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XXV cycle

COGNITIVE PROFILES OF TYPICAL AND ATYPICAL READERS:

EVIDENCE FROM THE ITALIAN ORTHOGRAPHY

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SUMMARY

Reading process has been the focus of a great amount of research over the past decades. However, recently Share (2008) claimed that reading research has been dominated by the study of the English language, and that this “Anglocentric research agenda” limited the relevance of the large amount of knowledge on reading in typical and atypical development. In line with this observation, there is evidence that learning to read transparent writing systems, such as Italian, is easier than learning to read opaque systems (Seymour, 2005), and that the precise weight of cognitive processes involved in reading varied systematically as a function of orthography’s transparency (e.g., Ziegler et al., 2010).

The series of studies reported in this thesis investigates the reading aloud process in the Italian transparent orthography, considering school-aged children who are typical readers or have Developmental Dyslexia (DD). The first two studies examined the role of verbal and visual-attentional cognitive processes in relation to reading fluency, considering children with typical development (Chapter 2) and with DD (Chapter 3). In particular, Chapter 2 describes a cross-sectional research that analyzes the predictors of reading fluency in primary school, investigating differences in the pattern of predictors for beginners (1^{st} and 2^{nd} grade) and expert readers (3^{rd} to 5^{th} grade). Results showed that concurrent predictors of reading fluency partially change when children become expert readers: whereas in 1^{st} and 2^{nd} grades text reading fluency was predicted by phonological awareness and rapid automatized naming, in 3^{rd} to 5^{th} grade also vocabulary, verbal short-term memory and visuo-spatial attention played a significant role in the model.

The study presented in Chapter 3 focuses on group differences in the cognitive underpinnings of reading fluency, comparing dyslexic children with chronological-age and reading-age matched controls. Children with DD were significantly impaired in all the measures included in the phonological domain and in the visuo-spatial attention and verbal-

visual recall tasks. Furthermore, this study provides an examination of the cognitive deficits that characterized the children with dyslexia involved in the study. Main finding is that a large group of children with DD exhibited multiple deficits, that included both the phonological and the non-verbal domains, whereas a lower number of children had a deficit exclusively in the phonological or exclusively in the visual-attention domains.

The last study presented (Chapter 4) is an experimental investigation of the autonomic response to reading tasks in children with DD and typical readers. This study also analyses the relationship between the physiological activation and some socio-emotional variables measured through questionnaires administered to children themselves and to their parents. Children with DD exhibit lower galvanic skin response during the reading aloud task. Then, it was observed a significant correlation of galvanic skin response and heart rate registered during reading tasks with parent's evaluation of emotional difficulties presented by their children. Theoretical implications for the science of reading, as well as clinical and educational issues, are discussed.

"The great tragedy of Science - the slaying of a beautiful hypothesis by an ugly fact."

Thomas H. Huxley

CHAPTER 1 – General introduction

1.1 Developmental dyslexia

Percy F. was a bright and intelligent 14-years-old boy, “in no way inferior to others of his age” (Morgan, 1896). He started school when he was 7 but he never learnt to correctly read words longer than one syllable. He also made mistakes writing his name, reversing the letters. He used to say that printed or written words have no meaning to him. Morgan (1896) was the first to describe a case of severe Developmental Dyslexia (DD) and to link it to “some congenital defect” (p. 1378); furthermore, he hypothesized that Percy’s difficulties were a consequence of a visual memory deficit, specific for words-form, that he defined “word blindness” (Kussmaul, 1877). However, he specified that Percy’s eyes were “normal”. The author also described what Percy’s teacher said about the boy: he would be “the smartest lad in the school if the instruction were entirely oral”. In his one-page paper, Morgan described most of the specific features of DD still used by our contemporary diagnostic manuals: it is a congenital deficit, independent from general intelligence and not associated to sensory or neurological deficits, that specifically affect word reading and spelling in children that received the same educational opportunities as their peers. Finally, the reading difficulties should be sufficiently severe as to interfere with everyday activities requiring literacy abilities.

