p* = .107; other errors: *F* = .993, *p* = .324). Mann Whitney test were used for the comparison of mixed, perceptual and phonological errors because of the non-normal data distribution. There was no significant difference in terms of semantic errors (*t*(46) = 1.017, *p* = .315) or other errors (*t*(46) = .511, *p* = .612), however, the mixed group produced a significantly higher percentage of phonological errors than controls (*U* = 137,00 *Z* = -3.287, *p* = .001). There was a marginally significant difference in mixed errors (*U* = 194.00, *Z* = -1.94, *p* = .052). No difference was found for perceptual errors (*U* = 250.00, *Z* = -1.14, *p* = .253).

Logistic regression analyses to examine the effect of psycholinguistic variables in the sublexical, lexical and mixed dyslexia subgroups and their controls

Logistic regression analyses were carried out for the individual children in the sublexical, lexical and mixed groups and their controls. The dependent variable was item accuracy (correct = 1; incorrect = 0) and the independent variables were untransformed values for spoken word frequency, visual complexity, word length (joint measure), phonological neighbours and imageability. It should be taken into consideration that the cases-to-independent variables varied across the children, according to the number of pictures the children were able to recognise in the word-picture matching task (WPVT). Also, compound nouns were removed. Hence, there are cases in which the cases-to-independent variables ratio is low (e.g., 8:1). Nevertheless, all the five predictors were kept in the analyses because the aim here was to examine which predictors most affected the naming accuracy for the dyslexic subgroups.

The distribution of the picture naming accuracy scores *per item* was not normal for all three groups of dyslexic children and controls. Inspection of the distribution of the variables prior to analyses led to spoken frequency and number of phonological neighbours (Nsize) being transformed using the formula ln (1+x). Transformed and untransformed values did not reveal substantial differences so untransformed data for naming accuracy, spoken frequency and phonological neighbours are reported. A summary of the results for the sublexical, lexical and mixed subgroups and their controls is given in Table V.22, V.23, and V.24, respectively.

Table V.22 Logistic regression analyses with psycholinguistic variables and naming accuracy per item for the sublexical group and controls

				95% CI confidence			
Sublexical dyslexics	Predictors	B	SE	Lower	Odd ratios	Upper	*p*
S1	Imag	3.907	1.725	1.693	49.767	1462.952	**.024**
	Nsize	1.265	.527	1.261	3.545	9.967	**.016**
	Word length	.645	.259	1.148	1.907	3.165	**.013**
S2	Imag	5.142	1.966	3.628	171.126	8071.600	**.009**
	Word length	-.310	.183	.513	.733	1.049	.089
S3	Imag	1.500	.862	.827	4.480	24.279	.082
S4	Imag	3.847	1.431	2.836	46.872	774.615	**.007**
Controls	Predictors	B	SE	Lower	Odd ratios	Upper	*p*
C1	Imag	4.245	1.893	1.705	69.742	2852.613	**.025**
C2	Imag	1.666	.960	.806	5.290	34.708	.083
C3	None						
C4	Imag	2.011	1.064	.929	7.474	60.131	.059
	Nsize	.655	.365	.941	1.925	3.938	.073
	Word length	.395	.232	.942	1.485	2.342	.089
C5	None						
C6	Imag	3.351	1.282	2.314	28.528	351.702	**.009**
C7	None						
C8	Imag	5.305	2.041	3.687	201.397	1101.56	**.009**
C9	Imag	6.104	3.069	1.093	447.623	183290.11	**.047**
	Nsize	1.599	.839	.956	4.949	25.619	.057
C10	Imag	4.249	1.668	2.663	70.030	1841.604	**.011**
C11	Imag	2.803	1.213	1.529	16.489	177.776	**.021**

C12	Imag	4.484	1.661	3.412	88.556	2298.368	**.007**
C13	Imag	4.489	1.625	3.683	88.992	2150.00	**.006**

Note: Significant results in bold.

Table V.23 Logistic regression analyses with psycholinguistic variables and naming accuracy per item for the lexical group and controls

				95% CI confidence			
Lexical dyslexics	Predictors	B	SE	Lower	Odd ratios	Upper	*p*
L1	Imag	4.324	1.924	1.738	75.501	3279.263	**.025**
	Nsize	1.256	.644	.993	3.513	12.419	.051
L2	Imag	1.883	.930	1.061	6.573	40.716	**.043**
L3	Imag	1.714	.953	.856	5.550	35.965	.072
	VisualComplex	.947	.527	.919	2.579	7.239	.072
L4	None						
L5	Imag	3.123	1.276	1.863	22.705	276.709	**.014**
L6	Imag	2.523	1.066	1.542	12.463	100.761	**.018**
Controls	Predictors	B	SE	Lower	Odd ratios	Upper	*p*
C1	Imag	1.666	.960	.806	5.290	34.708	.083
C2	Imag	2.011	1.064	.929	7.474	60.131	.059
	Nsize	.655	.365	.941	1.925	3.938	.073
	Word length	.395	.232	.942	1.485	2.342	.089
C3	Imag	4.484	1.661	3.412	88.556	2298.368	**.007**
C4	Imag	2.651	.952	2.192	14.175	91.671	**.005**
	Nsize	.449	.225	1.009	1.566	2.432	**.046**
C5	Imag	3.204	1.101	2.848	24.628	212.949	**.004**
C6	Imag	2.803	1.213	1.529	16.489	177.776	**.021**
C7	Imag	6.104	3.069	1.093	447.623	183290.11	**.047**
	Nsize	1.599	.839	.956	4.949	25.619	.057
C8	Imag	3.688	1.408	2.531	39.967	631.097	**.009**
C9	Imag	3.546	1.399	2.235	34.669	537.841	**.011**
C10	Imag	4.489	1.625	3.683	88.992	2150.00	**.006**
C11	Imag	3.813	1.662	1.742	45.285	1177.23	**.022**
	Nsize	.846	.465	.937	2.330	5.795	.069
C12	Imag	3.104	1.393	1.453	22.288	341.828	**.026**
C13	Imag	2.361	1.071	1.300	10.605	86.530	**.027**
C14	Imag	5.553	1.982	5.301	258.087	12566.11	**.005**
C15	None						

C16	Imag	2.284	.976	1.448	9.812	66.499	**.019**
C17	Imag	3.921	1.560	2.374	50.469	1073.057	**.012**

Note: Significant results in bold.

Table V.24 Logistic regression analyses with psycholinguistic variables and naming accuracy per item for the mixed group and controls

				95% CI confidence			
Mixed dyslexic	Predictors	B	SE	Lower	Odd ratios	Upper	*p*
M1	Imag	3.843	1.435	2.802	46.685	777.770	**.007**
M2	Imag	1.724	.941	.888	5.609	35.450	.067
M3	Imag	1.557	.795	.999	4.743	22.507	.050
M4	Imag	3.979	1.425	3.272	53.454	873.284	**.005**
M5	Imag	2.900	1.088	2.157	18.183	153.296	**.008**
M6	Imag	2.774	1.296	1.263	16.015	203.012	**.032**
M7	Imag	2.482	1.086	1.424	11.964	100.494	**.022**
	VisualComplex	1.187	.549	1.118	3.277	9.608	**.031**
M8	Imag	2.956	1.165	1.958	19.222	188.734	**.011**
M9	Imag	3.186	1.193	2.333	24.183	250.722	**.008**
M10	Imag	1.757	.898	.997	5.794	33.666	.050
M11	Imag	1.792	.964	.907	6.000	39.690	.063
M12	None						
M13	None						
M14	None						
M15	Imag	12.589	6.862	.423	29333.37	2.035	.067
M16	Imag	1.611	.965	.756	5.008	33.173	.095
M17	None						
M18	Imag	2.081	.948	1.251	8.012	51.331	**.028**
M19	Imag	4.783	1.949	2.62	119.450	5443.238	**.014**
	Spoken Freq.	-1.159	.653	.087	.314	1.128	.076
M20	Imag	5.483	2.591	1.498	240.578	38629.39	**.034**
	Nsize	1.902	1.087	.796	6.701	56.417	.080
M21	Imag	2.278	.933	1.566	9.755	60.761	**.015**
M22	Imag	3.025	1.346	1.472	20.588	287.919	**.025**
M23	Imag	3.865	1.443	2.820	47.724	807.716	**.007**
M24	Imag	3.816	1.598	1.980	45.413	1041.675	**.017**
	Word length	-.703	.303	.273	.495	.897	**.021**
Controls	Predictors	B	SE	Lower	Odd ratios	Upper	*p*

C1	Imag	4.381	1.759	2.544	79.922	2510.395	**.013**
C2	None						
C3	Imag	5.305	2.041	3.687	201.397	1101.56	**.009**
C4	Imag	3.688	1.408	2.531	39.967	631.097	**.009**
C5	Imag	2.843	1.024	2.306	17.170	127.845	**.006**
C6	Imag	1.666	.960	.806	5.290	34.708	.083
C7	Imag	2.651	.952	2.192	14.175	91.671	**.005**
	Nsize	.449	.225	1.009	1.566	2.432	**.046**
C8	Imag	3.217	1.815	.711	24.947	875.634	.076
	Nsize	1.021	.560	.927	2.776	8.312	.068
C9	Imag	2.803	1.213	1.529	16.489	177.776	**.021**
C10	Imag	4.871	1.633	5.314	130.507	3205.07	**.003**
	Frequency	-1.297	.689	.071	.273	1.055	.060
C11	Imag	5.553	1.982	5.301	258.087	12566.11	**.005**
C12	Imag	2.284	.976	1.448	9.812	66.499	**.019**
C13	Imag	3.484	1.260	2.757	32.591	385.327	**.006**
	Word length	.596	.314	.981	1.814	3.355	.058
	Nsize	.664	.346	.987	1.943	3.825	.055
C14	Imag	3.351	1.282	2.314	28.528	351.702	**.009**
C15	Imag	2.011	1.064	.929	7.474	60.131	.059
	Nsize	.655	.365	.941	1.925	3.938	.073
	Word length	.395	.232	.942	1.485	2.342	.089
C16	Imag	4.871	1.633	5.314	130.507	3205.307	**.003**
	Spoken freq	-1.297	.689	.071	.273	1.055	.060
C17	Imag	4.249	1.668	2.663	70.030	1841.604	**.011**
C18	Imag	4.280	1.847	1.935	72.248	2697.457	**.020**
C19	Imag	3.546	1.399	2.235	34.669	537.841	**.011**
C20	Imag	3.351	1.282	2.314	28.528	351.702	**.009**
C21	Imag	4.245	1.893	1.705	69.742	2852.613	**.025**
C22	Imag	3.204	1.101	2.848	24.628	212.949	**.004**
C23	Imag	3.104	1.393	1.453	22.288	341.828	**.026**
C24	Imag	2.006	.972	1.107	7.434	49.944	**.039**

Note: Significant results in bold.

The analyses revealed that for the majority of children in both the dyslexic and control groups, imageability was a significant predictor of naming accuracy.

Interim summary of results of the picture naming subsidiary analyses

The results of the qualitative analysis of the picture naming errors revealed that the sublexical group made a higher rate of phonological errors than controls, while the rate of naming errors made by the lexical group did not differ significantly from that of controls for any error type. The mixed group showed a significantly higher rate of phonological errors and marginally significantly higher rate of mixed errors than controls. The results of the item-based logistic regression analyses indicated that rated imageability was the main significant predictor of picture naming accuracy for dyslexics in the three subgroups as well as controls.

V.3.4.2.4.Relationship of semantics and phonology to naming, and of these to reading in the sublexical and lexical groups

In the light of the evidence (reviewed in Chapter I) for different cognitive profiles associated with the profiles of reading shown by the lexical and sublexical dyslexic groups (e.g., Ziegler et al. 2008; McArthur et al. 2013; Peterson et al., 2013), correlation analyses were carried out for the two groups separately looking at the associations of lexical and sublexical processes with the scores in the semantic and phonological assessments. Analyses were only conducted for the lexical and sublexical groups since these are the ones with the 'pure' forms of dyslexia. It needs to be acknowledged that the sample sizes were small, and therefore the results need to be considered accordingly.

Picture naming accuracy, latency and rate of phonological naming errors, as well as results from the standardised assessments of phonology and semantics, and irregular word and nonword reading accuracy were entered in correlation analyses. Correlation analysis was carried out with age partialled out as for the analyses reported in section V.2.5. A summary of the results for the sublexical and lexical group is given in Table V.25.

Table V.25 Correlations between naming, standardised assessment of semantics and phonology and reading scores for the sublexical and lexical group controlling for chronological age, results for the sublexical group are below the diagonal and those for the lexical group are above the diagonal

Measures	1	2	3	4	5	6	7	8	9	10	11
1. Rec.Voc.	-	.312	.608	.504	.718	.870	.578	.437	.207	.597	.599
2. Exp.Voc	-.962	-	-.371	.655	-.281	.500	.655	.853	.028	-.198	.688
3. Blending	-.998*	.976	-	.016	.552	.171	-.248	.057	.616	.881*	-.058
4. NWRep.	-.081	-.195	.022	-	.241	.649	.330	.493	.406	.417	.958*
5. RAN dig.	-.954	.835	.934	.377	-	.684	.290	-.303	-.053	.559	.370
6. RAN obj.	.019	.255	.039	-.998*	-.319	-	.813	.352	-.126	.273	.815
7. Phon.Err.	-.965	.856	.947	.341	.999*	-.283	-	.434	-.531	-.292	.563
8. Irr. acc.	.012	-.284	-.070	.996*	.290	-1.00**	.253	-	.367	.100	.453
9. Nwd acc.	-.087	-.188	.028	1.00**	.383	-.998*	.347	.995*	-	.794	.159
10. Pic. acc.	.381	-.619	-.435	.891	-.085	-.917	-.123	.929	.888	-	.289
11. Pic. time	.599	-.795	-.645	.750	-.330	-.789	-.367	.807	.745	.968	-

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

Sublexical group

Regarding the association between semantics and phonology, results indicated that blending was significantly associated with receptive vocabulary (p = .037) and rapid naming of objects was significantly associated with nonword repetition (p = .037). The rate of phonological naming errors was significantly associated with rapid naming of digits (p = .025).

Regarding the association between reading and the standardised assessments of phonology and semantics, nonword reading was significantly associated with nonword repetition (p = .004), and with rapid naming of objects (p = .043). A marginally significant association was found for nonword and irregular word reading (p = .063). Irregular word reading was marginally significantly associated with nonword repetition (p = .059) and significantly with rapid naming of objects (p = .020).

Lexical group

Regarding the association between semantics and phonology, results indicated that receptive vocabulary was marginally significantly associated with rapid naming of objects (p = .055).

Regarding the association between naming and the semantic and phonological variables, naming accuracy was marginally significantly associated with blending (p = .049), and naming latencies were significantly associated with nonword repetition (p = .010).

Finally, regarding the association between reading and the standardised assessments of phonology and semantics, results revealed that nonword reading was not significantly associated with any of the variables, while irregular word reading was marginally significantly associated with expressive vocabulary (p = .066).

Summary of results comparing dyslexic subgroups and controls

The sublexical group were significantly less accurate than controls in picture naming and made a significantly higher percentage of phonological errors. Regarding the cognitive assessments, the sublexical group were significantly poorer than controls in blending and rapid naming of objects. In contrast, the lexical group did not differ from age-matched controls in picture naming or rate of phonological naming errors, however, this group recognised fewer pictures than controls in the WPVT and had significantly poorer scores for receptive and expressive vocabulary. Finally, mixed dyslexic children were significantly less accurate in picture naming and their rate of phonological and mixed errors was higher than that of controls. They recognised significantly less pictures than controls in the WPVT and had lower scores in all the standardised assessments of semantics and phonology.

Regarding the logistic regression analyses, imageability was found to be the main significant predictor of naming accuracy for the children in all the dyslexic groups and controls.

Finally, looking at the association of results in the assessments of naming, semantics phonology and reading, results revealed that in the sublexical group nonword reading was significantly associated with nonword repetition and negatively with rapid naming of objects. Irregular word reading was marginally significantly associated with nonword repetition and negatively significantly associated with rapid naming of objects. This pattern of association differed for the lexical group, in that nonword reading was not significantly associated with any of the other measures, while irregular word reading was marginally significantly associated with expressive vocabulary.

V.4. Discussion

The primary aims of this chapter were to revisit the naming deficit hypothesis of dyslexia and to determine whether a naming deficit might be specific to certain types of dyslexia.

