Developmental Dyslexia and Anaphora Resolution in English L1/L2

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The Effect of Referent Abstractness

By

Nicoletta Simi

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To my mum Iosi, my biggest supporter

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INTRODUCTION

This book presents the results of three experimental studies focusing on the ability of people with developmental dyslexia to resolve ambiguous anaphoric sentences where concrete and abstract referents are present. Each study represents a step in the ongoing investigation of this issue and stems from questions left unanswered by previous research (cf. Chapter 1).

In this book, when the term "dyslexia" is used, we refer to developmental dyslexia as a broad inclusive category, distinct from acquired dyslexia. Since, to the best of our knowledge, despite some recent proposals by Friedman & Coltheart, 2018, no general consensus on any specific classification of the sub-types of dyslexia exists, no specific fine-grained distinctions among the individual types found in the literature are made in this overview. For the same reasons, the diagnoses received by the participants in our studies did not investigate the specific sub-types. This is a standard practice both in Italy and the UK. The widely-used diagnostic tests are not fine-tuned enough to unveil the subtle distinctions between different types of developmental dyslexia. Participants were therefore recruited on the basis of a diagnosis of developmental dyslexia and no cognitive impairments or medical issues. The major consequence of such an approach for any experimental research, as well as for any intervention, is that participants/learners form a somewhat fuzzy set. The great variability in the ways in which dyslexia manifests itself in individuals sharing a basic phonological memory deficit (which seems to be the universally-shared feature) is often ascribed to different levels of severity of the deficit.

Different etiological theories correspond to different types of dyslexia, and this has heated the debate concerning the possible biological and cognitive causes of dyslexia. However, there are still unresolved issues, for instance, whether the cause of dyslexia is only phonological or whether there are other causes that play a significant role in its occurrence. Several studies (Byrne, 1981; Scarborough, 1990, 1991; Stein et al., 1984; Vender, 2009; Waltzaman & Cairns, 2000; Wilsenach, 2006) have suggested that people with dyslexia also have difficulties in different aspects of language, not only phonology. The procedural memory deficit hypothesis, described in Chapter 1, accounts for this by positing that procedural memory impairment negatively affects all combinatorial, rule-governed, aspects of language. This results in difficulties in processing both phonological and

syntactic representations. Such difficulties are related to the cognitive effort required by the task (e.g., how complex the task is). Therefore, words with complex phonological representations, as well as sentences with complex syntactic representations, will create more difficulties for a person with dyslexia than words with simpler phonological representations or sentences with simpler syntactic representations. This is the result of their high demand in terms of procedural resources. Accordingly, people with dyslexia are expected to have difficulties in those activities that require knowledge held by the procedural memory system. Conversely, they are predicted to not have difficulties in the activities relying on their declarative memory system.

It is widely acknowledged that ambiguity and linguistic complexity have an outcome on the ability of people with dyslexia to efficiently read and understand a text (Hyönä & Olson 1995). However, their comprehension difficulties are usually seen as a result of their difficulties in their decoding and word recognition skills. Thus, it is widely believed that, when reading a text, decoding for them is so slow and arduous that it consumes all their cognitive resources. It is quite uncommon for people with dyslexia to read a text under the same time constraints as their typically-developed peers, and complex and ambiguous sentences are particularly difficult for them. Moreover, they often fail to understand what they read.

When this project started four years ago, the main objective was to investigate anaphora resolution in university students with dyslexia who were learning English as a second language. In a multilingual society such as ours, foreign language learning is a fundamental step on the educational path of any individual. In Italy, all students must attain at least the Common European Framework of Reference for Languages (CEFR) B1 level of English to graduate from a university programme. Foreign language learning seems to be an area with which even well-compensated adults with dyslexia continue to struggle throughout their academic history. For this reason, efforts are being made to try and help dyslexic students to overcome their difficulties by creating specific materials for foreign language teaching (Cappelli & Noccetti, 2018; Nijakowska et al., 2015).

However, it was soon evident that working with L2 learners had many limitations. To be able to activate the normal reading and comprehension processes which we use in our first language, it is first of all necessary to have sufficient vocabulary knowledge. It is, thus, important to establish which lexical threshold allows L2 readers to activate effective reading strategies. It is also possible that these readers are unable to use the contextual information efficiently because their vocabulary depth is insufficient. As Parry (1993) observes, a text may not have enough elements

for the readers to successfully guess the meaning or to produce successful inferences. When dealing with studies involving participants with dyslexia, all of this becomes more evident and may pose a challenge for the experiment design and the interpretation of results. These issues are discussed in Chapter 3, which presents the first experimental study.