The current definition of DD, or specific reading disability, is included in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000) and in the International Statistical Classification of Diseases and Related Health Problems (ICD-10; World Health Organization, 2004). However, there is still controversy about the diagnostic criteria and the precise definition, in particular regarding the IQ-discrepancy criteria, the issue of considering response to instruction as a further criterion (Fletcher, Coulter, Reschly, & Vaughn, 2004) and the relationships of DD with additional learning and communication disorders (Snowling & Hulme, 2012a). In the past decades a considerable amount of research have focused on DD, that affects about 3–7% of the population (Lindgren, De Renzi, & Richman, 1985, Rutter et al., 2004), investigating specific features, correlated deficits, epidemiological aspects and, primarily, examining possible causes of such difficulty.

Studies on typical reading development and on DD could be complementary. To understand dyslexia, we need to know how ordinarily children learn to read; this knowledge is useful to identify what can go wrong. On the other side, analyze atypical processes in learning to read will help to refine theories on typical development (Hulme & Snowling, 2009).

1.2 How do children learn to read?

Reading is a recent cultural invention, and despite there cannot be specific genes for reading, there are genetic influences on cognitive and behavioral traits necessary for proficiency in such cultural invention (Pennington & Olson, 2005). When we consider reading skills it is important to distinguish between reading accuracy and/or speed, and reading comprehension. Despite the aim of reading is usually comprehension, it is not possible to comprehend a text without having sufficient decoding skills (e.g. Gough & Tunmer, 1986). In this thesis, the term "reading" will refer to the ability to decode written text, and not the ability to extrapolate meaning from it.

Several theories proposed models of learning to read organized in stages or phases. Ehri (2005) reviewed some of these models (see Figure 1.1), helping to delineate an approximate sequence of stages in the development of reading (Hulme & Snowling, 2009).

Proponents	*Gough & Hillinger (1980)*	*Mason (1980)*	*Marsh et al. (1981)*	*Chall (1983)*	*Frith (1985)*	*Ehri (1998, 1999, 2002)*	*Stuart & Coltheart (1988)*	*Seymour & Duncan (2001)*
Number of Developmental Periods	2	3	4	5	3	4	2	4
1. Pre-reading	Cue reading	Contextual dependency	Rote, linguistic guessing	Stage 0: Letters/Book exposure	Logographic	Pre-alphabetic		Pre-literacy
2. Early reading		Visual recognition	Discrimination net guessing	Memory and contextual guessing		Partial alphabetic	Partial orthographic	Dual Foundation
3. Decoding		Letter-sound analysis	Sequential decoding	Stage 1: Decoding, attending to letters/sounds	Alphabetic	Full alphabetic	Complete orthographic	Logographic Alphabetic
4. Fluent reading	Cipher reading	Mason (1980)	Hierarchical decoding	Stage 2: Fluency, Consolidation	Orthographic	Consolidated alphabetic, Automaticity		Orthographic Morphographic

Figure 1.1 – A schematic summary of the approximate relationship between different stage/phase theories of learning to read. From: "Development of sight word reading: Phases and findings" by L. Ehri, 2005, in M. J. Snowling and C. Hulme (Eds.) *The science of reading: A handbook*, p. 139.

Reading development starts with quite arbitrary and unsystematic associations between printed and spoken words: preschoolers associate verbal labels to strings of letters, recognising words they are familiar with and paying no attention to letter order or phonological factors. This is called logographic stage (Frith, 1985), and is characterized by errors that showed how children are relying on the visual form of words: for example, they confuse words with similar length (e.g. children and policemen) or with other salient features in common (e.g. the double *t* in bottle and butter). Furthermore, they rely on the context in which a word is presented, so environmental print is a key element that modulates emergent literacy (Neumann, Hood, Ford, & Neumann, 2012). According to Seymour and Duncan's model (2001), based on Frith's one, during the logographic phase children gradually accumulate sight words, that is words read as visual wholes, in memory. In contrast to Frith's (1985) non-alphabetic logographic phase, Seymour and Duncan (2001) argue that grapheme-phoneme units are already used to connect words in memory. It should be noticed that some authors (Stuart & Coltheart, 1988) rejected the concept of an initial logographic stage, arguing that children learn to read directly using phonological processes.