V.4.1. Revisiting the naming deficit in dyslexia

Results considering the whole group of dyslexics revealed that they named significantly less pictures than CA controls, while there was no significant difference between dyslexics and RA controls. Dyslexics did not differ from CA controls on picture naming latencies, and both dyslexics and CA controls were faster than RA controls. Turning to the qualitative analyses of naming errors, dyslexics made a higher rate of phonological and mixed errors in comparison to CA controls, while there was no significant difference between dyslexics and RA controls in the rates of different types of naming error. Regression analyses carried out separately for the dyslexics and the CA and RA controls revealed that imageability was the only significant predictor of picture naming accuracy in all three groups. With respect to the other experimental tasks, dyslexics recognised significantly less pictures than CA controls in the word picture verification task (WPVT), while there was no significant difference between dyslexics and RA controls. Dyslexics performed as well as CA controls in picture judgment (PJs) accuracy, PJs latency, and choice reaction time (RT) latency, while they were significantly more accurate and faster than RA controls in the same tasks. It should be noted that the findings for PJs accuracy need to be considered with caution due to near ceiling levels of accuracy.

The results for picture naming do not corroborate the findings of Wolf and Obregón (1992), Swan and Goswami (1997) and Nation et al. (2001), in that in the present study there was no significant difference in the accuracy for dyslexics and RA controls. Rather, the findings seem to be broadly consistent with those of Snowling, Wagtendonk and Stafford (1988), who found that the dyslexic children named significantly less pictures than chronological age controls, but not reading age controls[39]. It should be noted that although the dyslexic children in the Swan and Goswami study experienced a severe picture naming deficit (indicating that naming deficits were not a consequence of reading experience), the authors argued that 56% of the dyslexics total number of pictures correctly named fell within the range for the reading age control group. Swan and Goswami concluded that the naming deficits of dyslexic children "were in the normal range in relation to the more stringent reading age matched group" (p. 338). Therefore, by using a more stringent criterion to select the reading age group it is likely that the dyslexics' picture naming accuracy would be similar to that of the RA controls. In the present study, control groups had reading ages between 6 months below and 12 months above their chronological ages. Also, only 1.12 months separated the RA controls' mean chronological age and their mean reading age, confirming that they were normal readers for their chronological age. In Swan and Goswami (1997), the difference between mean reading age and mean chronological age in the RA controls was 2.57 months, while in Snowling et al.

[39] Cross-sectional developmental trajectories (Thomas, Annaz, Ansari, & Scerif, 2009) for all TD and dyslexic children, not included in the results section because not crucial for the aims of the present study, supported the results of the analyses comparing the dyslexics, CA and RA controls means. By plotting the age in months of the children and accuracy in the picture naming task, it was found that the onset was significantly different at the youngest age of measurement in the dyslexic group ($p < .01$), but there was no significant difference in the developmental rate of naming between the dyslexics and TD children ($p = .511$). This indicated that the naming abilities of dyslexic children in the present study developed as well as those of the TD children, and that there was a significant difference between the naming accuracy of dyslexics and TD children when measurement started.

(1988), the reading age control group had a mean chronological age of 8;06 and a mean reading age of 8;08, therefore the gap was 2 months. The discrepancy in Swan and Goswami (1997) was wider than that in the present study.

Turning to the picture naming latencies no significant difference between dyslexics and CA controls was found, while CA controls and dyslexics were faster than RA controls. Snowling et al. (1988) suggested that dyslexic children have poor phonological representations in the output lexicon rather than a difficulty in retrieving phonological representations of words, on the grounds of a significantly higher percentage of naming errors in dyslexic children in comparison to age-matched controls, and in the absence of a significant difference in naming latencies (speed of word retrieval). Swan and Goswami (1997) stated that the discrepant results with the Snowling et al. (1988) findings might be explained by the stimuli used in the picture naming task, in that studies which include more long, low frequency nouns would be more likely to show a difference in naming accuracy between dyslexic children and reading age controls. In the present study, dyslexics produced a higher rate of phonological and mixed errors in comparison to age-matched controls but the difference between dyslexics and RA controls was not significant, indicating that the dyslexics' naming errors were consistent with their reading age. Also, contrarily to what was predicted by the literature on the picture naming deficit in dyslexic children, a significant word length effect was not found for the dyslexics' naming accuracy. When all the psycholinguistic variables, spoken frequency, visual complexity, imageability, word length and number of phonological neighbours were entered in the regression analyses, imageability was the only significant predictor of accuracy for the dyslexics and controls. This result was consistent with the one obtained for the TD children, and described in the previous chapter. Beside the evidence that imageability was a strong predictor of word recognition in dyslexia studies (e.g., Baddeley, Ellis, Miles, & Lewis, 1982; Jones, 1985), to the author's knowledge, this is the first study in which imageability has been included in the range of psycholinguistic variables possibly affecting naming accuracy in dyslexic children. In the Discussion section of the previous chapter, it was stated that Masterson, Druks and Gallienne (2008) interpreted the strong effect of imageability on the TD picture naming accuracy as a consequence of the role that perceptual/sensory features exert in supporting early lexical representations for objects (Funnell, Hughes, & Woodcock, 2006). Regarding the stimuli used by Swan and Goswami, it is plausible to suppose that items such as *clock*, *belt*, *potatoes*, *harmonica*, *whisk* would have received high ratings for imageability since instructions explicitly mention sensory experience in the form of mental pictures, sounds, tactile and olfactory images. Therefore it is reasonable to suppose that imageability would have exerted some effect on picture naming accuracy scores in the Swan and Goswami study had it been included as a variable.

Turning to the other experimental tasks, the findings that in the present study dyslexics were significantly less accurate in the word picture verification task (WPVT) than CA controls and that their performance was consistent with their reading age (no significant difference between dyslexics and RA controls in WPVT accuracy) run once more contrary to the findings of Swan and Goswami. In that study dyslexics were significantly more accurate than all the other groups in recognising the target pictures. The results of the present study indicated that dyslexics (as a group) knew significantly fewer items than children of the same chronological age. The apparently contradictory results might be explained with the presence in this study of some dyslexic children with impaired semantic knowledge. It would follow that the naming deficits of (at least) some of the dyslexic children were due to weak semantic representations of the items they were asked to name[40]. For its importance in the arguments of this thesis, this issue will be raised again later in section V.3.2. To anticipate, results for the dyslexic children indicated positive relationship between vocabulary knowledge and the rate of phonological errors.

Dyslexic children did not significantly differ from CA controls in the experimental tasks involving reaction times (picture naming, WPVT, PJs and choice reaction time). The evidence that dyslexic children were significantly faster than RA controls in all of these experimental tasks might be explained by the neurological maturation level which gives advantage to the dyslexic children (e.g., Kail, Hall, & Caskey, 1999). The lack of significant group effect in the simple reaction time task might be due to the nature of the task itself: the simple reaction time task, differently from the WPVT, PJs and choice reaction time task latencies, did not require a decision, therefore the reaction-time measure is the result of the movement component only (e.g., Ponsford & Kinsella, 1992). In the simple reaction time task

[40] Some of the dyslexic children might have weak semantic representations of the words associated to the pictures they were asked to name. There is evidence that children have a unitary semantic store for pictures and words (e.g., McGregor, Friedman, & Reilly, 2002).

the participant is required to focus attention on the stimulus that will always appear in the same position (middle of the computer screen). The same maturational level might be responsible for the significantly more accurate performance of the dyslexics in the PJs task in comparison to RA controls. As seen in the previous chapter, PJs accuracy was near ceiling for the older TD group and dyslexic children as well, meaning that the PJs task was quite easy for the older children.

The findings of Swan and Goswami, and the subsequent studies reviewed in Chapter III, indicated that the source of dyslexics' retrieval difficulty appeared to be a phonological one, and this led to the hypothesis in the present study that dyslexic children should perform worse than RA controls in tasks tapping phonology. Results from the standardised assessments of phonology revealed that the dyslexic children performed significantly worse than the CA controls, but similarly to the RA controls, in all the phonological tasks. In addition, dyslexics' scores on receptive and expressive vocabulary were significantly lower than those of the CA controls, but higher than those obtained by the RA controls, indicating that phonology and semantics might be the source of difficulties for, at least, some of the dyslexic children. It was reflected that both phonology and semantic activation are involved in picture naming, and that picture naming deficits might be due to different loci of impairment[41]: semantic (or post semantic/lexical access) or phonological output. A lack of (or weak) vocabulary knowledge might lead, for example, to weak connections between semantics and phoneme activation, which in turn might lead to incorrect phoneme activation.

V.4.2. Relationship of naming and phonology and semantics, and of all three to reading in dyslexic children

The results of the correlation analyses between semantics, phonology, naming and reading for the RA and CA controls, and dyslexic children are discussed in this section. To improve the readability and in line with the TD data discussed in the previous chapter, results are discussed in two sections. The first one is dedicated to the relations between naming, semantics and phonology, while the second section concerns the relations of naming and phonology and semantics to reading.

Intercorrelations between semantics, phonology and naming

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[41] Excluding the initial stage of object recognition.

With respect to the RA controls, the pattern of results reflected that obtained by the younger TD group. Results indicated a significant association between receptive vocabulary and nonword repetition. With regard to the relation between semantics, phonology and naming, the results revealed that picture naming accuracy correlated significantly with receptive vocabulary and PJs accuracy, and the rate of phonological errors was significantly negatively associated to nonword repetition.

Concerning the CA controls, the overall results were similar to those obtained for the older TD children. Nonword repetition was associated significantly to both receptive and expressive vocabulary. Blending did not correlate with any phonological or semantic measure. With regard to the relation between semantics, phonology and naming, the results of the correlation analyses indicated that picture naming accuracy correlated significantly with receptive vocabulary, expressive vocabulary and nonword repetition. The rate of phonological errors in picture naming correlated negatively significantly with expressive vocabulary, blending and nonword repetition. In line with the TD data, there was indication of developmental change in that, for example, nonword repetition was more strongly associated with receptive vocabulary in the CA than RA controls.

With regard to the dyslexic children, results revealed that receptive and expressive vocabulary scores were highly correlated. Also, receptive vocabulary was significantly associated with blending and nonword repetition. Expressive vocabulary was significantly associated with nonword repetition, as found also in the CA controls. A significant association was found between nonword repetition and blending. PJs accuracy was significantly associated with nonword repetition. The two measures of rapid naming (digits and objects) were significantly associated with each other, and rapid naming of objects was significantly correlated with picture naming and PJs latencies. This pattern of results is quite in line with that expected, in that the two measures of vocabulary knowledge were highly associated and this association was significantly higher than that with the phonological variables. Those variables tapping phonological processes (blending, nonword repetition) were also significantly correlated. Differently to TD children, rapid naming did not correlate with the other phonological measures and PJs accuracy was associated with nonword repetition rather than vocabulary, in contrast to what was expected on the grounds of the TD results, and since PJs was devised as a measure of associative semantics. In line with the findings for the older TD group, receptive and expressive vocabulary scores were significantly associated with nonword repetition. This would support findings (e.g., Metsala, 1999) of a mutual interaction between vocabulary and phonological abilities. Increasing vocabulary knowledge would support the mental representations of the sounds that comprise words, which might improve phonological processing and hence tasks such as nonword repetition.

Regarding the relation between semantics, phonology and naming, the results of the correlation analyses indicated that picture naming accuracy correlated significantly with receptive vocabulary, blending and nonword repetition. Swan and Goswami (1997) argued for a lack of relationship between receptive vocabulary and retrieval difficulties in the dyslexic children on the grounds of lack of a significant correlation between picture naming accuracy and receptive vocabulary (BPVS short-form) scores. The findings differed from those for controls in that the association was significant for the RA controls, and marginally significant for the CA controls. In the present study, the association between receptive vocabulary and picture naming accuracy was significant in all three groups of children, indicating that a more extensive level of vocabulary knowledge facilitates retrieval processes (Gershkoff-Stowe, 2002).

The association between semantic and phonological variables and of these to naming abilities seen in the dyslexic children resembles the pattern observed for the CA controls. Differently to CA controls, blending was found to be significantly associated with both receptive vocabulary and picture naming accuracy. This result was in contrast with the prediction that dyslexic children would show a weaker association of naming and reading with phonology on the grounds of the evidence reported in the literature that dyslexics have a phonological deficit. In the TD children, blending was not associated with any semantic or phonological measure, and it was reasoned that blending might represent a pure measure of phonological awareness differently to nonword repetition, which is affected by other factors, such as long-term knowledge. If it is true that some dyslexics are relying on lexical processes, and if it is true that blending is a pure measure of phonological awareness, blending should be negatively associated to receptive vocabulary in those dyslexic children with a primary sublexical impairment, in that semantics should be unimpaired.

In the dyslexic group, the rate of phonological naming errors correlated significantly with receptive and expressive vocabulary, indicating that those children with low levels of vocabulary knowledge were unlikely to produce phonological naming errors. Conversely, in the CA controls the rate of phonological naming errors was negatively correlated with the two measures of vocabulary and with nonword repetition.

In the studies of picture naming and developmental dyslexia, reviewed in Chapter III, children with dyslexia were unselected in terms of subtype. It might be speculated that the dyslexic children recruited in the reviewed studies were mainly children with phonological difficulties due to the selection procedure (for a discussion of referral bias, see for example Bowey & Rutherford, 2007). For example, Truman and Hennessey (2006) recruited most part of their dyslexic group from centres addressing oral language difficulties as well as literacy difficulty, and Swan and Goswami selected the dyslexic children from local private and public organisations specialised in the teaching of children with specific literacy difficulties. Moreover, Truman and Hennessey (2006) assessed dyslexic children using reading tests that did not include irregular words, which are sensitive to lexical processes, and Swan and Goswami assessed the reading age of the dyslexic children through a standardised test, which, however, did not comprise separate list of items to differentiate children in subtypes. Finally, the dyslexic sample recruited by Swan and Goswami obtained a standard receptive vocabulary score (in the BPVS, short form) which was comparable to that obtained by the CA controls. These lines of evidence might indicate that previous studies recruited predominantly dyslexic children with underlying phonological processing deficits, and whose vocabulary was unimpaired, and who might therefore be mainly children with a primary sublexical deficit.

Intercorrelations between semantics, phonology, naming, and reading

Concerning the relationship between semantics, phonology, naming and reading, the results from the RA controls revealed that nonword reading correlated significantly with blending and nonword repetition and that irregular word reading was significantly negatively correlated with blending. This pattern of association was consistent with that found in the younger TD group. Regarding the CA controls, nonword reading correlated significantly with expressive vocabulary and irregular word reading correlated significantly with receptive and expressive vocabulary. This pattern of results was in line with that found in the TD children, and supported the view of a developmental progression whereby phonological abilities support the reading of nonwords in novice readers, but with literacy experience the role of vocabulary becomes important in reading both nonwords and irregular words.

In the light of findings by Griffiths and Snowling (2002), it was expected that different patterns of results would be observed for the dyslexic group and the controls. The results for the dyslexic children revealed that nonword reading correlated significantly with blending, while irregular word reading did not correlate significantly with any measure. This pattern of results indicated that phonology plays a crucial role in sublexical processes as also found in novice TD readers, confirming the important role of phonological skills for early reading, while irregular word reading was not associated with phonological or semantic variables. If it is true that some dyslexics rely on lexical processes and their associated underlying variables, and some relying on sublexical processes, then when their results are amalgamated as in this analysis, it is likely that there will be no overall strong associations in the results. As consequence, it was expected that the pattern of association of nonword and irregular word reading with associated variables would differ for the primary lexical and sublexical dyslexic subgroups. This will be discussed in the next section.

V.4.3. Is the naming deficit specific to subtypes of dyslexia?

In order to address whether a naming deficit was specific to subtypes of dyslexia, two criteria were used for delineating the dyslexic children: one continuous and one discrete criterion.

Results from the continuous criterion revealed significant associations between the relative measure of sublexical strength and blending, and the rate of phonological errors in picture naming. The relation between the relative measure of sublexical strength and picture naming accuracy did not reach statistically significance. This was not surprising since picture naming involves both semantic and phonological processes, as discussed in Chapter III. Overall, this result might suggest that the dyslexic children who relied more on sublexical processes (had relatively more accurate nonword reading compared to irregular word reading) are less likely to have phonological problems and less likely to produce phonological naming errors. They also presented with weaker vocabulary knowledge, as indicated by the negative marginally significant correlation between sublexical strength and expressive vocabulary scores.