The research reported in this work is primarily inspired by the desire to gain a better understanding of the role of syntactic and lexical knowledge in text comprehension, and more specifically, of the effects of word concreteness/abstractness in anaphora resolution contexts for readers with dyslexia. We also aimed at investigating the resources necessary to process ambiguous anaphoric sentences. For the reasons discussed above, we decided to focus our research on the syntax/semantics interface, trying to understand the role of the referents' ontology in the interpretation and resolution of anaphoric cues.

The three experimental studies carried out are subsequent to one another, and their research questions stemmed from those left unanswered in the previous study. The first experimental study was carried out at the Linguistic Centre of the University of Pisa. It focused on dyslexia in the English Foreign Language classroom and it involved an instructional phase and an applied phase. The former had to be included in the protocol to make sure that the lexical items contained in the eye-tracked experiment were known to all participants. It should be noted that this first phase was conducted as part of a different research project on vocabulary acquisition and dyslexia which was meant to investigate whether instruction through specifically-designed training materials makes a difference in the acquisition of vocabulary and if there is a difference in the learning of concrete and abstract lexical items. However, the main research question of the doctoral study was grounded in the tenets of the procedural memory deficit hypothesis. It intended to verify whether L2 speakers of English with dyslexia experience trouble when they must interpret and resolve pronominal anaphora and the referent is a known concrete or abstract lexical item. In order to verify if the nature of the referent had a role, we created ambiguous contexts in which the pronoun could refer to either one of the two referents included in the stimulus sentence.

After this first experimental study, a new experimental study was designed to rule out the role of the participants' L2 proficiency in the main task and involved, therefore, only L1 speakers of English enrolled at the University of Lancaster. It originated first and foremost from the desire to provide an explanatory interpretation of the preferences observed in the dyslexic EFL learners' decision task. The study was, moreover, intended to provide further insight into the relationship between verbal working

memory resources, anaphora interpretation and developmental dyslexia. In this regard, it was grounded in research on deficits in reading comprehension, working memory resources in adults, and pronominal anaphora processing dependency on non-automatic working-memory linked processes. The underlying hypothesis was that the dyslexics' impairment in working memory has a larger extent than just phonology. In fact, it also has a result on the temporary storing of mental representations. Consequently, people with dyslexia have difficulties in keeping multiple representations in their working memory and, therefore, in processing pronouns in ambiguous contexts. Another question guiding the research was, whether recalling abstract words is easier when they follow a concrete word, and if this, combined with poor working memory resources, can explain the participants' preferences in terms of the cognitive demand imposed by abstract nouns.

Finally, with the last experimental study, it was our intention to verify whether the differences between readers with and without dyslexia observed in ambiguous pronominal anaphora resolution contexts could ultimately be ascribed to the processing demands imposed by handling a pronoun, rather than to the nature of the antecedents. Moreover, we wanted to confirm whether the same effect found in sentence-length contexts was observable in longer texts, hence in a more ecological environment inherently capable of reducing ambiguity. To this extent, we explored the resolution of both pronominal and lexical anaphora in short texts. The goal was to explore the coherence effect. There were three main research questions to this study. The first concerned the processes that are at work with the two types of texts (e.g., texts with pronominal anaphora and texts with lexical co-reference). Good readers make use of textual cues differently from poor readers (Oakhill et al., 1986). Hence, good and poor readers should be affected differently by referential coherence. Our second research question was to what extent texts including a higher number of abstract lexical items are more difficult to process than texts which include a larger number of concrete lexical items. Our third research question concerned the role that individual cognitive resources play in overall comprehension.

Chapters 1 and 2 provide an overview of the literature on dyslexia and reading comprehension processes in L1 and L2. Chapters 3, 4 and 5 discuss each of the three experimental studies. The final conclusions sum up the major findings as well as the limitations of this work and propose some possible applications and ideas for further research.

CHAPTER ONE

HISTORICAL BACKGROUND AND PROGRESS MADE ON DYSLEXIA STUDIES

1.0 Chapter Rationale

This chapter gives an overview of studies on dyslexia. In this chapter, we present the leading theories of developmental dyslexia and the role of memory in language, or rather of some types of memory, starting with the declarative/procedural model developed by Ullman (2004). In his hypothesis, Ullman theorizes that language depends on two cerebral systems: declarative memory and procedural memory. The functions of these two cerebral systems, together with their anatomical, physiological and biological bases, enable us to predict their role in language. Ullman (2004) hypothesizes that some developmental and acquired language disorders, such as specific language impairment (SLI), fluent and non-fluent aphasia and dyslexia, might find their origins in the dysfunction of one of the cerebral structures that underlies the two memory systems. Ullman and Pierpont (2005) proposed the Procedural Deficit Hypothesis (PDH) which considers SLI as a consequence of a procedural deficit, hence a deficit due to an anomalous development of the cerebral structures which underlie the procedural memory system. This hypothesis proposes that the same procedural deficit is also the cause of developmental dyslexia. In the following paragraphs, some of the evidence in favour of this hypothesis is discussed.