The transition between visual recognition of words and alphabetic reading depends on awareness of relationships between sounds and letters, that is the basis of the decoding skill (Frith, 1985). There is not complete agreement among the stage models described in Figure 1, regarding how early and in what way children start to use phonological information in reading. However, most of them assumed that in the path through fluent reading, there is a gradually change from decoding letter by letter to recognize larger patterns of letters, especially morphemic units. This constitutes the orthographic and last phase according to Frith (1985).

Often, for an expert reader, a quick glance at a word is enough to activate its pronunciation and meaning. The ability to sight-reading is supported by mnestic traces of not only high-frequent words, but of all words that readers can read from memory, and it is particularly important to identify irregular words. It is not a strategy because it does not involves choosing procedures to optimize outcomes, but it’s an automatic and unintentional process (Ehri, 2005). A well-developed sight-reading skill allows readers to focus their cognitive resources on constructing the meaning of the text while their eyes recognize individual words automatically. Stopping frequently to decode unrecognized or unfamiliar words, significantly slow down the reading process and the reader could lose the thread of the text, compromising comprehension. Ehri (1998, 1999, 2002) illustrated four phases of sight word reading development, describing for each phase the predominant type of connection that bonds written words to their representations in memory: (1) pre-alphabetic, characterized by visual and contextual connections, (2) partial alphabetic, involving connections between salient letters and sounds, (3) full alphabetic, involving complete connections between all the graphemes and phonemes in the words, and (4) consolidated alphabetic, with connections based on syllabic units. According to Ehri, decoding skill emerges in the third phase.

There are both strong theoretical and empirical evidence that oral reading, that is the oral translation of text with speed and accuracy, is a good indicator of overall reading competence (Adams, 1994; see Fuchs, Fuchs, Hosp, & Jenkins, 2001 for a review). As reported by Fuchs et al. (2001):

> "Efficient low-level word recognition frees up capacity for higher level, integrative comprehension processing of text; this is the key point in framing a theoretical argument that fluent oral reading from text serves as a performance indicator of overall reading competence, which includes the readers capacity, for example, to process meaningful connections within and between sentences, to infer the macrostructure of a passage, to relate text meaning by checking consistencies with prior information, and to make inferences to supply missing information." (p. 242).

The ability to learn to read depends on the acquisition and proper development of a variety of knowledge and skills, which depend on reading-related linguistic and non-linguistic cognitive abilities. Vellutino and colleagues (Vellutino, Fletcher, Snowling, & Scanlon, 2004) represented graphically the cognitive processes and different types of knowledge involved in learning to read (Figure 2).