Regarding the discrete criteria, it was found that naming and associated abilities differed for children with primary sublexical, lexical and mixed reading impairment. The results obtained with the continuous criterion appeared to complement those from the analyses using the discrete criterion.

Dyslexic children with a primary sublexical deficit performed significantly worse than age-matched controls in blending and rapid naming of objects. They were significantly less accurate than controls in picture naming and also had a significantly higher percentage of phonological errors. The primary lexical subgroup, on the other hand, performed significantly worse than controls in receptive and expressive vocabulary. They did not differ from age-matched controls in terms of picture naming accuracy or in rate of phonological naming errors. They recognised significantly fewer pictures in the WPVT. Dyslexic children with a mixed profile performed significantly worse than age-matched controls in both the semantic and phonological assessments. Mixed dyslexic children were significantly less accurate in picture naming and made significantly more phonological, and marginally significantly more mixed naming errors, than controls. They recognised significantly fewer items in the WPVT than controls. Regarding the influence of the psycholinguistic variables on picture naming accuracy, results indicated that imageability was the most significant predictor of naming accuracy for the dyslexics in the three subtypes as well as control children.

This pattern of results runs contrary to the strong version of the naming deficit hypothesis of dyslexia as a) not all the dyslexic children suffered from a naming deficit, and b) the naming deficit appeared to be specific to the sublexical profile. On the grounds of the arguments by Truman and Hennessey (2006) and Friedmann and Lukov (2008), those dyslexic children with impairment at the phonological output stage (i.e., those who show a high rate of phonological naming errors) tend to be those with relative nonword reading impairment and with poor phonological abilities (in the present study significantly lower blending and rapid naming of objects in comparison to age-matched controls). There was no evidence of a deficit in speed of retrieval for the dyslexics with a primary sublexical deficit, since their picture naming latencies were not significantly different from those of controls. With regard to passage reading, dyslexics in the sublexical group performed lower than age-matched controls in accuracy but did not differ from controls in reading rate and comprehension, indicating that reading fluency and comprehension were not substantially affected by the reading impairment.

Turning to the association of irregular word and nonword reading and the other measures, results revealed that the pattern of results varied for the sublexical and lexical group as predicted. It was suggested earlier (p. 202) that the lack of correlation found for the whole dyslexic group between irregular word reading and scores in the assessments of phonology and semantics might have been be the result of amalgamating scores for dyslexic subtypes relying on different reading processes. The findings from the analyses with the subtypes revealed that for the primary sublexical group nonword reading was significantly associated with nonword repetition and negatively with rapid naming of objects. Irregular word reading was significantly negatively associated with rapid naming of objects and there was a marginal association with nonword repetition. In the primary lexical group, on the other hand, nonword reading was not significantly associated with any measure, while irregular word reading was marginally significantly associated with expressive vocabulary. It needs to be borne in mind that the two groups were small, and therefore these results need to be considered with caution.

To delineate the cognitive profiles of the groups in further detail, the strengths and weaknesses of individual children in the sublexical and lexical groups are given in Table V.26 and V.27, respectively.

Table V.26 Strength and weakness in the naming, semantic, phonological and YARC reading assessment for the primary sublexical deficit group

Measure	SD1	SD2	SD3	SD4
Picture naming accuracy	×	× (low average)	✓	×
Phonological errors	×	✓	×	×
Mixed errors	✓	✓	✓	×
Picture naming latency	✓	×	✓	✓
WPVT accuracy	✓	✓	✓	✓
Receptive voc.	✓	✓	✓	✓
Expressive voc.	✓	✓	✓	✓
Nonword rep.	×	✓	× (low average)	✓
Blending	×	×	× (low average)	×
Rapid naming objects	×	✓	×	× (low average)
Rapid naming digits	✓	✓	✓	×
Digit span	× (low average)	× (low average)	× (low average)	× (low average)
YARC passage accuracy	×	✓	×	×
YARC passage rate	× (low average)	✓	✓	✓
YARC passage comprehension	✓	✓	✓	✓

Note: ✓= on average, × = below average

Inspection of the children's profiles in the sublexical group revealed that all the children were impaired in blending but none in any of the tasks involving semantics (vocabulary knowledge and the WPVT). Two out of four children were weak in nonword repetition, and two were impaired in the rapid naming of objects and of digits. Regarding picture naming, three of the four children were impaired, and three produced a high rate of phonological naming errors. All the children exhibited a low digit span score. The sublexical group did not have difficulties in reading comprehension.

Table V.27 Strength and weakness in the naming, semantic, phonological and YARC reading assessment for primary lexical deficit group

Measure	LD1	LD2	LD3	LD4	LD5	LD6
Picture naming accuracy	×	✓	×	×	✓	✓
Phonological errors	×	×	✓	✓	✓	✓
Mixed errors	✓	✓	✓	✓	✓	×
Picture naming latency	✓	✓	✓	✓	✓	✓
WPVT accuracy	×	×	×	×	✓	×
Receptive voc.	✓	×	×	×	×	×
Expressive voc.	✓	×	✓	×	× (low average)	× (low average)
Nonword rep.	× (low average)	✓	✓	×	✓	×
Blending	✓	✓	✓	✓	✓	✓
Rapid naming objects	✓	×	× (low average)	✓	✓	✓
Rapid naming digits	✓	×	✓	✓	✓	✓
Digit span	✓	× (low average)	× (low average)	×(low average)	×(low average)	✓
YARC passage accuracy	✓	×	×	×	×	×
YARC passage rate	✓	×	×	×	×	×
YARC passage comprehension	✓	×	×	×	✓	✓

Note: ✓= on average, × = below average

With regard to the primary lexical deficit group, although it is true that this group did not significantly differ from age-matched controls in the rate of naming errors, nevertheless some of them produced phonological naming errors, in contrast to what might be expected in the light of Friedmann and Lukov’s (2008) study. In that study some of the dyslexics with a profile of surface dyslexia produced mixed naming errors (i.e., responses that were both semantically and phonologically related to the target). In the present study, some of the lexical group were impaired in picture naming and some produced phonological naming errors.

Of note is that none of the children in the lexical group showed impairment in the blending task, but five of the six children were impaired in one or both of the vocabulary assessments. Although the WPVT was used in the present study as a means of eliminating items in the picture naming data that children were unfamiliar with, since the foils in the WPVT were semantically related to the targets, overall task performance can be considered a measure of semantics (cf. its extensive use with aphasic patients with auditory comprehension deficits, e.g., Franklin, Turner, Ralph, Morris, & Bailey, 1996). If we accept that overall performance in the WPVT is an assessment of semantics then all six of the children in the primary lexical group show evidence of impairment in at least one of the semantic tasks. The results for the lexical and sublexical subgroups therefore show a double dissociation with regard to performance in blending and in the semantic tasks.

Similarly to the sublexical group, half the lexical group were impaired in nonword repetition and two out of the six children in rapid naming (objects and digits). Digit span score was low in the majority (four out of six children) of the lexical group[42]. While reading accuracy and rate was impaired in almost all the lexical group, reading comprehension was impaired in half of the children with lexical impairment. According to Nation (2005), these three children were poor comprehenders, as their decoding skills (as assessed in the nonword subtask from the DTWRP) were in the average range (stanine score ≥ 4, as per test manual), but their reading comprehension standard score was more than 1 *SD* below that of the normative sample (YARC passage reading comprehension standard score < 85).

[42] Digit span forwards is considered to be a short-term memory task, while digit span backwards is considered to be a working memory task (Pickering & Gathercole, 2004). Helland and Asbjørnsen (2004) found a discrepancy in dyslexic subgroups between digit span forwards and backwards. Dyslexic children were classified into three groups according to their level of language comprehension and mathematical skills. The three groups consisted of those with good language comprehension and good mathematical skills, those with good language comprehension and poor mathematical skills, and those with language impairment. Although the classification by Helland and Asbjørnsen differed from that employed in the present study, analyses were conducted to see whether differences in the lexical and sublexical group occurred in digit span forwards and backwards. Results did not reveal any significant differences ($p > .05$) between the sublexical and lexical groups in digit span forwards and backwards.

In conclusion, the findings from the present study indicated that the dyslexic children, as a group, had phonological and semantic deficits in relation to age-matched controls, but when the children were differentiated according to subtypes on the basis of their reading profile, different patterns of deficit were observed.

CHAPTER VI. Conclusion

VI.1. Overview

The literature review revealed that naming difficulties in dyslexic children are part of the constellation of symptoms due to phonological impairment. However, none of the studies investigating naming in dyslexic children included an independent assessment of phonological abilities. In addition, none of the studies reviewed investigated whether naming deficits would be specific to subtypes of dyslexia. This was considered important since there is mounting evidence for distinct subtypes of developmental dyslexia (e.g., Castles & Friedmann, 2014). The data collected were from 35 dyslexic children aged 8 to 9 years, and from 122 typically developing (TD) children aged 4 to 9 years. Picture naming, word-picture verification, single and choice reaction time, non-verbal associative semantics (the PJs task), receptive and expressive vocabulary, nonword repetition, blending, rapid naming of digits and objects, nonword and irregular word reading and reading passages were assessed thorough a battery of tasks consisting of experimental (devised for the purpose of this project) and standardised tests. In addition, qualitative analysis of picture naming responses, and regression analyses of the psycholinguistic variables affecting naming accuracy were undertaken.

In Chapter IV I aimed to investigate the developmental progression of the critical tasks used in the present study in a sample of TD children aged 4 to 9 years, followed by examination of the relationship between semantics, phonology to naming and of all three to reading ability in order to establish a context for the analyses of the data for the dyslexic children, and increase our understanding of the development of naming in children in general. Correlation analyses were also conducted with the data separated for younger (4-6;11 years) and older (7-9 years) TD children in order to explore whether the patterns of association would differ with age and reading experience.

Chapter V addressed the principal research aims of this thesis. Dyslexic children were compared to 35 chronological age and 24 reading age control children, selected from the sample of TD children. Group comparisons of performance in the experimental and standardised tasks were conducted in order to revisit the phonological naming hypothesis of dyslexia. In addition, two criteria were adopted to examine whether the naming deficit might be specific to children with different profiles of dyslexia.

In the next sections the main results for the typically developing children and the dyslexic children are reviewed, together with the factors that may have contributed to them. The limitations of the study are explored, and implications for reading intervention for dyslexic children with sublexical and lexical primary impairment are discussed.

VI.2. Results for the typically developing children

The results indicated developmental progression and lack of ceiling and floor effects for all the experimental tasks, with the exception of picture judgment and choice reaction time accuracy which both exhibited a near ceiling effect, in particular for the older children.

Overall the results of the correlations between semantics, phonology, and naming for the younger and older TD groups indicated that naming accuracy was significantly associated with phonological and semantic variables, as would be expected, since picture naming involves both semantic and phonological processes. Rate of phonological errors in picture naming was significantly associated with nonword repetition accuracy in both the younger and older groups. Moreover, in the older group, the rate of phonological naming errors was found to be negatively correlated with vocabulary knowledge and blending, suggesting that as children's vocabulary size increases and phonological abilities become more efficient, the likelihood of making phonological naming errors decreases.

Regarding the relationship between semantics, phonology and naming to reading, results indicated that in the younger children nonword and irregular word reading were correlated with measures of phonology, assessed by nonword repetition and blending. On the contrary, for the older TD children, nonword and irregular word reading were correlated with expressive vocabulary, and rapid naming of digits correlated significantly with nonword reading. In the present study, the pattern of results was interpreted in terms of the contribution of phonology and semantics to nonword and irregular word reading during reading development: in the early stages, phonology is fundamental to support nonword and irregular word reading, but with reading experience, semantics comes to make a significant contribution to reading, especially for irregular word reading (Nation, 2009; Ricketts, Davies, Masterson, Stuart, & Duff, submitted). The correlation between nonword reading and expressive vocabulary in the older TD group was unexpected. This was explained in terms of a wordlikeness effect, in that the nonwords in the DTWRP (FRLL, 2012) were generated from segments of real words. It would be useful for future studies to control for wordlikeness by employing two groups of nonwords, one constructed from segments of real words and one from roots and suffixes that do not exist in English words (e.g., Coltheart & Leahy, 1996). V. Coltheart and Leahy (1992), in a study with novice readers (grade 1 and 3) and adult readers found that both children and adults were better at reading nonwords constructed from real words than nonwords generated from segments of words which did not exist in English. In particular, grade 1 children did not take advantage from reading wordlike nonwords; on the contrary they used GPC rules while more skilled readers took advantage of their increasing sight vocabulary to read nonwords. As reading develops and children become proficient readers, their reading experience combined with the expansion of vocabulary knowledge (e.g., Ouellette & Beers, 2009) might provide children with strategies to facilitate word recognition. Evidence in the literature (e.g., Share, 1995; Stuart, Masterson, Dixon, & Quinlan, 1999) suggested that increasing proficiency in lexical processes supports sublexical processes in that GPC correspondences can be inferred from the orthographic knowledge acquired with reading experience.

The findings from the TD children were also used as grounds to formulate hypotheses relevant to the principal research aims of the thesis. In the next section, the findings for the dyslexic children will be discussed.

VI.3. Results for the dyslexic children

Regarding the first research aim, that is revisiting the phonological naming deficit hypothesis of dyslexia, the findings revealed that the dyslexic children named accurately significantly less pictures than CA controls, while the dyslexics' naming accuracy scores were consistent with their reading age, in that dyslexics' naming did not significantly differ from that of the RA controls. Comparisons were carried out on words children were able to recognize (unfamiliar items as indicated by performance in the WPVT were removed on an individual basis) and after compound nouns were removed. Regarding picture naming latencies, there was no significant difference between dyslexics and CA controls, while both these groups were significantly faster than RA controls. Analyses of the naming errors revealed that dyslexic children produced significantly more phonological and mixed naming errors than CA controls, but the difference for these two error types relative to RA controls did not reach significance. Finally, regression analyses revealed that imageability was the only significant predictor of naming accuracy in dyslexics and CA and RA controls. These results did not support the view that naming difficulties of dyslexic children are deviant (e.g., Swan & Goswami, 1997), rather they corroborated the findings of Snowling et al. (1988), who found that dyslexics' naming abilities were consistent with their reading age. In the attempt to examine whether dyslexics' naming difficulties were due to "unique difficulties in retrieving the *phonological codes"* (Swan & Goswami, p. 349) of known names, the present study explored not only whether the dyslexic children produced more phonological naming errors and whether naming accuracy was affected by word length (Swan & Goswami, 1997), but I also sought independent evidence for a phonological impairment in the dyslexic children, following the literature reviewed in Chapter III.

The results of the comparison between dyslexics, CA and RA controls in blending, nonword repetition, rapid naming of objects and digits revealed that dyslexic children were worse than CA controls in all the phonological assessments, while dyslexics' scores in the phonological tasks resembled those of the RA controls. This suggested that the dyslexics' phonological abilities (at least those assessed in the current study) were in line with their reading age. Fowlert and Swainson (2004) carried out a study with 93 first grade and 67 fourth grade typically developing children, allocated as good and poor readers on the basis of their grade equivalent score in two reading tasks: word identification and word attack from the Woodcock Reading Mastery Test (Form G)-Revised (Woodcock, 1998). In addition naming, receptive vocabulary, nonword repetition, and long-term memory were assessed. Findings revealed that, compared to good readers, poor readers had difficulties in naming known objects. Interestingly, there was no significant interaction between grade (first vs fourth) and reader group (poor vs good readers) on tasks assessing the phonological representations of the words children were asked to name. Fowlert and Swainson (2004) stated "these findings are consistent with the idea that the development of phonological representations in the lexicon is delayed, but not deviant, in children with reading difficulties, such as they apparently have acquired full phonological information about a smaller repertoire of words at any given age" (p. 270).

Regarding the semantic assessments, dyslexics' receptive and expressive vocabulary scores were significantly lower than those of the CA controls. In line with findings from the picture naming task, this result was inconsistent with the findings of Swan and Goswami, who reported that dyslexic participants' receptive vocabulary scores were similar to those of the CA controls. There is evidence in the literature that poor readers, or children at risk to be, have weaker receptive vocabulary knowledge than better readers (e.g., Gathercole, Willis, Emslie, & Baddeley, 1992). This would indicate that some words have weak representations within semantics for at least some dyslexic children. In comparison to RA controls, dyslexic children in the present study obtained higher scores in both the receptive and expressive vocabulary tasks. This finding may have been due to combining the results for some dyslexics with high and some with low scores on the vocabulary measures.