1.1 An Overview of the Research on Dyslexia

Dyslexia is a combination of abilities and difficulties that affect the learning process in one or more of reading, spelling and writing. It is a persistent condition. Accompanying weaknesses may be identified in areas of speed of processing, short-term memory, organization, sequencing, spoken language and motor skills. There may be difficulties with auditory and/or visual perception. It is particularly related to mastering and using written language, which may include alphabetic, numeric and musical notation.

> *Dyslexia can occur despite normal intellectual ability and teaching. It is constitutional in origin, part of one's make-up and independent of socio-economic or language background. Some learners have very well-developed creative skills and/or interpersonal skills, others have strong oral skills. Some have no outstanding talents. All have strengths*. British Dyslexia Association (2007).

The above British Dyslexia Association (BDA) definition of dyslexia is now the most common and widely used. It shows how dyslexia has different manifestations and it is quite accepted that it affects the learning process of reading, spelling and writing. However, this large agreement was not reached until very recent years. In fact, dyslexia and learning difficulties in general (SLDs) have attracted the interest of scholars of all nationalities and backgrounds. All are motivated by the same need to find a common place where solutions can be found.

Prior to 1900, studies had found many cases of dyslexic children or adults, but they were classified as people with literacy difficulties and dyslexia was not recognized as a disability per se. Only in 1994, with the publication of "The Code of Practice", issued by the Department of Education and Employment of the UK, was dyslexia finally officially recognized as a learning difficulty in its own, albeit with some reservations. Prior to the official issue of this document, in fact, the phrases "specific learning difficulty" or "specific developmental dyslexia" appeared in the scientific literature to describe the same group of children, that is, those who were not as good as others at specific learning.

Since the 19th century, the issue of child development and of how children learn have been topics of great interest, but few empirical research methods have been employed until recently. Before, definitions such as "word-blindness" (Kussmaul, 1877) or "strephosymbolia" (Orton, 1925) were used to theorize the problem. The use of these strictly medical terms indicates that these learning difficulties were recognised and classified as medical problems, and that the medical profession at that time played a dominant role in the field of learning difficulties. Only in 1869, with the contribution of Sir Francis Galton, cousin of Charles Darwin and famous anthropologist, did the problem acquire its first educational perspective and, as an educationalist himself, Galton was able to investigate individual differences in children's learning abilities. Despite his innovative work, not much progress was made on the causes of childhood learning difficulties.

In 1877, in an article entitled "Word-deafness and Word-blindness", Adolph Kussmaul, a German physician who was particularly interested in how reading problems manifested themselves in adults with neurological impairment, described how many of his patients were not able to read

properly or to use words in the right order. He defined this as "word blindness". The term spread in scientific and medical journals and was used to describe the characteristics of those adults and children who had problems in learning how to read (Grigorenko, 2001). This phrase, in the end, implicitly conveyed the idea that these patients were neurologically impaired. In 1887, Rudolf Berlin, a German ophthalmologist, was the first to replace the phrase "word blindness" with the word "dyslexia" in his article "A special type of word blindness: Dyslexie" (Macdonald, 2009). However, as mentioned above, this term was not in common usage until the second part of the last century.

Another important piece of work and its subsequent publication issued in 1891 is credited to Dr. Jules Dejerine, a French neurologist, who described the condition of one of his patients in his paper. He reported that his patient had suffered a brain injury after an accident and had consequently lost several language functions, including the ability to read. Dr. Dejerine concluded that those who had reading impairments might also have suffered brain injuries. Dejerine's argumentation seemed to reinforce Kussmaul's hypothesis that reading difficulties were associated with neurological impairment. Despite his efforts, this remained merely a hypothesis and it was not supported by any strong evidence.

In the light of the current knowledge on literacy difficulties, dyslexia and child development, many of the 19th century studies appear now outdated. However, scientific research on child development was not fully developed back then, and there were few journals which would spread the results of such studies. At that time, Dr. James Hinshelwood, a Scottish eye surgeon, noticed that a congenital defect in the brain related to eyesight was causing reading difficulties in one of his patients. This provided some support for the "word blindness" theory.

Various definitions were proposed in the following years, the first of which was the term "strephosymbolia" coined in 1925 by Dr. Samuel Orton, a professor in neurology and neuropathology. Orton's work investigated the impact that educational treatment had on this condition. The word "strephosymbolia" indicated the tendency to reverse letters in children with reading difficulties. He also introduced the label "developmental alexia" which was used to describe the difficulties of these children.