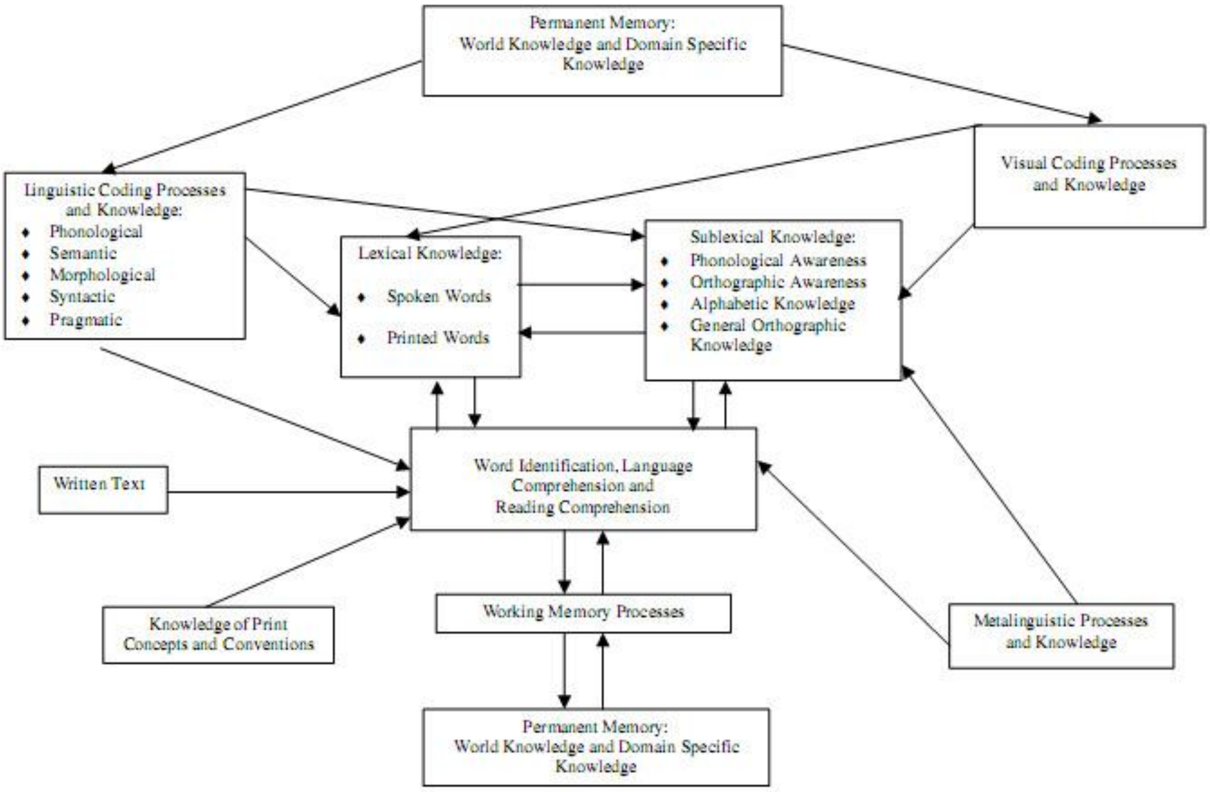


Figure 1.2 - Cognitive processes and different types of knowledge involved in learning to read. From: "Specific reading disability (dyslexia): What have we learned in the past four decades?" by F. R. Vellutino, J. M. Fletcher, M. J. Snowling, & D. M. Scanlon, D. M., 2004, *Journal of child psychology and psychiatry, 45*(1), p. 4.

1.3 Cognitive deficit models of Developmental Dyslexia

Of all the behaviorally-defined disorders that affect children, DD is probably the most studied and the one for which we currently have the best theoretical understanding. For a long time, knowledge on DD was dominated by the idea of a single cognitive deficit that provide a complete causal account of the development of the reading disorder, necessary and sufficient to explain all its features. In the following paragraphs, causal hypothesis considered in the past literature will be examined.

1.3.1 Deficits in general learning abilities

Dyslexia has been attributed to deficits in general learning abilities, implicated in all learning processes and not just involved in learning to read. For example, DD has been variously attributed to deficiencies in selective attention (Douglas, 1972), associative learning (Brewer, 1967; Gascon & Goodglass, 1970), implicit learning (Vicari et al., 2005; Vicari, Marotta, Menghini, Molinari, & Petrosini, 2003), cross-modal transfer (Birch, 1962; Birch & Belmont, 1964), serial-order processing (Bakker, 1972; Bogaerts, Szmalec, Hachmann, Page, & Duyck, 2013; Szmalec, Loncke, Page, & Duyck, 2011), and basic speed of processing (Breznitz & Meyler, 2003).

The main remark to the studies reporting differences between poor and normal readers on general learning abilities is that they did not control for reader group differences in verbal coding ability or memory processes that might be affected by verbal coding deficits (Vellutino et al., 2004). Empirical research that implement such controls, obtained results discredited group differences on measures of general learning abilities (e.g. for selective attention: Vellutino et al., 1996; for associative learning: Hulme, Goetz, Gooch, Adams, & Snowling, 2007; Messbauer & de Jong, 2003; for implicit learning: Howard Jr, Howard, Japikse, & Eden, 2006; for cross-modal transfer: Vellutino, 1979, 1987; Vellutino & Scanlon, 1982).