Regarding the relationship between semantics, phonology and naming, and of all these three to reading, the findings for the dyslexic children for semantics, phonology and naming resembled those of the CA controls, in line with what was expected. However, differently from the CA controls, blending was found to be significantly associated with receptive vocabulary and picture naming accuracy. This is not surprising since picture naming comprises both phonological and semantic processes, however, it is not clear why the same association was not found in either the correlation analyses for the whole TD sample, or in the correlations carried out separately for the CA and RA control groups. In all these groups nonword repetition, but not blending, was significantly associated with picture naming. Nonword repetition and blending are thought to tap different components of phonology ability: nonword repetition is considered a measure of phonological short-term memory and blending a measure of phonological awareness (e.g., Kohnen, Nickels, Castles, Friedmann, & McArthur, 2012). In an attempt to explain the finding, it was reasoned that nonword repetition is affected by several factors as indicated in Chapter II (pp. 32-33), and there is evidence that nonword repetition (and more generally verbal recall) relies on activation of long-term memory representations[43] (e.g., Gathercole, 1995; Casalini et al., 2007; Gupta & Tisdale, 2009; Polisėnská, 2011). On the other

[43] Increasing evidence has demonstrated that lexical-semantic representations may affect short-term memory performance and, in particular, immediate serial recall as in the digit span task (e.g., Burgess & Hitch, 2006; Bannard & Matthews, 2008; Acheson, MacDonald, & Postle, 2011).

hand, blending seems to be a pure measure of phonological awareness, unaffected (or less affected) by lexical-semantic representations, and in this study it may represent the cognitive marker of the sublexical group, in that blending was impaired in all the dyslexic children with a primary sublexical deficit, but not in any of the children with lexical primary deficit. Another noteworthy result from the correlation analyses was that the rate of phonological naming errors correlated significantly with receptive and expressive vocabulary, suggesting that dyslexics with lower vocabulary scores were unlikely to produce phonological naming errors.

Regarding the intercorrelations between semantics, phonology, naming and reading, results were consistent with findings of Griffiths and Snowling (2002), in that the pattern of correlations for the dyslexic children differed from those of both the control groups. For the RA controls nonword reading was significantly associated with blending and nonword repetition, while irregular word reading was significantly negatively associated with blending. For the CA controls, nonword reading was significantly associated with expressive vocabulary and irregular word reading was significantly correlated with receptive and expressive vocabulary. These findings corroborated the previous results for the younger and older TD groups described in Chapter IV. Differently from controls, results for the dyslexic children revealed that nonword reading correlated significantly with blending, while irregular word reading did not correlate significantly with any measure. The lack of correlation for irregular word reading was interpreted as a result of combining results for children with different types of deficit. To anticipate, when the dyslexic group were classified according to their reading profile, the relationship between semantics, phonology, naming and reading differed for the sublexical and lexical group. Although the sample sizes were small, and therefore results need to be considered with caution, this result indicates distinctive patterns of association for the two dyslexic subgroups.

Finally, with regard to the last research aim, of whether the naming deficit might be specific to children with different subtypes of dyslexia(s), two different classification method were used: one continuous and one discrete. Both yielded similar results. The former was devised as measure of relative sublexical strength to follow Griffiths and Snowling (2002). The latter involved classifying dyslexic children into discrete subgroups, following McArthur et al. (2013), and comparing the lexical, sublexical and mixed groups to age-matched controls. The results revealed that picture naming difficulties were specific to the dyslexic children with a primary sublexical impairment. The sublexical group also produced a higher rate of phonological naming errors and performed worse than CA controls in blending. No evidence of a deficit in semantic tasks was found. On the contrary, dyslexics with a primary lexical impairment, presented with impaired vocabulary (receptive and expressive) and below average WPVT accuracy scores, but preserved blending task performance. Picture naming accuracy and rate of phonological and mixed naming errors appeared to be similar to those of the controls.

Nevertheless, when looking at the performance of individuals within the groups, not all the children with primary sublexical impairment presented with picture naming deficits and phonological naming errors. Analogously, not all the children with primary lexical impairment obtained picture naming scores and a rate of phonological errors comparable with those of the controls.

VI.4. Factors to be considered in the interpretation of results

VI.4.1. Sample selection

In earlier chapters (Chapter III and V), I stated that the difference in results between the previous studies investigating picture naming in dyslexic children and the present one might be due to the sample selection criteria. I have speculated that the dyslexic children recruited in the reviewed studies were mainly children with phonological difficulties because they were selected for centres addressing oral language difficulties (Truman & Hennessey, 2006), and organisations specialised in the teaching of children with specific literacy difficulties (Swan & Goswami, 1997). I have claimed that this would bias towards recruiting children with a mainly sublexical profile because children were mainly assessed with reading tests which did not comprise lists of words sensitive to different types of dyslexia (Castles & Friedmann, 2014).

In addition, Swan and Goswami excluded the hypothesis of a naming deficit due to weak semantic knowledge on the grounds of the average receptive vocabulary standard score and of the significantly higher number of pictures that dyslexic children were able to recognise (in the object-name recognition task) in comparison to CA controls. In the present study phonological errors in picture naming and unimpaired vocabulary knowledge were associated with a profile of phonological dyslexia, while impaired semantics was associated with surface dyslexia. It is probable that the children recruited in previous studies (who presented with good receptive vocabulary knowledge) were phonological dyslexics.

VI.4.2. Chronological age and reading age control groups

An issue that has recurred in the research into naming deficits in dyslexics has concerned whether the dyslexics have lower phonological scores than RA controls or just lower than CA controls, therefore it would have been informative to compare the lexical and sublexical groups to reading age controls as well as to age matched controls. As noted in the previous chapter (p. 170) there were not sufficient reading age controls (using the stringent selection criteria adopted in the present study) to match to the lexical and sublexical groups to allow meaningful comparisons.

There is an on-going debate (e.g., Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; McDougall, Borowsky, MacKinnon, & Hymel, 2005; McArthur et al., 2013; Peterson et al., 2013) about whether it is preferable to use reading age matched controls when investigating primary lexical and sublexical impairments. The reason is that if dyslexics and reading age controls are matched on word reading, the profile of dyslexic children with a lexical impairment is more likely to resemble the profile of younger readers, leading to the conclusion that the lexical dyslexic reading profile resembles immature reading rather than representing a genuine reading disorder, as in phonological dyslexia. Therefore, it would be informative for the future to include not only reading age and chronological age matched controls but also to constitute a group of controls matched to the primary lexical deficit group on nonword reading and to the primary sublexical group on irregular word reading (Wybrow & Hanley, 2015).

VI.4.3. Classifying the dyslexic children

In Chapter I, I discussed studies that have involved subcategorization of dyslexic children according to their reading profile (e.g., Castles & Coltheart, 1993; Heim, Tschierse, Amunts, & Wilms, 2008; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; Manis, Seidenberg, Stallings, & Joanisse, 1999; McArthur et al., 2013; Pacheco et al., 2014; Peterson & Pennington, 2012; Peterson, Pennington, & Olson, 2013; Peterson, Pennington, Olson, & Wadsworth, 2014; Wybrow & Hanley, 2015; Ziegler et al., 2008; Sotiropoulos & Hanley, submitted; but see also Murphy & Pollatsek, 1994). Although these have proved to be informative in terms of understanding underlying cognitive markers and have resulted in targeted intervention programmes, there is as yet no agreement as to what is (or are) the best method(s) for classifying children with specific reading difficulties. In addition, I acknowledged that there is no common understanding of the best method(s) for selecting control groups.

Turning to the present research, we saw in Chapter V that when the five different classification schema were used to subcategorise the dyslexic children on the basis of irregular word and nonword reading scores, different percentages of children were classified as having a primary lexical or sublexical impairment. On the grounds of this evidence, it might be argued that subgroup classification is not a useful approach, and that a continuous classification measure (e.g., Griffiths & Snowling, 2002) or a single case study approach might be more effective methods for studying reading difficulties. In addition, the finding that only small numbers of dyslexic children were found to fall into the 'pure' subtypes of primary lexical and sublexical impairment might be additional reason to bring into question the utility of a subtyping approach. I suggest below though that these may not be strong reasons for abandoning such an approach, at least at the present time.

The finding that, using the Castles and Coltheart scheme, only 17% of the dyslexic children in the present study were classified as having a primary lexical impairment and only 11% a primary sublexical impairment does not run against the theoretical assumption that an imbalance in the efficiency of lexical and sublexical processes falls along a continuum (as discussed in McArthur et al., 2013). This is because the cutoff criteria specified in the various schemes for allocation to subgroups are arbitrary and only provide a means for isolating children at the ends of the continua who might be expected to have associated deficits of just one type.

It was argued until relatively recently that a phonological deficit was the single underlying cause of dyslexia (see, for example, Snowling & Davidoff, 1992). Thus, the investigation of different underlying causes of dyslexia is relatively new. It has been suggested (e.g., see Coltheart, 2001) that in cognitive domains where little is currently know it is helpful to use a labelling approach as an initial ground-clearing exercise in order to provide researchers with ideas about what kinds of distinctions and associations are of relevance in the domain. These ideas can be used to refine models of the functional architecture of the system for that particular domain, but then the classification can be replaced by new lines of research. The evidence in the present study, together with results from other similar studies, showing that the primary lexical and sublexical impairment profiles were associated with antithetic cognitive deficits, affirms that the subtyping approach is currently useful for contributing to understanding of the heterogeneity of dyslexia. In addition, since the children with a mixed profile, involving impairment of both lexical and sublexical processes, were shown to have a combination of the associated non-literacy deficits that the lexical and sublexical groups had (the children in the mixed subgroup showed both semantic and phonological difficulties) then this is further confirmation of the utility of subgrouping for identifying associations (i.e., potential underlying impairments).

I suggest then that at the present time classifying dyslexic children on the basis of irregular word and nonword reading ability would appear to be helpful for the endeavour of identifying deficits associated with different reading profiles. I discuss in following sections why this may be informative for developing targeted intervention programmes and for refining and extending theories of normal cognition (Nickels, Kohnen and Biedermann, 2010). Before this, there is discussion in the next section of factors that might have affected the distribution of subtypes of dyslexia in the present study.

VI.4.4. Age, instruction and intervention as potential influences on the distribution of dyslexic subtypes

In the present study, the three dyslexic subgroups differed in terms of chronological age: the sublexical group (Mean age 108.50, *SD* = 3.32) were overall six months older than the lexical group (Mean age 102.34, *SD* = 4.88). There is no agreement in the literature about the association between age and the prevalence of phonological and surface dyslexia. On the grounds of the dual route model, Peterson, Pennington and Olson (2013) hypothesised that pure cases of phonological and surface dyslexia would be more prevalent early in literacy development, before impairment to one process might impair acquisition of the other. On the contrary, findings from Peterson et al.'s study revealed that there was no evidence to support this view, rather the prevalence of both phonological and surface dyslexia increased with age. The children in this study were broadly of the same age as those assessed in Stanovich, Siegel and Gottardo (1997), while other studies (e.g., Manis et al. 1996, Friedmann & Lukov, 2008[44], Peterson et al., 2013) examined samples considerably older than the

[44]Surface dyslexics in Friedmann and Lukov's (2008) study ranged in age from 10;08 to 15;10 as well as two adults aged 21 and 43 years old.

children in the present study. Although the children with reading difficulties and CA controls in Stanovich et al. (1997) were all third grade, with a mean age of 107.5 and 107.8 months respectively, it is not clear whether age differed between the dyslexic subtypes. Since factors such as type of instruction can lead to changes in subtype identification over time (Peterson et al. 2014), it is not excluded that in the present study age and school year (i.e., some of the dyslexic children were Year 3 and some Year 4) might have impacted the subtypes classification.

A further complicating factor concerning subtype classification is to do with differences in the types and amount of reading remediation that the children in the present study received. Manis et al. (1996) discussed the possible outcomes of remediation type on lexical and sublexical processes, and it is even conceived that inappropriate remediation may exaggerate imbalanced reading profiles. The evidence that some dyslexic children in the present study attended a reading intervention programme without having undertaken comprehensive reading (and cognitive processes) assessments leads to the possibility that they might have received nonspecific remediation for their difficulties, which may have yielded an even more unbalanced reading profile. In the next section possible reading intervention aiming to address the locus of impairment of the lexical and sublexical groups is discussed.

VI.5. Implications for reading intervention

Following the Rose Review (2006, 2009) and the increasing knowledge among educationalists that early intervention improves the prospect of improvement for children with reading difficulty, many schools in the UK implemented early intervention programmes, providing reading support for children whose reading is behind expected levels. In spite of the effort made by the schools I recruited to identify children at risk of dyslexia and to implement interventions for children struggling with reading, as highlighted in the previous section, often children were not administered assessments to fully identify their strengths and weakness in reading and related cognitive processes; therefore, interventions were not selective or tailored to the children’s specific difficulties. As a consequence, children with reading difficulties might have started an intervention programme based on one of the (several) components of reading, which was not always the area that the child struggled most with. For example, following the recommendations of Rose (2006), primary schools in the UK are using phonics as the principal method to teach decoding. In the primary schools I recruited phonics were taught from the last year of the Early Years Foundation Stage (EYFS)[45] and, more systematically, from the autumn term of the Reception year[46]. As soon as children "at risk" of literacy problems were identified by teachers, they were invited to attend additional reading sessions. While, on the one hand this is remarkable, since for many years psychologists have stressed the importance of early identification and intervention for children with dyslexia (e.g., Snowling, 2012b), on the other hand children may be attending a general reading intervention programme, which may work for some, but not all, the dyslexic children.

Moreover, there is increasing acknowledgement of the importance of carrying out theoretically driven reading intervention (e.g., Griffiths & Stuart, 2013; Compton, Miller, Elleman, & Steacy, 2014), in that the findings will increase our understanding of the mechanisms of intervention (e.g., Kohnen et al., 2008a) and thereby result in more effective treatment, and the outcomes of the intervention will provide insight for theory. Also, as highlighted by Nickels, Kohnen and Biedermann (2010), the assessment and the intervention of children with cognitive deficits may help to develop and extend theories of reading development in typically developing children.

In light of the evidence that dyslexia is a heterogeneous disorder, and so it may require different forms of remediation (Broom & Doctor, 1995a; 1995b; Brunsdon, Hannan, Nickels, & Coltheart, 2002; Rowse & Wilshire, 2007; Brunsdon, Coltheart, & Nickels, 2005; Kohnen, Nickels, Brunsdon, & Coltheart, 2008a; Kohnen, Nickels, Coltheart, & Brunsdon, 2008b; McArthur et al., 2013a; McArthur et al., 2015), and the evidence that different reading profiles are associated with different cognitive deficits (e.g., McArthur et al., 2013), I suggest next possible reading

[45] In 2003, the Department for Education in UK introduced the assessment of children's progress at the end of the Foundation Stage (3-5 years old). As consequence, all schools and Ofsted-registered early years providers must deliver a curriculum for children from birth to 5 years old, consistent with standards for learning set by the EYFS (http://www.foundationyears.org.uk/eyfs-statutory-framework/). The areas of learning are personal, social and emotional; communication, language and literacy; problem solving, reasoning and numeracy; knowledge and understanding of the world; physical development; and creative development.

[46] In some of the Ofsted-registered early years providers (e.g., private nurseries), children of 2 years old are familiarised with letter knowledge.

intervention programmes for the sublexical and lexical group identified in the present study.

Based on previous research, it would be expected that children with reading difficulties where the problem seems to originate from phonological processing would benefit from a phonologically based intervention programme. Conversely, children with reading difficulties mainly due to weak semantics would benefit from a lexical intervention programme. Brunsdon, Coltheart and Nickels (2005) affirmed "Overall, it would be reasonable to suspect that the use of mnemonics may be beneficial when the treatment aim is specifically to train orthography-semantic connections, as in specific homophone reading and spelling treatment programmes where the individual demonstrates impaired access to semantic information for target words (though, even in this instance, a verbally mediated orthography-semantic association treatment may be equally effective). In contrast, mnemonics may not offer any treatment advantage when treatment simply targets irregular word reading or spelling, when the individual already knows the meaning of target words" (p. 243). It is reasoned that if the locus of the impairment is with entries in the orthographic input lexicon, any technique that encourages detailed orthographic analysis may work (irrespective of use of mnemonics), whereas if the problem is due to weak (or non-existent) vocabulary then a technique that uses mnemonics to consolidate (or establish) the semantic representations themselves would be effective[47].