Only in the mid-1930s, did the term "dyslexia" start to appear in the scientific literature. The word is of Greek origin and its literal meaning is anomaly (*dys*-) of language (-*lexia*). From that moment onward, learning difficulties, especially dyslexia, came to be viewed as educational problems, and publications concerning teaching methods to help children with SLDs began to appear. Educationalists and psychologists started to acquire a

better understanding of child development and this gave them the opportunity to start theorizing about the origins of childhood learning difficulties and how they might best be managed. This shift in perspective contributed to shed a new light on the whole matter.

Until the 20th century, in fact, children affected by learning disabilities were considered impossible to teach to and were classified as "subnormal" or even "severely subnormal" (Education Act, 1944 cited in Farrell 2006). They were often described as "uneducable" and they were thought to be unable to benefit from education. It was only thanks to the new studies on childhood development and learning that this situation eventually changed. Children with SLDs were now seen as children who could in fact learn, but at their own pace. Eventually, educationalists also produced actual teaching methodologies to manage such learners.

In 1956, Anna Gillingham and Bessie Stillman, educators and psychologists, published the first teaching method to help children with dyslexia. They created a multi-sensory approach based on the analysis of language. With this innovative technique, they developed a method of teaching reading through a phonic, auditory and kinaesthetic approach. Their method consisted in asking children to say a word aloud, then in showing them how to write the word first, and then how to listen to the word. Children would then be asked to try crafting the word using modelling clay. Despite this being the first attempt to find a practical solution, there are schools still using this method to this day. It is now known as the "Gillingham-Stillman method". The medical community was still interested in dyslexia, though, and Dr. Orton collaborated with Gillingham and Stillman in the publication of their teaching manual (Gillingham & Stillman, 1956). Dr. Orton's theories and approach have gained many supporters over the years.

Another, much more controversial, approach was developed by G. Doman and colleagues (Doman et al., 1963), who in 1963 theorized a new method called "patterning". This methodology was built on the idea that children with learning disabilities had missed out on some stages of neurological development. The two scholars believed that missing these developmental stages, as human evolutionary steps, would create many problems in physical mobility and in language and communication. The treatment they proposed included motor activities such as crawling, balancing and stretching which would take children through the developmental stages they had missed. These exercises had to be done daily and performed for at least 12 months. Doman and colleagues (1963) believed that after this intense period of training, the children would acquire a normal hemispherical dominance and full neurological organization. At

the beginning, this hypothesis received strong criticism for lack of scientific evidence, but in later years it gained many supporters. The authors founded the Philadelphia Institute for the Achievement of Human Potential and were able to create branches in many countries around the world. Their first assessment that abnormalities in the cerebellum might cause learning impairments, which had not yet been proven, has eventually found evidence and support in the studies of Fawcett and Nicolson, two British psychologists, who in Fawcett and Nicolson (1995), stated that:

> *[..] damage to different parts of the cerebellum can lead to different symptoms, including disturbances in posture and balance, limb rigidity and dyscoordination or decomposition of movement*. (Fawcett & Nicolson, 1995)

U.S. schools and scholars produced great achievements in a relatively short time, but a major step forward was taken in the UK in 1963, when the Word Blind Centre for Dyslexic Children was established in London with financial support from Invalid Children's Aid Association. This Centre mainly focused on teaching children with dyslexia, but also involved research. This fact motivated young researchers to investigate dyslexia, its causes and possible solutions. One of these researchers was M. J. Snowling, who started working on the issue in the 1980s. She published her research on the importance of phonological processing in dyslexia in the mid-80s (Snowling, 1987) which is still considered one of the major breakthroughs in the understanding of this learning difficulty.

By the 1980's, the attitude towards dyslexia had changed: it was not seen as a deficit anymore, but many considered it a learning "difference". This new conceptualization was probably due to the work of H. Gardner, who in 1983 published the book *Frame of Mind: Multiple Intelligences*. In his work, the scholar concluded that intelligence was expressed in several different ways, and linguistic ability was only one of them. Later, several studies showed that 5%-10% of school-age children fail to learn how to read, and that this cannot be tracked back to "intelligence", educational opportunities, nor the child's environment (Habib, 2000).