1.3.2 Language-based deficits

Currently, there is strong and highly convergent evidence that the key deficit in DD lies within the language system, affecting in particular the phonological component, which is responsible of the access and manipulation of the underlying sound structure of words (Ramus et al., 2003; Scarborough, 1990; Snowling, 2000; Swan & Goswami, 1997). The phonological deficit hypothesis (Frith, 1997; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; Snowling, 1987; Wilding, 1989, 1990) affirms that phonological skills are directly related to reading ability, and a deficit involving this low level component of language is the proximal cause of dyslexia. Evidence from children and adults with dyslexia showed that they frequently perform below the level of typical readers on explicit phonological tasks tapping phonological awareness, term used to refer to a wide range of skills involved in discriminating and manipulating the sounds of speech (Adams, 1994; Bowey, 1994; Wagner & Torgesen, 1987), and it is clearly demonstrated that the phonological deficit represents the most reliable and specific correlate of DD in children (Beaton, 2004; Blachman, 2000; Fletcher et al., 1994; Morris et al., 1998; Ramus, 2003; Snowling, 2000; Snowling & Hulme, 2012a; Stanovich & Siegel, 1994; Vellutino et al., 2004; Vellutino & Scanlon, 1987). Even dyslexic adults that reach reasonable levels of reading accuracy show persistent low phonological sensitivity (Bruck, 1990; Elbro, Nielsen, & Petersen, 1994). Phonologically based trainings and interventions also demonstrated to have positive effects on decoding difficulties (Hatcher, Hulme, & Ellis, 1994; Scanlon, Vellutino, Small, Fanuele, & Sweeney, 2005; Vellutino et al., 1996; see Snowling & Hulme, 2011 for a recent review). Finally, several electrophysiological, anatomical and neuroimaging studies confirm this hypothesis (Blau, van Atteveldt, Ekkebus, Goebel, & Blomert, 2009; Dougherty et al., 2007; Paulesu et al., 2001; Rumsey et al., 1992; for a review: Habib, 2000; Ramus, 2004). However, the large evidence showing a correlational and causal link between reading difficulties (but also proficient reading) and phonological domain, does not exhaust the questions concerning the endophenotype of dyslexia. In particular, two distinct orders of questions could be posed:

(1) what cause the phonological deficit (Figure 1.3)?

Figure 1.3

(2) is there a direct link between the phonological deficit and reading difficulties or some other cognitive processes are involved as mediators (Figure 1.4)?

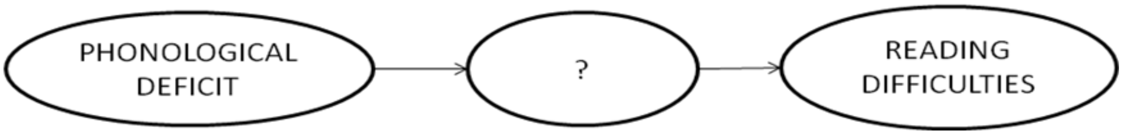


Figure 1.4

Concerning the first question, it has been hypothesized that problems in speech perception (Figure 1.5) might lead to the generation of inadequate phonological representations (McBride-Chang, 1995; Paul, Bott, Heim, Wienbruch, & Elbert, 2006; Serniclaes, Heghe, Mousty, Carré, & Sprenger-Charolles, 2004). However, it was showed that children with dyslexia have on average only mild speech perception difficulties (Adlard & Hazan, 1998; Chiappe, Chiappe, & Siegler, 2001; Manis et al., 1997), possibly due to the presence of a subgroup of this children that shows broader oral language difficulties (Joanisse, Manis, Keating, & Seidenberg, 2000; see Hulme & Snowling, 2009 for a review).

Figure 1.5

Another possible cause of the phonological deficit that has been investigated in the literature is a problem in processing basic temporal auditory cues (Tallal and Piercy, 1973; Tallal, 1980; see also Reed, 1989), which subsequently causes problems in the accurate processing of rapid acoustic changes in speech (Figure 1.6).