In the light of evidence for links between oral language skills and word reading both in typically developing children and in children with reading and language difficulties, and the evidence that expressive and receptive vocabulary predict intervention responsiveness, Duff et al. (2008) argued for the inclusion of oral language skills (e.g., vocabulary) in the possible factors affecting reading intervention. Duff and colleagues implemented a new intervention combining oral reading associated to phonological training and vocabulary instruction. The sample consisted of 12 children aged 8 years who had received a reading intervention in the past, but who did not demonstrate any improvement (Hatcher et al., 2006). The intervention they received consisted of training in letter-sound knowledge, phoneme awareness

[47] Mnemonics might be used as a hook to link orthographic representations with semantic representations if the locus of impairment is in the connection from orthographic input to semantics.

and the link of these skills to reading and writing, and was delivered by a trained teaching assistant on a daily basis for 20 weeks. The new holistic intervention lasted 9 weeks and was carried out on a daily basis by a trained teaching assistant. There were two sessions of 15 minutes each. In the first session children were asked to read an easy book, use a booklet with rich vocabulary instruction and write a story. In the other session, children were trained in phonological awareness tasks (e.g., blending) by using items semantically related (where possible) to the day's target word they were asked to learn. The method of vocabulary instruction consisted of first, providing a context for the target word, inviting the child to repeat it to fix the phonological representation of the new word, followed by additional exercises to reinforce both the storage of the word in the mental lexicon and to secure its phonological representation. Turning to the present study, I suggest this type of intervention might help children with primary lexical impairment who presented with phonological errors in the picture naming task, on the grounds that vocabulary growth would reinforce (or better specify) the lexical representations, which in turn would enhance the phonological representations of words, and therefore their production.

VI.6. Limitations and possibilities for future research

VI.6.1. Participants

The dyslexic children in the present study were not recruited from clinics or special classes. Therefore it is likely that they were not affected by referral biases (e.g., Bowey & Rutherford 2007) and were a representative sample.

It was noted in the previous section that all the dyslexic children were attending reading intervention, and this varied in duration, length of sessions, group size, and personnel delivering the intervention[48]. It may be that the literacy instruction the dyslexic children were exposed to in and beyond the classroom (Duff et al., 2014; Peterson, Pennington, Olson, & Wadsworth, 2014) affected the balance between lexical and sublexical reading profiles (e.g., Manis et al., 1996), resulting in the large number of children that were identified with a mixed dyslexia profile, and small samples of children with primary lexical and sublexical impairment. It will be

[48] For a review of the potential factors affecting reading intervention, please see Griffiths and Stuart (2013).

important for future studies to investigate intervention history to ascertain its influence on subtype classification.

In addition, it was noted that two of the four children with primary sublexical impairment were described as “late talkers” and attended speech and language therapy in the past, while none of the primary lexical group were described in these terms. The majority of children in the lexical group had familiarity for dyslexia. Although the groups in the present study are too small to allow for definitive conclusions, it would be informative to examine these factors in future studies, for the overlapping incidence of specific language impairment (e.g., Chilosi et al., 2009; McArthur, Hogben, Edwards, Heath, & Mengler, 2000; Nash, Hulme, Gooch, & Snowling, 2013; Ramus, Marshall, Rosen, & van der Lely, 2013) and the link between genetic factors and subtypes of dyslexia. Castles, Datta, Gayan and Olson (1999) reported that there seemed to be a greater inherited component in the case of developmental phonological dyslexia than developmental surface dyslexia, although there was evidence of genetic contribution (familiarity for dyslexia) in both of their subgroups.

VI.6.2. Materials

In the picture naming task children were asked to try to find a name in the case of unfamiliar pictures, and in Chapter IV (p. 120) I noted that this might have encouraged the older TD children to produce more semantic naming errors than “don’t know” responses. This might explain the difference found in the rate of semantic errors in the TD children between the present study and that of Budd et al. (2011), where the rate of these was lower. However, in the present study items were eliminated prior to analysis when the children were unfamiliar with the concept, on the basis of responses in a word-picture verification task (where responses needed to be correct for both targets and semantic foils to be counted as correct). This should have led to a reduction in the rate of responses involving guessing. In the study of Budd et al., in order to assess whether or not children knew the objects in the pictures, a picture-word matching task was used in which the pictures used in the naming task were presented simultaneously with a semantic foil, a phonological foil and a visual foil on the computer screen. This was the same as the method used in the Swan and Goswami (1997) study. In Chapter III (p. 44) it was noted that the word-picture verification task used in the present study should be more sensitive than a multiple-choice task in identifying deficits in word comprehension and, in general, to eliminate forced guessing (Breese & Hillis, 2004; Cole Virtue & Nickels, 2004), therefore it seems that the method used in the present study for taking out unfamiliar items may have been more stringent than that used by Budd et al. (2011) and Swan and Goswami (1997). It will be informative to examine whether the different methods for eliminating unfamiliar items result in different rates of semantic errors.

The PJs task was found not to be a sensitive task for older children due to ceiling level performance. Use of a more taxing task could have resulted in group differences which would indicate that the dyslexics did have a difficulty with associative semantics, at least in some of the children classified as having a primary lexical impairment.

Measures of receptive and expressive vocabulary, as used in the present study, have typically been used as assessments of semantic knowledge, as seen in the studies reviewed in Chapter II (e.g., Nation & Snowling, 2004; Ouellette, 2006; Ricketts, Nation, & Bishop, 2007; Ouellette & Beers, 2009; Duff & Hulme, 2012). Ouellette (2006) and Ouellette and Beers (2009) employed receptive and expressive vocabulary to tap "the number of lexical (phonological) entries (i.e., vocabulary breadth) and the extent of semantic representation (i.e., depth of vocabulary knowledge)" (Ouellette, 2006, pp. 554-555). This distinction was validated by the observations that children's vocabulary growth "encompasses adding and refining phonological representations to the lexicon as well as storing and elaborating the associated semantic knowledge" (p. 555). On the other hand, Ricketts et al. (submitted) argued, "Oral vocabulary knowledge is an important part of semantic knowledge. However, semantic knowledge goes beyond this, encompassing knowledge of the meaning-based relationships between words, the meaning of phrases and so on (…)" (Ricketts, Davies, Masterson, Stuart, & Duff, submitted, p. 5). It seems then that there is little agreement on what the ideal measure of semantics should consist of. I would suggest that measures that go beyond the two used to assess lexical-semantic knowledge in the present study will need to be considered in future work.

The present study addressed deficits in phonological and semantic processes as potential underlying causes of reading difficulty. However, a number of other causes have been suggested, and restricted visual attention span has been supported by recent research. This is thought to involve a reduction in the number of orthographic units (e.g., letters or syllables) that can be processed in parallel (Valdois, Bosse, & Tainturier, 2004; Valdois et al., 2003). The theoretical model used by Bosse and Valdois (2003) proposed two reading procedures which differ in the span involved: the global procedure requires visual attention to extend over the whole letter string, whereas in the analytic procedure visual attention is focused successively on parts of the input string. Thus, global processing requires a larger visual attention span. If visual attention span is too restricted to cover entire words, these words cannot be processed in parallel, and serial analysis of the letter string remains the only available reading strategy (van den Boer, de Jong, & Haentjens-van Meeteren, 2012). On the grounds of the evidence of multiple deficits underlying reading disorders, it would be informative to include visual attention span tasks in future studies as part of the dyslexics' assessment.

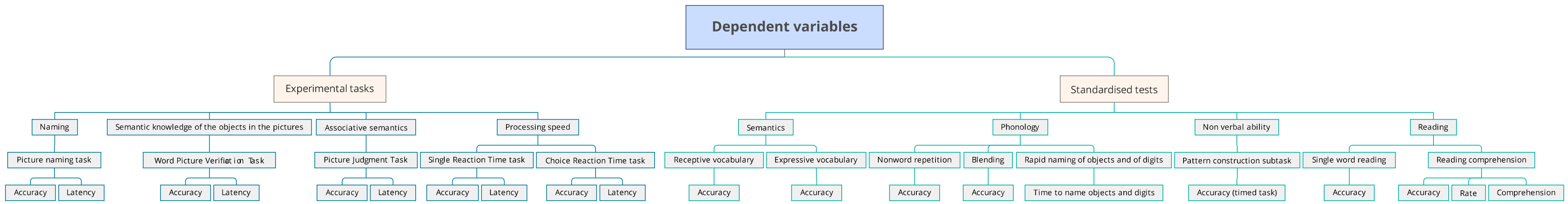
VI.7. Conclusions

The present study aimed to revisit the naming and phonological deficit hypothesis of dyslexia by exploring naming abilities in a sample of typically developing children aged 4 to 9 years and a group of dyslexics aged 8 to 9. Picture naming abilities were assessed through one of the most widely used paradigms for investigating how semantic and phonological information can be accessed and retrieved. Picture naming accuracy and latency scores were recorded. The results of a word-picture verification task were used to eliminate unfamiliar items prior to analysis. Examination of the influence of psycholinguistic variables on naming accuracy and qualitative analysis of picture naming errors were undertaken. Assessments of phonological and semantic abilities were carried out. To the author's knowledge, this was the first time phonological abilities were independently explored when investigating whether a naming deficit in dyslexic children might be due to a phonological deficit. It was also the first such study to examine the potential naming deficit in dyslexic children classified into subtypes of dyslexia.

The present study therefore contributed to issues raised by Hennessey, Deadman and Williams (2010): "Other measures of phonological processing ability were not included to evaluate the extent of the phonological processing deficit among the dyslexic readers. While there is empirical support for nonword reading and picture naming speed to be sensitive indicators of deficient phonological representations, as we argue above, it is recommended that additional measures of phonological processing, such as phonological awareness and/or nonword repetition, be included in future studies. Future studies should also consider evaluating semantic and other oral language skills (…). Of interest, for example, is whether strengths or weaknesses in semantics or vocabulary moderate the degree of semantic involvement during word naming in normal and dyslexic readers".

The findings revealed that a naming deficit was apparent in the sample of dyslexic children when compared to age-matched controls, but naming accuracy was in line with that of reading age controls, therefore the naming abilities of the dyslexic children, at least in this study, would be considered delayed rather than deviant. The findings also revealed that the results for the group were deceptive, as some of the dyslexic children did not have a naming deficit. Although it was acknowledged that it is unclear at present which methods of classification for dyslexic subtypes are the most valid, and therefore those employed in the present study may not be the optimal ones, the findings nevertheless indicated that as a group, the dyslexics showed a naming deficit and exhibited a higher rate of phonological errors than age-matched controls, corroborating previous findings. However, when the sample of dyslexic children were divided on the basis of their reading profile it was only the children classified as having a primary sublexical deficit who were identified (as a group) as having a naming deficit. There were also differences between the subtypes in terms of associated deficits when individual profiles of strengths and weaknesses were examined. In the primary sublexical deficit group, a difficulty with blending was an associated deficit. In the group of children identified as having a primary lexical deficit, weak semantics appeared to be the associated deficit. The findings suggest that it is important to classify developmental reading difficulties in order to identify underlying deficits and tailor specific reading intervention programmes. In a recent review, Ramus (2014) stated "Admittedly, the evidence that different kinds of poor readers require different types of intervention is scarce. But the claim that one intervention fits all is also totally premature and bound to turn out to be wrong. It is already obvious that it cannot be true that all poor readers have the same problem, and that they all benefit from the same intervention. What we need is much more research on specific subtypes of dyslexia, and on what specific interventions best suit each kind of poor reader and each type of dyslexia." (p. 3373). The findings from the present study are wholly in accord with this conclusion.

APPENDIX A


Dependent variables
Experimental tasks
Standardised tests
Naming
Semantic knowledge of the objects in the pictures
Associative semantics
Processing speed
Picture naming task
Word Picture Verification Task
Picture Judgment Task
Single Reaction Time task
Choice Reaction Time task
Accuracy
Latency
Semantics
Phonology
Non verbal ability
Reading
Receptive vocabulary
Expressive vocabulary
Nonword repetition
Blending
Rapid naming of objects and of digits
Pattern construction subtask
Single word reading
Reading comprehension
Time to name objects and digits
Accuracy (timed task)
Rate
Comprehension

APPENDIX B

Stimuli for the picture naming task and age of acquisition (AoA) for individual items from Funnell et al. (2006)

Category	Items	AoA (in months)
Animals	Armadillo	>138
	Beaver	90
	Butterfly	<43
	Camel	<43
	Cheetah	115
	Cow	<43
	Donkey	46
	Giraffe	<43
	Koala	73
	Llama	>138
	Ostrich	74
	Pelican	>138
	Penguin	<43
	Scorpion	108
	Seahorse	46
	Squirrel	<43
	Tapir	>138
	Vulture	>138
Fruits/Vegetables	Apple	<43
	Asparagus	>138
	Aubergine	>138
	Broccoli	63
	Carrot	<43
	Chilli	>138
	Coconut	70
	Courgette	>138
	Garlic	135
	Grapes	<43
	Lemon	<43
	Mushroom	52
	Pear	<43
	Pineapple	55
	Radish	>138
	Rhubarb	>138
	Strawberry	<43
	Tomato	52
Implements	Binoculars	67
	Camera	<43
	Can-opener	98
	Chisel	>138
	Corkscrew	127
	Grater	91

	Hammer	<43
	Ladle	>138
	Microscope	121
	Rake	80
	Ruler	57
	Saw	65
	Spanner	99
	Spoon	<43
	Torch	<43
	Trowel	>138
	Watch	<43
	Whisk	113
Vehicles	Barge	>138
	Bus	<43
	Caravan	50
	Fork-Lift	>138
	Hovercraft	132
	Jet-Ski	137
	Milk-Float	136
	Motorbike	<43
	Parachute	67
	Plane	<43
	Rocket	<43
	Sledge	125
	Submarine	98
	Tandem	>138
	Tank	87
	Tractor	<43
	Windsurf	138
	Yacht	121

APPENDIX C

Values for spoken frequency, imageability, visual complexity, word length (phonemes, letters, syllables and the the joint measure) and phonological neighbours for the stimuli from Funnell et al. (2006)

Items	Spoken Frequency	Imageability	Word length in phonemes	Word length in letters	Word length in syllables	Word length joint measure	Phonological neighbour 1	Phonological neighbour 2	Visual Complexity
Aeroplane	4	6	7	9	3	19	0	1	4
Apple	5	6	4	5	2	11	0	3	1
Armadillo	1	4	7	9	4	20	0	1	5
Asparagus	3	5	9	9	4	22	0	0	4
Aubergine	3	5	6	9	3	18	0	0	2
Barge	2	4	3	5	1	9	8	11	3
Beaver	2	5	4	6	2	12	4	5	3
Binoculars	2	5	9	10	4	23	0	0	4
Broccoli	5	6	7	8	3	18	0	0	4
Bus	6	6	3	3	1	7	14	18	4
Butterfly	4	6	7	9	2	18	0	1	4
Camel	2	6	5	5	2	12	3	5	3
Camera	5	6	6	6	3	15	0	1	4
Canopener	3	5	8	9	4	21	0	0	3
Caravan	2	5	7	7	3	17	0	1	4
Carrot	5	6	5	6	2	13	1	2	2
Cheetah	2	5	4	7	2	13	0	1	5
Chilli	5	5	4	6	2	12	4	5	2
Chisel	2	4	5	6	2	13	2	2	3
Coconut	3	6	7	7	3	17	0	1	3
Corkscrew	4	6	7	9	2	18	0	1	4