When dyslexia was first identified as a real difficulty, children were classified as dyslexic if there was a "discrepancy" between the expected reading skills, as per their age or IQ, and their actual reading skills (Snowling & Stackhouse, 2006). This argumentation, however, holds no ground for various reasons (Gathercole & Alloway, 2006). First, IQ is not related to the ability to read. There are students with a low IQ who can read perfectly well even though they might have reading comprehension difficulties (Alloway et al, 2004). Moreover, different studies have pointed

out that dyslexic children have an average or even higher than average IQ. Thus, their inability to progress in learning has nothing to do with their intelligence. Second, measures of verbal IQ may underestimate cognitive abilities among poor readers with moderate language impairments. For these reasons, the "discrepancy theory" fails to identify those children with the most severe problems but who have a low verbal IQ. Alloway et al. (2004) state that these children hide the specificity of their reading problem with their low IQ. Finally, another limitation of the discrepancy theory of dyslexia is that it cannot be applied to children who have not yet reached the age to show this discrepancy.

The idea that dyslexia represents a different way of learning rather than a proper deficit received further support thanks to Silverman (2002). Silverman showed that dyslexic children can make progress using programmes specifically designed to develop their visual-spatial thinking. Recently, many authors have tried to offer new perspectives on dyslexia and to provide new definitions which would help cast light on the causes behind the disorder (Peer & Reid, 2003; Farrell, 2006; Siegel, 2006; Nijakowska, 2010).

Peer and Reid (2003) wrote:

> *Children with dyslexia will **usually**, **but not always**, have difficulty with reading*. (p. 9)
>
> *Spelling difficulties are **often** an obvious characteristic of dyslexia*. (p. 10)
>
> *Children with dyslexia **may** also have difficulties with both expressive writing and their actual handwriting style*. (p. 10)

It is evident that there is no universal agreement on what constitutes dyslexia. The distinctive signs which justify the diagnosis of a person as dyslexic are still debated. If a person has difficulties in one or more of the areas mentioned above, he/she may or may not be diagnosed with a learning difficulty. Such complexity may be explained by the fact that different types of dyslexia exist (Givon & Court 2010; Friedman & Coltheart, 2018) and that they can manifest with variable severity. This has proven challenging for those who have tried to develop intervention techniques.

A general agreement, despite the BDA definition reported at the beginning of this section, on the causes and manifestations of dyslexia has not been reached to this day and no theory has ever been able to exclude the other.

In fact, going against the idea that dyslexia is only a learning difficulty, Nijakowska (2010) points out that developmental dyslexia has been included in the international classification of diseases, mental disorders and related health problems. The scholar identifies four kinds of specific difficulties in learning to read and spell:

> *[..] specific developmental disorders of scholastic skills and more specific categories such as specific reading disorders, specific spelling disorders* and *specific developmental disorders of motor function.* Nijakowska (2010)

As is evident, great progress has been made from the days of early research on dyslexia. It is no longer seen as a medical condition or as a cognitive deficit. This new perspective has made it easier to manage all its different aspects and new light has been cast on the individual issues. This has provided teachers with tools to find the best solutions for each one of their students with dyslexia. Furthermore, the growing attention received by SLDs over the past few years has led academics and researchers to create many online platforms where teachers can find in-depth articles and research-based materials that can be used in their classroom practice.

This has contributed to creating a more widespread understanding of dyslexia, to the point where even teachers with no specific training can identify learners with SLDs, point them in the right direction to receive support and make provisions to help them develop their potential in class. Two of the most recent websites worth mentioning that include articles and papers are "Bright Solutions for Dyslexia"[1] by Susan Barton and "Dyslexia for Teachers as a Foreign Language" (Nijakowska et al., 2015)[2]. The latter comprises the results of two research projects; one carried out by Kormos J. and Nijakowska J. (2011-2013) and the other carried out by Nijakowska alone (2014-2016).

1.2 Developmental Dyslexia

Lété & Ducrot (2008) showed that the initial phases of learning how to read are mainly connected with visuospatial perception which provides the ability to organize and plan the retrieved information in a coherent way. These are the skills that enable us to recognize a square, cube or pyramid. They also help us to retrace our way across a city, because we have a visual map in our memory from the last time we were there. Impairments of these abilities can have a devastating effect on some of the simplest daily

[1] http://www.dys-add.com
[2] http://www.dystefl.eu

functions that we take for granted. Such studies have identified different visuospatial skills:

- the **figure-ground perception:** the ability to focus on a specific aspect of a visual stimulus (the figure), and perceive it from what remains in the range of vision (the background);
- the **form constancy perception:** the ability to see a form and find it among others, even if it has a different size or a different position in space. It encompasses the ability to identify forms, letters, or words irrespectively of their orientation;
- the **visual spatial relation perception:** the ability to perceive an object in space and its spatial relations to other objects or visual stimuli. This aspect is particularly important for reading because it can relate to the ability to identify the letters in the right place inside the written word.

This approach to the analysis of reading mechanisms is complementary to another approach that tries to explain the fundamental development of linguistic abilities when we encounter written words. This would include the ability to understand a rule in the grapheme-phoneme correlation and use it and the skills that enable us to understand new words, to expand our vocabulary (thanks to frequent exposure to written material) and to develop the "semantic networks" that help us to understand phrases of increasing complexity. The debate about the role of visual abilities, on the one hand, and of the linguistic processes, on the other, has marked the research on the aetiology of Developmental Reading Disorder (DRD), or rather Developmental Dyslexia (DD).

Developmental dyslexia has a neurobiological origin and it is characterized by difficulties in accuracy and/or recognition speed. Unexpected spelling and decrypting issues are also signs of this kind of impairment. Modern studies (Alloway & Alloway, 2014; Gathercole et al., 2004; Siegel, 1988; Wagner et al., 2007) have shown that the levels of education and intellectual abilities have no impact on the development of dyslexia. Although the most credited hypothesis sees the DD's core deficit at the level of phonological representation (Snowling, 2006), there are many studies that show evidence of visual deficits in a small number of subjects affected by dyslexia (Atkinson, 1993; Johnston et al., 2017; Raghuram et al., 2018; Ramus et al. 2003; Stein, 2001; Stein & Walsh, 1997). This is evidence of the fact that dyslexia does not result from a phonological deficit only, but it is possible to hypothesise a more complex picture of this deficit. In the next section, we will discuss the main theories on the origin of dyslexia.

1.3 Aetiological Theories of Dyslexia

In this section, the leading aetiological theories of developmental dyslexia are described: (1) the "phonological theory", (2) the "rapid auditory processing theory", (3) the "cerebellar theory" and (4) the "magnocellular theory".

1.3.1. The Phonological Theory

In 2002, the International Dyslexia Association provided a further definition:

> *Developmental dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by 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; they are not the result of generalized developmental disability or sensory impairment.*

This definition focuses on the inability of people with dyslexia to efficiently process written language. According to several studies (Catts et al., 2017; Costenaro & Pesce, 2012; Goswami, 2002; Goswami, 2014; Hulme & Snowling, 2014; Ramus et al., 2003; Snowling, 2000), this is due to underdeveloped phonological awareness. The phonological theory assumes that people affected by dyslexia are not able to represent, store and/or retrieve speech sounds. This explains how reading difficulties can be ascribed to the fact that learning how to read an alphabetic system requires learning the correspondences between graphemes and phonemes, namely the correspondences between letters and constituent sounds of speech. There is no doubt that phonology has a central and causal role in dyslexia. Studies (Kormos & Smith, 2012; Lockiewicz et al., 2020; Nijakowska, 2010) showed that this phonological impairment is at the basis of dyslexics' difficulty in learning a foreign language. This may be problematic for those researchers working on L2 learning and dyslexia (see experiment 1, chapter 3).

Throughout the years, scholars have conceptualized the language system as a hierarchical set of constituents, each specific to different properties of the language. The highest levels comprise constituents pertaining to semantics, syntax and discourse. The lowest level includes the phonological constituents devoted to the processing of the distinctive sound elements that constitute language.

In this view, the phoneme is the fundamental element of the linguistic system. However, before identifying, understanding, storing in memory and retrieving a word, the word must be broken down into its phonetic units by the phonological module of the brain (Shaywitz et al., 1995). This process happens quite automatically in the spoken language. Reading reflects the spoken language, but it is certainly much more difficult to master. Despite the fact that both speaking and reading rely on phonological processing, there is a slight but consistent difference: speaking is natural, but reading is not. Readers must transform the visual perception of alphabetic scripts into spoken ones. Therefore, they must decode graphemes and retrieve their corresponding phonemes. To be able to do this, they must first be aware of the internal phonological structure of spoken words. This is exactly what happens when a child learns to read. However, when children have dyslexia, a deficit in the phonological module of language impairs their ability to segment the written word into its phonological components. This deficit blocks access to the "higher" linguistic processes and, consequently, to retrieving meaning from a text. Although the language processes which involve comprehension and meaning are believed to be unimpaired, they cannot take active part in supporting these processes because they can only be accessed after the words have been decoded and recognised (Chen et al., 2016; Nijakowska, 2010; Ober et al., 2020).