Courgette	4	5	5	9	2	16	0	1	3
Cow	4	6	2	3	1	6	11	13	3
Donkey	3	6	5	6	2	13	1	2	3
Fork-Lift	2	5	7	8	2	17	0	1	5
Garlic	5	6	5	6	2	13	0	0	3
Giraffe	3	6	5	7	2	14	0	1	4
Grapes	5	6	5	6	2	13	2	3	2
Grater	4	5	5	6	2	13	1	3	4
Hammer	3	6	4	6	2	12	1	3	2
Hovercraft	1	5	9	10	3	22	0	1	5
Jet-Ski	1	4	6	6	2	14	0	1	4
Koala	2	6	6	5	2	13	0	1	3
Ladle	3	5	5	5	2	12	1	4	2
Lemon	4	6	5	5	2	12	0	1	2
Llama	2	4	4	5	2	11	1	2	3
Microscope	2	5	9	10	3	22	0	1	5
Milk-float	1	5	8	9	2	19	0	1	5
Motorbike	3	6	7	9	3	19	0	1	5
Mushroom	5	6	6	8	2	16	0	1	2
Ostrich	2	5	6	7	2	15	0	0	3
Parachute	2	5	7	9	3	19	0	1	3
Pear	4	6	2	4	1	7	11	12	2
Pelican	2	4	7	7	3	17	0	1	3
Penguin	3	6	7	7	2	16	0	1	3
Pineapple	4	6	7	9	2	18	0	1	4
Radish	2	5	5	6	2	13	1	1	3
Rake	2	5	3	4	1	8	20	28	2
Rhubarb	3	5	5	7	2	14	0	0	3
Rocket	2	5	5	6	2	13	3	4	4
Ruler	4	6	4	5	2	11	3	4	4
Saw	3	5	2	3	1	6	13	17	2
Scorpion	2	5	7	8	2	17	0	1	4
Seahorse	2	5	5	8	2	15	0	0	3

Sledge	2	5	4	6	1	11	1	3	4
Spanner	2	5	5	7	2	14	1	2	3
Spoon	6	6	4	5	1	10	5	6	2
Squirrel	4	6	7	8	2	17	0	1	3
Strawberry	5	7	8	10	2	20	0	1	4
Submarine	2	5	8	9	3	20	0	1	4
Tandem	2	4	6	6	2	14	1	1	4
Tank	3	5	4	4	1	9	4	9	5
Tapir	1	3	4	5	2	11	0	1	3
Tomato	5	6	6	6	3	15	0	1	2
Torch	4	6	3	5	1	9	6	8	3
Tractor	3	6	6	7	2	15	0	2	5
Trowel	2	5	6	6	2	14	0	3	3
Vulture	2	5	5	7	2	14	1	2	4
Watch	6	6	3	5	1	9	4	4	3
Whisk	3	5	4	5	1	10	2	4	3
Windsurf	2	4	7	8	2	17	0	1	4
Yacht	2	5	3	5	1	9	10	11	4

APPENDIX D

Mean values for the semantic relatedness rating for items in the Word-Picture Verification task

Target	Spoken word	Mean
Aeroplane	*Helicopter*	6.0
Apple	*Orange*	6.1
Armadillo	*Tortoise*	4.6
Asparagus	*Leek*	5.3
Aubergine	*Marrow*	5.0
Barge	*Canoe*	4.9
Beaver	*Otter*	6.0
Binoculars	*Telescope*	6.3
Broccoli	*Cauliflower*	6.2
Bus	*Train*	6.0
Butterfly	*Wasp*	5.0
Camel	*Horse*	4.9
Camera	*Telephone*	3.4
Canopener	*Nut cracker*	4.7
Caravan	*Taxi*	4.6
Carrot	*Pumpkin*	4.6
Cheetah	*Lion*	6.1
Chilli	*Ginger*	5.0
Chisel	*Screwdriver*	5.6
Coconut	*Walnut*	4.4
Corkscrew	*Drill*	4.2
Courgette	*Parsnip*	5.0
Cow	*Sheep*	5.4
Donkey	*Zebra*	5.3
Fork-Lift	*Crane*	5.3
Garlic	*Onion*	6.4
Giraffe	*Antelope*	4.4
Grapes	*Cherry*	5.4
Grater	*Sieve*	5.0
Hammer	*Axe*	5.4
Hovercraft	*Dinghy*	5.3
Jet-Ski	*Snowmobile*	5.2
Koala	*Monkey*	4.3
Ladle	*Spatula*	5.1
Lemon	*Tangerine*	6.0
Llama	*Goat*	5.0
Microscope	*Glasses*	5.0
Milk-Float	*Taxi*	3.5
Motorbike	*Tricycle*	5.1
Mushroom	*Beetroot*	4.3
Ostrich	*Flamingo*	5.3

Parachute	*Balloon*	4.7
Pear	*Fig*	5.1
Pelican	*Stork*	5.6
Penguin	*Seal*	5.1
Pineapple	*Melon*	5.5
Radish	*Potato*	5.3
Rake	*Broom*	5.1
Rhubarb	*Celery*	4.5
Rocket	*Satellite*	5.2
Ruler	*Thermometer*	3.9
Saw	*Penknife*	4.4
Scorpion	*Ant*	4.0
Seahorse	*Octopus*	4.9
Sledge	*Raft*	3.9
Spanner	*Pliers*	5.3
Spoon	*Fork*	6.5
Squirrel	*Mouse*	4.4
Strawberry	*Blackcurrant*	6.1
Submarine	*Catamaran*	4.7
Tandem	*Scooter*	4.6
Tank	*Lorry*	4.7
Tapir	*Elephant*	3.7
Tomato	*Pepper*	4.9
Torch	*Candle*	5.5
Tractor	*Mower*	4.8
Trowel	*Shears*	5.7
Vulture	*Hawk*	6.0
Watch	*Clock*	6.7
Whisk	*Tongs*	4.2
Windsurf	*Skateboard*	4.1
Yacht	*Lifeboat*	5.3

APPENDIX E

Mean values for the familiarity rating for items in the Word-Picture Verification task

Target	Mean
Aeroplane	5.6
Apple	6.4
Armadillo	1.5
Asparagus	4.3
Aubergine	3.7
Barge	2.9
Beaver	2.7
Binoculars	3.2
Broccoli	5.3
Bus	6.1
Butterfly	5.2
Camel	3.1
Camera	6.0
Can opener	5.0
Caravan	3.6
Carrot	6.0
Cheetah	2.5
Chilli	4.9
Chisel	2.8
Coconut	3.4
Corkscrew	4.6
Courgette	4.6
Cow	5.5
Donkey	3.6
Fork-Lift	2.4
Garlic	5.7
Giraffe	3.7
Grapes	5.6
Grater	4.8
Hammer	4.2
Hovercraft	2.5
Jet-Ski	2.3
Koala	2.2
Ladle	3.7
Lemon	5.8
Llama	2.0
Microscope	3.0
Milk-Float	2.7
Motorbike	4.7
Mushroom	5.9
Ostrich	2.4
Parachute	2.9

Pear	5.1
Pelican	2.3
Penguin	3.3
Pineapple	4.8
Radish	3.7
Rake	3.8
Rhubarb	4.1
Rocket	3.3
Ruler	5.7
Saw	3.9
Scorpion	2.0
Seahorse	2.3
Sledge	2.7
Spanner	3.5
Spoon	6.5
Squirrel	4.6
Strawberry	6.1
Submarine	2.4
Tandem	2.3
Tank	3.1
Tapir	1.3
Tomato	6.3
Torch	4.9
Tractor	3.9
Trowel	3.3
Vulture	2.1
Watch	6.4
Whisk	4.1
Windsurf	2.6
Yacht	2.8

APPENDIX F

Items in the Picture Judgment task

Practice Items	
1.	Pyjamas, *Bed*, Chair
2.	Bird, Fishbowl, *Nest*
3.	Ball, *Dog*, Bee

Test items (target picture listed first)	
1.	Ticket, *Bus*, Caravan
2.	Saddle, Camel, *Horse*
3.	Library, Map, *Book*
4.	Picnic, *Strawberry*, Lemon
5.	Carrot, Spoon, *Fork*
6.	Anchor, Windsurfer, *Yacht*
7.	Tractor, Elephant, *Cow*
8.	Garden, *Butterfly*, Pelican
9.	Cheese, *Grater*, Ladle
10.	Stamp, Box, *Envelope*
11.	Parachute, Rocket, *Plane*
12.	Feather, *Ostrich*, Cheetah
13.	Picture, Binoculars, *Camera*
14.	Arm, Clock, *Watch*
15.	Sledge, Koala, *Penguin*
16.	Bell, *Tandem*, Motorbike
17.	Leaf, *Giraffe*, Tiger
18.	Tree, Rhubarb, *Pear*
19.	Tie, *Shirt*, Shorts
20.	Sandwich, *Tomato*, Mushroom

Items semantically related to the target are in italic

APPENDIX G

Information leaflet for parents of children aged 4-5

Page 4

Do you have to take part?

You decide whether you want to take part – and even if you say 'yes', your child can drop out at any time or say that s/he doesn't want to answer some questions.

You can tell me that your child will take part by signing the consent form.

Will you know about the research results?

I will send you a short report as soon as the study is completed.

Who is funding the research?

The researcher is supported by a Bloomsbury Colleges studentship.

The project has been reviewed by the Research Ethics Committee at the Institute of Education and ethical approval has also been obtained from the Department of Psychology and Human Development.

Thank you for reading this leaflet.

Silvia Roncoli - Prof. Jackie Masterson
Department of Psychology and Human Development
Institute of Education
20, Bedford Way
WC1H 0AL London

sroncoli@ioe.ac.uk or XXX
J.Masterson@ioe.ac.uk or 020 7612 6903

IOE LONDON Leading education and social research Institute of Education University of London

Development of word naming and knowing and their relationship to emergent literacy

A research project

Information for Parents and Carers

My name is Silvia Roncoli and I am a MPhil/PhD student at the Institute of Education, University of London.

This leaflet tells you about my research.
I hope the leaflet will be useful and I would be pleased to answer any questions you may have.

Please would you explain the research to your child and talk over whether they want to participate. I will also ask the children during sessions if they are happy to take part and I will propose all the activities as a series of games.

Criminal Record Bureau (CRB) clearance has been obtained

Page 2

Why is this research being done?

The research is part of an on-going large scale research looking into the development of children's ability to give the names of the items they are shown in pictures. Data collected in very young children will inform researchers on which factors affect literacy development over the school-age.

Who will be in the project?

In the project monolingual children (i.e., those who have English as their main and first language) aged 4-to-9 years old will participate.

What will happen during the research?

Children will be assessed individually on tasks that will be presented in the form of games. Your child will see some pictures of simple objects (e.g. a cat, an anchor) on the screen of a computer.

S/He will be asked if they know what the name of each object is and if so to say the name out loud, and to answer some questions about the object. The answers will be recorded.

Your child will also take part in a task where they are asked to blend sounds to make up words, to make patterns with blocks and to say the meaning of some words.

The tasks will be divided between 4 sessions lasting about 30 minutes each.

Page 3

What will happen to your child if she/he takes part?

I will not be looking for right or wrong answers, only for what everyone really knows.

Could there be problems for your child if he/she takes part?

I hope your child will enjoy participating in the tasks.
I will only carry out the testing with your child if s/he indicates that s/he is happy to take part at the outset of each testing session.
Some children may get tired by some activities. If they want to stop, we will stop. If you have any problems with the project, please tell me (sroncoli@ioe.ac.uk).

Will doing the research help you?

I hope your child will enjoy helping me. The research will mainly help to find new ideas to help children with naming and reading problems, in future.

Who will know that you have been in the research?

All information about children will be confidential and **anonymous**. Information will be stored securely and your child's name and school **will not** appear in any of our reports. All records and audio-recordings will be labeled only with the number we allocate to your child.

Information leaflet for parents of children aged 6-9

Page 4

Do you have to take part?

You decide whether you want to take part – and even if you say 'yes', your child can drop out at any time or say that s/he doesn't want to answer some questions.
You can tell me that your child will take part by signing the consent form.

Will you know about the research results?

I will send you a short report as soon as the study is completed.

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The project has been reviewed by the Research Ethics Committee at the Institute of Education and ethical approval has also been obtained from the Department of Psychology and Human Development.

Thank you for reading this leaflet.

Silvia Roncoli - Prof. Jackie Masterson
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Development of word naming and knowing and their relationship to emergent literacy

A research project

Information for Parents and Carers

My name is Silvia Roncoli and I am a MPhil/PhD student at the Institute of Education, University of London.

This leaflet tells you about my research.
I hope the leaflet will be useful and I would be pleased to answer any questions you may have.

Please would you explain the research to your child and talk over whether they want to participate. I will also ask the children during sessions if they are happy to take part and I will propose all the activities as a series of games.

Criminal Record Bureau (CRB) clearance has been obtained

Page 2

Why is this research being done?

The research is part of an on-going large scale research looking into the development of children's ability to give the names of the items they are shown in pictures. Data collected in very young children will inform researchers on which factors affect literacy development over the school-age.

Who will be in the project?

In the project monolingual children (i.e., those who have English as their main and first language) aged 6-to-9 years old will participate.

What will happen during the research?

Children will be assessed individually on tasks that will be presented in the form of games. Your child will see some pictures of simple objects (e.g. a cat, an anchor) on the screen of a computer.

S/He will be asked if they know what the name of each object is and if so to say the name out loud, and to answer some questions about the object. The answers will be recorded. Your child will also take part in a task where they are asked to blend sounds to make up words, to make patterns with blocks and to say the meaning of some words. Also a simple reading test of single words and a task with a story where I will ask some questions about what happened in the story.

The tasks will be divided between 4 sessions lasting about 30 minutes each.

Page 3

What will happen to your child if she/he takes part?

I will not be looking for right or wrong answers, only for what everyone really knows.

Could there be problems for your child if he/she takes part?

I hope your child will enjoy participating in the tasks.
I will only carry out the testing with your child if s/he indicates that s/he is happy to take part at the outset of each testing session.
Some children may get tired by some activities. If they want to stop, we will stop. If you have any problems with the project, please tell me (sroncoli@ioe.ac.uk).

Will doing the research help you?

I hope your child will enjoy helping me. The research will mainly help to find new ideas to help children with naming and reading problems, in future.

Who will know that you have been in the research?

All information about children will be confidential and **anonymous**. Information will be stored securely and your child's name and school **will not** appear in any of our reports. All records and audio-recordings will be labeled only with the number we allocate to your child.

Leading education and social research
Institute of Education
University of London

Development of word naming and knowing and their relationship to emergent literacy

Consent form

Name of child ______________________________

Date of birth ______________________________

Name of parent/carer ______________________________

I have received a copy of the information leaflet for this project.
I am aware that my child's responses will be recorded and that my child's name and the name of the school will remain confidential in the reporting of the study.
I understand that my child is able to withdraw from this research at any time.

I am willing to let my child participate in the research.