Katz et al. (1990) conducted a study where they were able to show that other consequences of impaired phonological functioning must be present if dyslexia results from undeveloped phonological specialization. They describe how poor readers cannot efficiently name items that are presented to them in pictures, and that, when dyslexics misname objects, the incorrect answers seem to share some phonological characterisation with the correct answer. Furthermore, misnaming does not result from a lack of knowledge or ignorance. In the experiment, a picture of a volcano was presented to one of the subjects and she named it "tornado". When given the opportunity to elaborate, she demonstrated that she knew what the picture represented, and she was able to enumerate all the characteristics of a volcano and to point to pictures of other volcanos. She could simply not recall the word "volcano". In the same study, another subject with a reading difficulty was able to describe in detail what the word "apocalypse" denotes. She knew the meaning and the correct usage. However, she was not able to recognize the word on a printed page. She could not decode or identify the written word. This suggests that, whereas the phonological component is impaired in dyslexia, the higher-level components remain intact.

Other studies (Jones et al., 2016; Wang et al., 2018; Willburger et al., 2008; Wolf et al., 2002) have pointed out these issues with automatic

naming, as well as problems with short-term memory. These could be another indication of a more basic phonological deficit. Efficient processing of phonological information has a prominent role on reading development (Holliman, 2016; Jared et al., 2016; Milledge & Blythe., 2019; Rayner et al., 2001) and, therefore, developing efficient phonological abilities at a young age is fundamental for its subsequent development. Any kind of phonological difficulty or impairment in preschool years, whether it persists after formal reading instruction or not, might be a barrier to reading acquisition both in native and in foreign language and should be addressed in a timely fashion. Of course, many people with dyslexia learn to read, and they can achieve the same levels in academic subjects as their typically-developed peers. These so-called "compensated dyslexics" perform as well as non-dyslexics in tests of word accuracy because they have learned how to decode or identify words. Nevertheless, timed tests reveal that decoding remains very difficult for compensated dyslexics (Cowan et al., 2017; Hancock et al., 2017; Pugh et al., 2000; Richlan et al., 2011). Word identification is not automatic or fluent for them, and, in the end, reading remains a tiring activity.

1.3.2. The Rapid Auditory Processing Theory

The rapid auditory processing theory was originally introduced by Tallal et al. (1993) to provide an explanation for specific language impairments[3] (SLI) but was later extended to dyslexia as well. Although both theories start from the assumption that dyslexia originates in a cognitive deficit, the rapid auditory processing theory contrasts with the phonological theory as it maintains that phonological deficits in dyslexia are due only to an auditory deficit (Tallal et al., 1993). Tallal et al. (1993) investigated impairment in the auditory processing of the language in the temporal lobe. He observed that children affected by it can neither properly perceive and process acoustic events, nor recognise sounds in speaking. Such inability to represent short sounds and fast transactions is the cause of several difficulties, especially when these acoustic events represent phonemic contrasts (as in 'ta' or 'da).

Tallal and colleagues extended his investigation of auditory processing to people with dyslexia and found poor performance in auditory tasks such

[3] The Specific Language Impairment (SLI) is a kind of evolutionary impairment that is present when a child is unable to properly acquire his/her own language despite a normal non-verbal intelligence, normal hearing, and no problem on the emotional or social levels.

as sound discrimination, temporal order judgement and backward masking[4]. These findings led the author to conclude that dyslexia was the consequence of such auditory processing deficits.

1.3.3. The Visual Theory

The visual theory reflects the second most controversial matter in dyslexia research. As mentioned above, not everyone agrees with the idea that dyslexia results from an impairment in the visual area. Many scholars, however, see visual impairment as the origin of difficulties in the processing of letters and words in texts (Lovegrove et al., 1980; Saksida et al., 2016; Stein & Walsh, 1997;). The visual theory, however, does not exclude a phonological deficit; it only puts emphasis on the impact of a visual deficit on reading problems. Ramus et al. (2003) state that biologically, the suggested cause of visual dysfunction is grounded in the division of the visual system into two separate routes that have different roles and properties: the magnocellular and parvocellular routes. The model starts from the idea that, in people with dyslexia, the magnocellular route is interrupted, and this would lead to damages in visual processing and, as a consequence, to abnormal binocular control and visuospatial attention.

Livingston et al. (1991) state that reading (and writing) are processes which are very demanding on the visual system. Eden et al. (1996) build on this idea. They believe that many reading errors are due to deficient visual processing, ranging from visuospatial scanning errors to incorrect visual-linguistic integration. Additional visual and oculomotor abnormalities have been identified in people with dyslexia. Visual perceptual studies have shown that dyslexics process visual stimuli more slowly.