Signed______________________ date______________

APPENDIX H

Mean accuracy and T score of nonverbal ability task for the TD children according to school year group (standard deviations are in parentheses)

Measures	Nursery (N=11)	Reception (N=11)	Year 1 (N=30)	Year 2 (N=23)	Year 3 (N=38)	Year 4 (N=9)
Nonverbal ability (T score)	50.91 (7.61)	50.27 (5.46)	53.04 (7.45)	55.57 (9.40)	53.82 (8.35)	49.89 (2.03)
Nonverbal ability (raw scores)	8.55 (3.91)	15.82 (6.57)	28.77 (6.18)	25.04 (7.50)	23.58 (5.92)	23.89 (2.09)

APPENDIX I

Summary of percentage accuracy and latencies (msecs) in the experimental tasks for the typically developing children according to school year group (standard deviations are in parentheses) with all picture naming items included

Measures	Nursery (N=11)	Reception (N=11)	Year 1 (N=30)	Year 2 (N=23)	Year 3 (N=38)	Year 4 (N=9)
Picture naming accuracy	33.08 (6.11)	42.30 (7.92)	46.94 (9.28)	53.56 (9.41)	57.60 (6.87)	62.81 (7.14)
Picture naming latency	1619 (234)	1482 (180)	1560 (390)	1440 (228)	1314 (243)	1256 (102)
WPVT accuracy	41.67 (12.01)	51.89 (13.46)	67.13 (8.35)	73.55 (8.81)	76.39 (6.30)	78.55 (2.96)
WPVT latency	2809 (626)	2786 (573)	2328 (309)	2340 (255)	2195 (240)	2219 (227)
PJs accuracy	79.09 (14.29)	84.09 (9.70)	87.67 (10.81)	92.61 (8.24)	95.79 (5.52)	98.33 (3.54)
PJs latency	7066 (2961)	5024 (1816)	3656 (1151)	3389 (694)	2876 (943)	3233 (636)
Simple reaction time latency	732 (227)	610 (166)	576 (214)	522 (134)	490 (134)	438 (104)
Choice reaction time accuracy	80.05 (.09)	89.14 (5.89)	94.12 (5.74)	94.08 (7.46)	97.81 (2.83)	98.15 (1.96)
Choice reaction time latency	689 (132)	624 (97)	576 (111)	597 (115)	518 (83)	480 (48)

Correlations between chronological age in months and accuracy and latency scores in the experimental tasks for the typically developing children with all picture naming items included

Measures	1	2	3	4	5	6	7	8	9
1. Age (months)									
2. Picture naming accuracy	.727**								
3. Picture naming latency	-.320**	-.312**							
4. WPVT accuracy	.740**	.770**	-.270**						
5. WPVT latency	-.464**	-.312**	.330**	-.579**					
6. PJs accuracy	.564**	.583**	-.296**	.527**	-.257**				
7. PJs latency	-.582**	-.531**	.373**	-.659**	.550**	-.318**			
8. Simple reaction time latency	-.386**	-.306**	.194	-.309**	.427**	-.193	.330**		
9. Choice reaction time latency	-.448**	-.386**	.393**	-.342**	.459**	-.142	.393**	.686**	
10. Choice reaction time accuracy	-.489**	-.436**	.289**	-.435**	.488**	-.202*	.439**	.588**	-.389**

Note: *$p < .05$, **$p < .01$

APPENDIX J

Correlations between accuracy and latency scores (msecs) in the experimental tasks for the typically developing children with adjusted picture naming scores

Measures	1	2	3	4	5	6	7	8
1. Picture naming accuracy	-							
2. Picture naming latency	-.312***	-						
3. WPVT accuracy	.770***	-.270**	-					
4. WPVT latency	-.312***	.330***	-.579***	-				
5. PJs accuracy	.583***	-.296**	.527***	-.257**	-			
6. PJs latency	-.531***	.373***	-.659***	.550***	-.318***	-		
7. Simple reaction time latency	-.306**	.282**	-.309**	.427***	-.233**	.330***	-	
8. Choice reaction time accuracy	-.043	.298**	.037	.100	-.076	.047	.440***	-
9. Choice reaction time latency	-.386***	.393***	-.342***	.459***	-.211*	.393***	.686***	.559***

Note: *$p < .05$, **$p < .01$, ***$p < .0001$

APPENDIX K

Correlations between accuracy and latency scores (msecs) in the experimental tasks for the typically developing children with adjusted picture naming scores and PJs outliers removed

Measures	1	2	3	4	5	6	7	8
1. Picture naming accuracy	-							
2. Picture naming latency	-.234*	-						
3. WPVT accuracy	.450**8	-.272**	-					
4. WPVT latency	-.071	.352**8	-.584**8	-				
5. PJs accuracy	.397**8	-.274**	.545**8	-.327**	-			
6. PJs latency	-.431**8	.434**8	-.719**8	.594**	-.436***	-		
7. Simple reaction time latency	-.159	.267**	-.281**	.390**	-.232*	.322***	-	
8. Choice reaction time accuracy	.335**8	-.258**	.544**8	-.390**	.339***	-.561***	-.420***	-
9. Choice reaction time latency	-.252**	.210*	-.414**	.441***	-.199*	.460***	.560***	-.358***

Note: $*p < .05$, $**p < .01$, $***p < .001$

APPENDIX L

Correlations matrix with the transformed psycholinguistic variables for the typically developing children

	1	2	3	4
1. Spoken Frequency	-			
2. Visual Complexity	-.381**	-		
3. Word length (joint measure)	-.243	.329*	-	
4. Phonological Neighbours	.133	-.183	-.810**	-
5. Imageability	.744**	-.229	-.140	.088

Note: *$p < .05$, **$p < .01$

APPENDIX M

Correlations between the phonological and semantic standardised tasks for the typically developing children

Measures	1	2	3	4	5
1. Receptive vocabulary	-				
2. Expressive vocabulary	.811***	-			
3. Nonword repetition	.758***	.611***	-		
4. Blending words	.536***	.398**	.538***	-	
5. Rapid naming digits (secs)	-.517***	-.460**	-.410***	-.278**	-
6. Rapid naming objects (secs)	-.437***	-.401**	-.509***	-.086	.657***

Note: ** $p < .01$, *** $p < .001$

APPENDIX N

Correlations between the phonological and semantic standardised tasks for the typically developing children with rapid naming outliers removed

Measures	1	2	3	4	5
1. Receptive vocabulary	-				
2. Expressive vocabulary	.811***	-			
3. Nonword repetition	.765***	.613***	-		
4. Blending words	.586***	.396**	.558***	-	
5. Rapid naming digits (secs)	-.522***	-.538**	-.465***	-.391***	-
6. Rapid naming objects (secs)	-.412***	-.414**	-.537***	-.181	.599***

Note: ** $p < .01$; *** $p < .001$

APPENDIX O

Mean standard score and percentage correct score in the YARC single word reading standardised test, and mean standard score in the YARC standardised test of reading passage accuracy, rate, and comprehension for the TD children (standard deviations are in parentheses)

Measures	Year 1 (N=30)	Year 2 (N=23)	Year 3 (N=38)	Year 4 (N=9)
YARC single word	107.52 (11.50)	104.87 (11.73)	100.61 (9.10)	99.67 (5.39)
YARC single word (% correct)	30.89 (15.12)	47.03 (16.58)	58.99 (11.63)	65.56 (7.31)
YARC passage accuracy	112.07 (10.43)	111.35 (10.21)	106.05 (10.05)	100.56 (5.83)
YARC passage rate	110.39 (8.89)	111.27 (10.68)	105.16 (10.18)	98.33 (2.75)
YARC passage comprehension	108.41 (11.12)	104.87 (12.10)	105.13 (6.50)	99.67 (4.18)

APPENDIX P

Correlations between nonword, irregular word, and regular word subtasks, and total reading score in the DTWRP (FRLL, 2012) for the typically developing children

Measures	1	2	3
1. Nonwords (% correct)	-		
2. Irregular word (% correct)	.816***	-	
3. Regular word (% correct)	.862***	.921***	-
4. Total (% correct)	.936***	.956***	.971***

Note: ***p < .001

APPENDIX Q

Correlations between experimental measures, standardised scores and reading scores for the TD children controlling for chronological age and with logarithm transformed data for number for phonological errors, results for the younger group are below the diagonal and those for the older group are above the diagonal

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Rec.Voc.	-	.634**	.033	.399**	.133	-.190	.378**	-.248	-.303*	.179	.155	.628***	-.305*
2. Exp.Voc	-	-	.090	.417**	-.070	-.168	.371*	-.422**	-.322*	.456**	.425**	.307	-.508**
3. Blending	.041	-	-	.214	-.007	.124	.146	-.003	-.439***	-.208	.057	.094	-.015
4. NWRep.	.280*	-	.063	-	-.110	-.493**	.189	-.264*	-.258*	.238	.138	.417**	-.318*
5. RAN dig.	-.199	-	.051	.148	-	.395**	-.229	.023	-.097	-.226	-.352**	.040	.055
6. RAN obj.	.011	-	.247	-.242	.498**	-	-.294*	.145	.082	-.203	.076	-.509***	.187
7. PJs acc.	.270*	-	.101	.080	.289	.408*	-	-.029	-.117	-.095	-.010	.268*	-.247
8. PJs time	-.128	-	.042	-.044	.021	.196	.042	-	-.044	-.206	-.068	-.255*	.578***
9. Phon.Err.	-.147	-	-.033	-.288*	.012	-.154	-.068	-.174	-	.138	-.060	-.115	-.030
10. Irr. acc.	-.009	-	.321*	.443**	-.157	-.139	.054	.073	-.429**	-	.687***	.077	-.117
11. Nwd acc.	.198	-	.553***	.434**	-.070	-.039	.047	.069	-.398*	.696***	-	-.100	.131
12. Pic. acc.	.677***	-	.047	.407**	-.097	.047	.339**	-.118	-.441**	.284	.309	-	-.273*
13. Pic. time	.004	-	-.076	.030	-.002	-.019	-.111	.156	.075	-.124	-.213	-.025	-

Note: *p < .05, **p < .01.

APPENDIX R

Mean chronological age and standard scores in background measures for poor readers and chronological age (CA) and reading age (RA) control groups (standard deviations in parentheses)

Measures	Dyslexics (*N*=35)	CA controls (*N*=35)	RA controls (*N*=24)	T-tests
Chronological age (months)	101.89 (6.85)	101.57 (6.51)	77.42 (7.12)	D vs RA *t*(57)=13.27, *p*<.001 D vs CA *t*(68)=.197, *p*=.845
Nonverbal ability (T score)	52.86 (10.33)	52.91 (6.34)	53.50 (7.44)	D vs RA *t*(57)=.791, *p* =.432 D vs CA *t*(68)=.694, *p* =.490*
DTWRP total score (SS)	80.60 (5.97)	101.49 (3.03)	103.33 (4.04)	D vs CA *t*(51)=18.45,*p*<.001* D vs RA t(57)=16.25, *p*<.001
YARC single word reading (SS)	78.51 (6.81)	98.57 (4.96)	104.50 (7.41)	D vs CA *t*(62)=14.08, *p*<.001* D vs RA *t*(57)=13.88, *p*<.001
YARC passage accuracy (SS)	86.43 (4.94)	102.26 (5.18)	108.50 (6.20)	D vs CA *t*(68)=13.09, *p*<.001 D vs RA *t*(57)=15.19, *p*<.001
YARC passage rate (SS)	86.66[α] (9.55)	101.26 (6.47)	108.55[b] (6.18)	D vs CA *t*(65)=7.38, *p*<.001 D vs RA *t*(50)=9.11, *p*<.001
YARC comprehension (SS)	95.40 (10.34)	102.34 (4.82)	105.50 (9.42)	D vs CA *t*(48)=3.60, *p*<.01* D vs RA *t*(57)=3.82, *p*<.001

Note: [α] N = 32, [b] N = 20, * = Welch-Satterthwaite correction

APPENDIX S

Child Questionnaire

Child's name……………………………………………………………………

1. Was your child's birth process unusual or prolonged in any way? E.g. CS, Forceps, etc?

----

2. Was your child born early or late for term (more than 2 weeks early or more than 10 days late)?

----

3. Was your child late at learning to walk (16 months or later)?

----

4. Was your child late at learning to talk (2-3 words phrases at 18 months or later) ?

----

5. In the first 3 years of life, did your child suffer from any illness (apart from coughs/colds etc)?

----

6. Has your child had any ear infections, hearing problems or grommets?

----

7. Has your child ever attended speech and language therapy?

----

8. Is there any history of learning difficulties in your immediate family?

----

9. Has your child had a diagnosis of?

THANK YOU VERY MUCH FOR YOUR HELP

If you need more information about the questions, please do not hesitate to ask:

• Silvia Roncoli – Researcher
Email: sroncoli@ioe.ac.uk
Mobile: XXX

APPENDIX T

Strengths and Difficulties Questionnaire

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain or the item seems daft! Please give your answers on the basis of the child's behaviour over the last six months or this school year.

Child's Name .... Male/Female

Date of Birth..

	Not True	Somewhat True	Certainly True
Considerate of other people's feelings	☐	☐	☐
Restless, overactive, cannot stay still for long	☐	☐	☐
Often complains of headaches, stomach-aches or sickness	☐	☐	☐
Shares readily with other children (treats, toys, pencils etc.)	☐	☐	☐
Often has temper tantrums or hot tempers	☐	☐	☐
Rather solitary, tends to play alone	☐	☐	☐
Generally obedient, usually does what adults request	☐	☐	☐
Many worries, often seems worried	☐	☐	☐
Helpful if someone is hurt, upset or feeling ill	☐	☐	☐
Constantly fidgeting or squirming	☐	☐	☐
Has at least one good friend	☐	☐	☐
Often fights with other children or bullies them	☐	☐	☐
Often unhappy, down-hearted or tearful	☐	☐	☐
Generally liked by other children	☐	☐	☐
Easily distracted, concentration wanders	☐	☐	☐
Nervous or clingy in new situations, easily loses confidence	☐	☐	☐
Kind to younger children	☐	☐	☐
Often lies or cheats	☐	☐	☐
Picked on or bullied by other children	☐	☐	☐
Often volunteers to help others (parents, teachers, other children)	☐	☐	☐
Thinks things out before acting	☐	☐	☐
Steals from home, school or elsewhere	☐	☐	☐
Gets on better with adults than with other children	☐	☐	☐
Many fears, easily scared	☐	☐	☐
Sees tasks through to the end, good attention span	☐	☐	☐

Signature .... Date ....

Parent/Teacher/Other (please specify:)

Thank you very much for your help

APPENDIX U

Information leaflet for children with reading difficulties

Page 4

Do you have to take part?
You decide whether you want to take part – and even if you say 'yes', your child can drop out at any time or say that s/he doesn't want to answer some questions.
You can tell me that your child will take part by signing the consent form.

Will you know about the research results?
I will send you a short report as soon as the study is completed.

Who is funding the research?
The researcher is supported by a Bloomsbury Colleges studentship.

The project has been reviewed by the Research Ethics Committee at the Institute of Education and ethical approval has also been obtained from the Department of Psychology and Human Development.

Thank you for reading this leaflet.

Silvia Roncoli - Prof. Jackie Masterson
Department of Psychology and Human Development
Institute of Education
20, Bedford Way
WC1H 0AL London

sroncoli@ioe.ac.uk or XXX
J.Masterson@ioe.ac.uk or 020 7612 6903

Development of word naming and knowing and their relationship to emergent literacy

A research project

Information for Parents and Carers

My name is Silvia Roncoli and I am a MPhil/PhD student at the Institute of Education, University of London.

This leaflet tells you about my research.
I hope the leaflet will be useful and I would be pleased to answer any questions you may have.

Please would you explain the research to your child and talk over whether they want to participate. I will also ask the children during sessions if they are happy to take part and I will propose all the activities as a series of games.

Criminal Record Bureau (CRB) clearance has been obtained

Page 2

Why is this research being done?
The research is part of an on-going large scale research looking into the development of children's ability to give the names of the items they are shown in pictures. Data collected in very young children will inform researchers on which factors affect literacy development over the school-age.

Who will be in the project?
In the project monolingual children (i.e., those who have English as their main and first language) aged 8-to-9 years old will participate.

What will happen during the research?
Children will be assessed individually on tasks that will be presented in the form of games. Your child will see some pictures of simple objects (e.g. a cat, an anchor) on the screen of a computer.

S/He will be asked if they know what the name of each object is and if so to say the name out loud, and to answer some questions about the object. The answers will be recorded.

Your child will also take part in a task where they are asked to blend sounds to make up words, to make patterns with blocks and to say the meaning of some words. Also a simple reading test of single words and a task with a story where I will ask some questions about what happened in the story.

The tasks will be divided between 4 sessions lasting about 30 minutes each.

Page 3

Will my child be scored, or told their answers are wrong?
I will not be looking for right or wrong answers, only for what everyone really knows.

Could there be problems for your child if he/she takes part?
I hope your child will enjoy participating in the tasks. I will only carry out the testing with your child if s/he indicates that s/he is happy to take part at the outset of each testing session.
Some children may get tired by some activities. If they want to stop, we will stop.
If you have any problems with the project, please tell me (sroncoli@ioe.ac.uk).

Will doing the research help you?
I hope your child will enjoy helping me. The research will mainly help to find new ideas to help children with naming and reading problems, in future.

Who will know that you have been in the research?
All information about children will be confidential and **anonymous**. Information will be stored securely and your child's name and school **will not** appear in any of our reports. All records and audio-recordings will be labeled only with the number we allocate to your child.

APPENDIX V

Description of results of comparisons between dyslexics, CA and RA controls in the standardized assessment of semantics and phonology with logarithm transformation for blending, rapid naming of objects and of digits

Levene's test indicated that homogeneity of variance was met for blending ($F(2, 91) = .378$, $p = .686$) and rapid naming of objects ($F(2, 88) = 2.750$, $p = .069$). Welch's F test correction was applied for rapid naming of digits ($F(2, 88) = 3.649$, $p = .030$).

The analysis yielded a main effect of group for blending ($F(2, 91) = 11.305$, $p < .0001$). Post-hoc (Bonferroni) comparisons indicated that CA controls blending scores were significantly higher than those obtained by dyslexics ($p = .001$) and RA controls ($p < .0001$). The dyslexics' blending scores were similar to those obtained by the RA controls ($p = .901$).