Over the past 30 years (Eden et al., 1996; Goswami, 2014; Hairston et al., 2005; Johnston et al., 2008; Laasonen et al. 2001; Livingston et al., 1991; Provazza et al., 2019), scholars have tried to provide examples of this slowness. Initially, research was dedicated to the early processing of the visual stimuli temporal sequences. Once a stimulus is introduced and then removed from the subject's sight, it usually remains for a short time. This is what is called visual persistence, and it is thought to be caused by ongoing neural activity which continues after the stimulus has ended. The experiments used to assess the time course of visual persistency involve the presentation of two stimuli in succession and the determining of when the two stimuli

[4] Backward masking is an effect that occurs when a low sound is followed by a sensitive higher sound and the second one disables the perception of the first one. It is an effect that happens within milliseconds, and it obviously depends on the frequency of the sound involved.

are perceived as one. Such studies have demonstrated that children with reading difficulties have significantly longer separation thresholds.

1.3.4. The Cerebellar Theory

The automaticity/cerebellar theory of dyslexia is widely discussed in Nicolson & Fawcett (1990). According to their view, the problems of people with dyslexia would not be confined to reading alone. Rather, they would suffer of a generalised deficit in executing tasks in an automatic way. The automatization of tasks is strictly related to the functioning of the cerebellum which plays a fundamental role in motor control and, therefore, in speech articulation as well. The biological claim behind the cerebellar theory of dyslexia is, then, that the cerebellum of dyslexic people is mildly dysfunctional, and that a number of cognitive difficulties derive from this fact (Ramus et al., 2003). Nicolson and Fawcett (1990) noted in particular that retarded or dysfunctional articulation could be responsible for deficient phonological representations.

The cerebellum plays a crucial role in the automatization of over-learned tasks, such as driving, typing and reading. An impairment in automatizing tasks is therefore likely to affect, among other things, the efficient learning of grapheme-phoneme correspondences. Nicolson & Fawcett (1990) stated that the idea behind the automatization concept is characterized by the adage "practice makes perfect" or rather:

> *Automatic processing is well learnt in long-term memory, is demanding of attention only when a target is presented, is parallel in nature, is difficult to alter, to ignore or to suppress once learned and is virtually unaffected by load.* Schneider and Shiffrin (1977)

Nicolson & Fawcett (1990) hypothesised that it is possible that automatization impairments may be the cause underlying dyslexic performance. Certainly, automatization plays an essential role in reading. When automatization is at its best, the cognitive load is reduced, and the processing speed increases. The two authors based their research on the initial finding of Anderson (1982) who identified two main stages in skill acquisition processes: at first "knowledge compilation", and then "production tuning". Knowledge compilation initially represents, in Anderson's terms, the acquisition of the declarative knowledge of what should be done, and then, the gradual "proceduralisation" of the knowledge. According to this hypothesis, a declarative form would change into automatic "production rules" which capture the procedural knowledge of how to achieve the goal. In his research, Anderson (1982) was able to

demonstrate that this theory of learning could apply not only to motor tasks, but also to a range of cognitive skills, including geometrical reasoning, computer programming, language development and letter recognition and more.

Readers with dyslexia exhibit longer vocalization latencies, slower lexical access and less efficient use of phonological encoding in single-word identification (Perfetti, 1999). This slowness affects short-term memory, and this causes difficulties in comprehension. Nicolson & Fawcett (1990) showed that an improvement in short-term memory is possible with age and this can only be explained in terms of improvement in processing speed. Thus, as it is, memory span is partially determined by the degree of automatization. Hence, evidence about dyslexia is compatible with an "automatization deficit" framework.

Having established that this hypothesis is plausible, doubts still remain as to whether dyslexic people have other deficits besides the reading related ones, specifically in cognitive and motor tasks. Nicolson & Fawcett (1990) believe that dyslexic children often have some impairments in the basic skills, but they are somewhat able to mask them by means of coping strategies and, in particular, by active allocation of extra attentional resources to the task (Nicolson & Fawcett, 1990). According to the authors, dyslexic and non-dyslexic children can achieve equivalent performances in many tasks. They just need to work harder than children without dyslexia.

1.3.5. The Magnocellular Theory

The magnocellular deficit theory postulates that the core deficit of dyslexia is the impairment in the magnocellular pathway (Stein, 2001). The specialized cells, known as magnocells, are responsible for the timing of both sensory (mainly visual and auditory) and motor (movement) events (Doyle & McDowall, 2015). Compared with chronological age-matched controls, individuals with dyslexia show less sensitivity in detecting motion (Conlon et al., 2013; Hansen et al., 2001; Pellicano & Gibson, 2008; Tschentscher et al., 2019).

The magnocellular theory (Stein, 2001) is considered the theory that somewhat integrates all the others. It is an attempt at generalizing from the visual theory, since it assumes that magnocellular impairment is not restricted to the visual routes. It is, however, generalized to all sensorial modalities (visual, auditory and even tactile). Furthermore, Ramus states that as the cerebellum is able to receive massive input from a variety of magnocellular systems in the brain, it will also be affected by the general magnocellular deficit.