Results of the ANOVAs yielded a significant effect of group for rapid naming of objects ($F(2, 88) = 5.174$, $p = .008$). Post-hoc (Bonferroni) comparisons indicated that CA controls rapid naming of objects scores were significantly higher than those obtained by dyslexics ($p = .012$). The dyslexics' scores were similar to those obtained by the RA controls ($p = 1.00$). CA controls were marginally faster than RA controls in the rapid naming of objects ($p = .051$).

Results of the ANOVAs with Welch's correction[49] also yielded a significant effect of group for rapid naming of digits ($F(2, 45) = 21.824$, $p < .0001$). Post-hoc (Bonferroni) comparisons indicated that CA controls were significantly faster than dyslexics ($p < .0001$) and RA controls ($p < .0001$) in rapid naming of digits, while no significant difference between dyslexics and RA controls ($p = 1.00$) was found.

[49] Results did not change if Welch's correction was not applied ($F(2, 88) = 17.221$, $p < .0001$).

APPENDIX W

Description of results of comparisons between dyslexics, CA and RA controls in the standardized assessment of semantics and phonology

The analysis yielded a significant effect of group for receptive vocabulary ($F(2, 91) = 34.853$, $p < .0001$). Post-hoc tests (Bonferroni) indicated that the CA controls had significantly higher receptive vocabulary scores than the dyslexic group and RA controls ($p < .0001$). Dyslexics' receptive vocabulary scores were significantly higher than those of the RA controls ($p = .001$). There was also a significant effect of group for expressive vocabulary ($F(2, 65) = 25.918$, $p < .0001$). CA controls had significantly higher expressive vocabulary scores than dyslexics ($p < .0001$) and RA controls ($p < .0001$). Dyslexics' expressive vocabulary scores were significantly higher than those of RA controls ($p = .007$).

Regarding the phonological assessments, the analysis yielded a main effect of group for blending ($F(2, 91) = 12.303$, $p < .0001$). Post-hoc (Bonferroni) comparisons indicated that CA controls blending scores were significantly higher than those obtained by dyslexics ($p < .0001$) and RA controls ($p < .0001$). The dyslexics' blending scores were similar to those obtained by the RA controls ($p = .906$).

Results of the ANOVAs with Welch's correction[50] yielded a significant effect of group for nonword repetition ($F(2, 51) = 18.347$, $p < .0001$). CA controls had significantly higher nonword repetition scores than all comparison groups ($p < .0001$), while no difference in the nonword repetition scores between RA controls and dyslexics ($p = .242$) was found. Results of the ANOVAs with Welch's correction[51] also yielded a significant effect of group for rapid naming of digits ($F(2, 45) = 20.618$, $p < .0001$). CA controls were significantly faster than dyslexics ($p = .016$) and RA controls ($p = .011$) in rapid naming of objects. Dyslexics' rapid naming of objects scores were similar to those obtained by RA controls ($p = .100$). Finally, there was a

[50] Results did not change if Welch's correction was not applied: nonword repetition ($F(2, 91) = 16.040$, $p < .0001$).

[51] Results did not change if Welch's correction was not applied: rapid naming of objects ($F(2, 88) = 4.554$, $p = .013$) and rapid naming of digits ($F(2, 88) = 14.894$, $p < .0001$).

significant main effect of group for rapid naming of objects ($F(2, 45) = 6.438$, $p = .003$), CA controls were faster than dyslexics ($p < .0001$) and RA controls ($p < .0001$), while no significant difference between dyslexics and RA controls ($p = 1.00$) was found.

APPENDIX X

Description of results of comparisons between dyslexics, CA and RA controls in the experimental tasks

Picture naming task

The following analyses involved adjusted picture naming scores (i.e., unfamiliar and compound nouns were removed). Median naming latency and percentage of correct naming responses were the dependent variables. Since the distribution of latency scores was slightly positively skewed for all three groups, log transformation was used. However, it did not produce different results, thus the analyses for untransformed data are reported (the analysis with transformed data is in Appendix Y). Levene's test indicated homogeneity of variances (picture naming accuracy: $F = .113$, $p = .893$; latency: $F = 1.383$, $p = .256$). The analysis yielded a main effect of group for picture naming accuracy ($F(2, 91) = 13.769$, $p < .0001$). Post-hoc (Bonferroni) comparisons revealed that the CA controls were significantly more accurate than dyslexics ($p = .000$, Cohen's $d = 1.005$) and RA controls ($p = .000$, Cohen's $d = 1.28$). There was no significant difference in the number of pictures correctly named for the dyslexics and RA controls ($p = .879$, Cohen's $d = .27$).

The effect of group was also significant for latency ($F(2, 91) = 4.162$, $p = .019$). Bonferroni post-hoc tests revealed that the dyslexics were significantly faster in naming than RA controls ($p = .016$, Cohen's $d = .68$) and that there was no significant difference between dyslexics and CA controls ($p = 1.00$, Cohen's $d = .02$). The CA controls were significantly faster than RA controls ($p = .021$, Cohen's $d = .68$).

Word picture verification task (WPVT)

According to the Kolmogorov-Smirnov test, accuracy data were normally distributed for dyslexic children and RA controls (both *p*s = .200) but not for the CA controls ($p = .008$). Nevertheless, the absence of outliers motivated the choice of a parametric test. The distribution of the latency was normal one for the dyslexics and CA and RA controls (all *p*s = .200). Levene's F test indicated that variances for accuracy differed significantly between groups ($F(2, 91) = 7.418$, $p = .001$) while the assumption of homogeneity was met for latencies ($F(2, 91) = .846$, $p = .432$). To overcome the violation of the assumption of homogeneity of variance for the accuracy data, the more conservative Welch's F test was used. The analysis yielded a main effect of group for accuracy[52] ($F(2, 49) = 8.167$, $p = .001$). Post-hoc (Bonferroni) tests indicated that CA controls correctly recognised more pictures than dyslexics ($p = .021$, Cohen's $d = .76$) and RA controls ($p = .003$, Cohen's $d = .88$). No significant difference was found between scores for RA controls and dyslexics ($p = 1.00$). No significant main effect was found for latencies ($F(2, 91) = 2.982$, $p = .056$).

Picture judgment task (PJs)

There was a near ceiling effect for the PJs accuracy scores, especially for the CA controls. The Kolmogorov-Smirnov test indicated that the assumption of normality was not met for PJs accuracy for the CA controls and dyslexics ($p < .0001$) while data distribution for the RA controls resembled marginally a normal shape ($p = .053$). Regarding the latency data distribution, the assumption of normality was not met for the RA controls ($p = .005$) or the dyslexics ($p = .034$) while the distribution of data for the CA controls was normal ($p = .200$). This led to transformation of the data using logarithm transformation. Since the outcome did not change whether transformation was applied or not, results with untransformed data are reported next, while the results with transformed data are consigned to Appendix Z.

Levene's F test indicated that homogeneity of variance was met for the PJs latency score ($F(2, 91) = .019$, $p = .981$) but not for accuracy ($F(2, 91) = 13.127$, $p < .0001$), therefore Welch's F test was applied. Results revealed a main effect of group for accuracy[53] ($F(2, 48) = 8.758$, $p = .001$). Bonferroni post-hoc comparisons revealed that dyslexics were significantly more accurate than RA controls ($p = .001$, Cohen's $d = .78$). No significant difference was found between dyslexics and CA controls ($p = .386$, Cohen's $d = .50$). CA controls were significantly more accurate than RA controls ($p < .0001$, Cohen's $d = 1.13$). There was also a significant effect of group for latencies ($F(2, 91) = 6.318$, $p < .0001$). Dyslexics were significantly faster than RA controls ($p = .010$, Cohen's $d = .77$), and CA controls were significantly faster than RA controls ($p = .004$, Cohen's $d = .88$). There was no significant difference between the CA controls and dyslexics ($p = .927$, Cohen's $d = .091$).

[52] Results did not change whether Welch's correction was not applied: ($F(2, 91) = 6.769$, $p = .002$).

[53] Results did not change whether Welch's correction was not applied: ($F(2, 91) = 12.938$, $p < .0001$).

Simple and choice reaction time tasks

This analysis aimed to address the issue (Chapter IV, p. 79) of whether dyslexics may suffer from a processing speed impairment. Choice reaction time (RT) task accuracy was not entered into the analyses due to the near ceiling scores for all three groups of children. Exploratory data analyses revealed that the distribution of simple reaction time (RT) latencies was normal for the dyslexics and CA and RA controls (Kolmogorov- Smirnov test: all ps > .05). The distribution of choice RT latencies was normal for the dyslexics and CA controls (Kolmogorov- Smirnov test: both ps > .05), but not for the RA controls (Kolmogorov- Smirnov test: $p = .043$). Inspection of the data distribution revealed the presence of an outlier in the RA control group. Analyses were repeated twice with the outlier in and out of the analyses. Homogeneity of variance was assessed with Levene's test (simple reaction RT latencies: $F = .423$, $p = .656$, choice RT latencies $F = 5.116$, $p = .008$). The one-way ANOVA yielded a main effect of group for choice RT latencies ($F(2, 91) = 7.904$, $p = .001$). Post-hoc tests (Bonferroni) indicated that the dyslexics ($p = .005$, Cohen's $d = .76$) and the CA controls ($p = .003$, Cohen's $d = .90$) were significantly faster than the RA controls. No significant difference between the CA controls and dyslexics on choice reaction time latencies was found ($p = 1.00$, Cohen's $d = .16$). There was no significant effect of group for simple RT latencies ($F(2, 91) = .287$, $p = .751$).

APPENDIX Y

Description of results of comparisons between dyslexics, CA and RA controls in the picture naming task with logarithm transformation for picture naming latency

Levene's test indicated homogeneity of variances (F = .940, p = .394). The effect of group was also significant for latency ($F(2,91)$ = 4.030, p = .021). Bonferroni post-hoc tests revealed that the dyslexics were significantly faster in naming than RA controls (p = .017) and that there was no significant difference between dyslexics and CA controls (p = .849). The CA controls were significantly faster than RA controls (p = .022).

APPENDIX Z

Description of results of comparisons between dyslexics, CA and RA controls in the PJs task with logarithm transformation for PJs accuracy and latency

Levene's F test indicated that homogeneity of variance was met for the PJs latency score ($F(2, 91) = 1.349$, $p = .265$) but not for accuracy ($F(2, 91) = 16.140$, $p < .0001$), therefore Welch's F test was applied.

Results revealed a main effect of group for accuracy[54] ($F(2, 48) = 8.686$, $p = .001$). Bonferroni post-hoc comparisons revealed that dyslexics were significantly more accurate than RA controls ($p = .011$). No significant difference was found between dyslexics and CA controls ($p = 1.00$). CA controls were significantly more accurate than RA controls ($p = .003$). There was also a significant effect of group for latencies ($F(2, 91) = 6.539$, $p = .002$). Bonferroni post-hoc comparisons revealed that dyslexics were significantly faster than RA controls ($p = .011$), and CA controls were significantly faster than RA controls ($p = .003$). There was no significant difference between the CA controls and dyslexics ($p = 1.00$).

[54] Results did not change if Welch's correction was not applied: ($F(2, 91) = 13.247$, $p < .0001$).

APPENDIX A1

Summary of the multiple regression analysis for the dyslexic children, CA and RA controls with logarithm transformation for picture naming accuracy and rated spoken frequency and number of phonological neighbours

	B	SE(B)	β	*t*	Sig. (*p*)
Dyslexics					
Constant	-4.643	1.321		-3.515	.001
Spoken frequency	-.366	.403	-.120	-.833	.409
Visual complexity	.005	.131	.004	.039	.969
Phono. Neighbour	.211	.232	.142	.912	.366
Word length	-.014	.052	-.043	-.263	.794
Imageability	1.374	.228	.816	6.035	.000
	B	SE(B)	β	*t*	Sig. (*p*)
CA controls					
Constant	-6.126	1.282		-4.777	.000
Spoken frequency	-.465	.392	-.168	-1.188	.240
Visual complexity	.047	.127	.037	.368	.715
Phono. Neighbour	.552	.225	.376	2.453	.018
Word length	.065	.050	.208	1.294	.201
Imageability	1.416	.221	.854	6.406	.000
	B	SE(B)	β	*t*	Sig. (*p*)
RA controls					
Constant	-5.988	1.308		-4.578	.000
Spoken frequency	-.452	.399	-.165	-1.133	.263
Visual complexity	-.048	.130	-.038	-.366	.716
Phono. Neighbour	.516	.229	.355	2.249	.029
Word length	.059	.051	.190	1.143	.258
Imageability	1.353	.225	.824	6.002	.000

Note: Dyslexics model: R^2 = .767, ΔR^2 = .589. ANOVA: $F(5, 51)$ = 14.607, $p < .0001$. CA controls: R^2 = .775, ΔR^2 = .601. ANOVA: $F(5, 51)$ = 15.333, $p < .0001$. RA controls: R^2 = .759, ΔR^2 = .576. ANOVA: $F(5, 51)$ = 13.853, $p < .0001$.

APPENDIX B1

Correlations between experimental measures, standardised assessments and reading scores for the CA and RA controls controlling for chronological age with logarithm transformation of blending and number of phonological errors for the RA controls and with logarithm transformation of PJs accuracy and number of phonological errors for the RA controls, results for the RA controls are below the diagonal and those for the CA controls are above the diagonal

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Rec.Voc.	-	.820***	.143	.470**	.190	-.149	.354*	-.225	-.143	.371*	.258	.672***	-.187
2. Exp.Voc	-	-	.340	.612**	.074	-.249	.216	-.345**	-.512*	.618***	.508*	.605**	-.135
3. Blending	.357	-	-	.166	.094	.030	.210	-.099	-.485**	-.242	.118	.233	-.062
4. NWRep.	.442*	-	.370	-	.056	-.641***	.355*	-.325*	-.416*	.129	-.008	.592***	-.230
5. RAN dig.	-.366	-	-.165	.104	-	.324	-.138	-.128	-.089	-.142	-.279	.294	.072
6. RAN obj.	-.031	-	.205	-.350	.252	-	-.324 *p* = .062	.145	.297	.012	.212	-.377*	.240
7. PJs acc.	.222	-	-.100	-.205	.091	.291	-	-.017	-.237	-.012	.098	.377*	-.181
8. PJs time	-.176	-	.128	-.203	.182	-.002	-.025	-	-.096	-.325	-.101	-.275	.535**
9. Phon.Err.	-.233	-	-.168	-.437*	-.123	-.063	-.237	-.021	-	.082	-.151	-.262	-.290
10. Irr. acc.	-.298	-	-.438*	.203	-.103	-.137	-.029	-.217	.082	-	.686**	.128	-.071
11. Nwd acc.	.178	-	.695***	.430*	.294	.250	.076	-.015	-.151	-.393	-	-.013	.275
12. Pic. acc.	.653**	-	.261	.163	-.208	-.019	.381*	-.167	-.262	-.184	.156	-	-.341*
13. Pic. time	-.067	-	-.190	.031	.103	-.504*	-.197	.467*	-.290	.211	-.269	.119	-

Note: $*p < .05$, $**p < .01$, $***p <. 001$.

APPENDIX C1

Correlations between experimental measures, standardised scores and reading scores for the dyslexic children controlling for chronological age, with logarithm transformation of number of phonological errors, picture naming latency and PJs accuracy scores

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Rec.Voc.	-												
2. Exp.Voc	.642***	-											
3. Blending	.536**	.302 *p* = .078	-										
4. NWRep.	.484**	.532**	.419*	-									
5. RAN dig.	.068	-.004	.055	.045	-								
6. RAN obj.	-.129	-.112	-.164	-.181	.657***	-							
7. PJs acc.	.112	.031	.242	.394*	.059	.094	-						
8. PJs time	-.222	-.127	-.126	-.143	-.013	.230	-.159	-					
9. Phon. Err.	.369*	.462**	.032	.176	.202	-.169	-.089	-.236	-				
10. Irr. acc.	.141	.318 *p* = .062	.185	.312 *p* = .068	-.203	.133	.045	-.110	-.052	-			
11. Nwd acc.	-.106	-.009	.403*	.186	-.168	-.004	.125	.098	-.246	.495**	-		
12. Pic. acc.	.596***	.330 *p* = .053	.434**	.447**	.157	-.097	.310 *p* = .070	-.333 *p* = .050	.070	.005	-.066	-	
13. Pic. time	-.430**	-.105	-.416*	-.182	.112	.383*	.172	-.018	-.205	-.035	.009	-.157	-

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

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