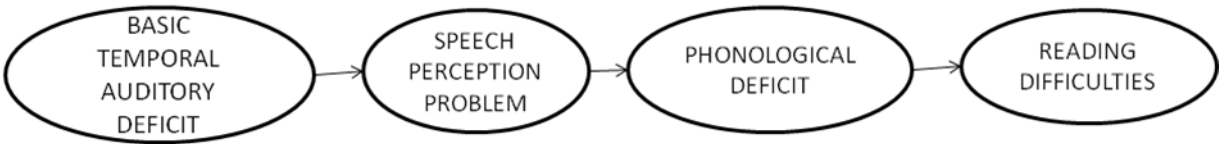


Figure 1.6

However, some studies on dyslexics have found evidence which is inconsistent with this hypothesis (Bretherton & Holmes, 2003; Marshall, Snowling, & Bailey, 2001; Nittrouer, 1999). Additionally, Tallal and Stark (1982) analyzed a group of dyslexic children without oral language difficulties finding evidence that a deficit in auditory perception was actually associated to oral language difficulties, rather than being specifically correlated to reading problems (see also Grube, Cooper, Kumar, Kelly, & Griffiths, 2013; Heath, Hogben, & Clark, 1999). Furthermore, in a series of experiments Mody and colleagues (Mody, Studdert-Kennedy, & Brady, 1997; Studdert-Kennedy & Mody, 1995) showed that difficulties of poor readers using speech stimuli were due to speech discrimination deficits rather than auditory temporal order judgment. In summary, it seems that speech perception problems and deficits in rapid auditory perceptual skills cannot account for the phonological impairment found in children with dyslexia, and when they occur they appear to be directly related to oral language difficulties rather than to the reading deficit. Furthermore, it is possible that impairments in speech perception tasks may be the consequence rather than the cause of a phonological deficit (Ramus, 2004).

Considering the second question, several possible cognitive processes have been hypothesized to be mediators of the association between the phonological deficit and behavioral symptoms of dyslexia. For example, some scholars suggested the role of weak phonological coding on verbal memory skills, in particular in storing and/or retrieving printed words as distinct orthographic units as well as in processing verbal information in working memory (Elbro, 1996; Gathercole & Baddeley, 1990; Hulme, 1981; Snowling, 2000; Wagner & Torgesen, 1987); tasks to investigate this abilities are, for example, pseudo word repetition, forward and backward digits span task. Another problem that may contribute to difficulties in learning to read and could be caused by a phonological deficit is slow naming speed, usually measured with rapid automatized naming (RAN) tasks (Manis, Seidenberg, & Doi, 1999; Snowling & Hulme, 1994; Swan & Goswami, 1997; Wolf & Bowers, 1999; for different interpretation of RAN see: Kail & Hall, 1994, Lervåg & Hulme, 2009), or weak visual-verbal paired-associate learning (Vellutino, Scanlon, & Spearing, 1995; Wimmer, Mayringer, & Landerl, 1998; Windfuhr & Snowling, 2001; but see also Hulme et al., 2007; Litt & Nation, 2014).

Also higher order language skills, such as lexical knowledge and syntactic competence, have been associated to DD. For example, some Authors hypothesized that poor vocabulary may be a basic cause of difficulties in learning to read in some impaired readers (Dickinson & Tabors, 2001; Snow & Tabors, 1993, Vellutino & Scanlon, 1982). It seems reasonable to infer, on logical grounds, that children with a limited vocabulary could have difficulties in acquiring fluency in word and text reading, even if they have adequate phonological decoding skills. Vocabulary knowledge has also been associated to the acquisition of reading-related phonological skills (Metsala, 1999; Metsala & Walley, 1998). Then, given the demonstrated advantage that the linguistic context could provide in the word identification process, especially in poor readers (Perfetti & Roth, 1981; Stanovich, 1980; Tunmer, 1989; Tunmer & Chapman, 1998), it would seem that syntactic and semantic deficits that hinder children's ability to use this linguistic context, could contribute to beginning reading problems in such children. However, vocabulary and syntactic knowledge appear not to be sensitive measures to distinguish between dyslexics and normally achieving readers, except in comparisons involving older children characterized by long-standing reading disorder (e.g., Fletcher, Satz, & Scholes, 1981; Snowling, 2000; Stanovich, 1986; Vellutino, Scanlon, & Tanzman, 1988; Vellutino et al., 1996). Such findings suggest that early reading difficulties showed by children with DD, may not be caused primarily by lexical or syntactic deficits, but be a consequence of prolonged reading problems (Vellutino et al., 2004). Furthermore, the comorbidity with oral language impairment could again play a role (Catts, Hogan, & Fey, 2003).

1.3.3 Visual- and attentional- based deficits

Despite the strong evidence of the role of phonological deficit as cause of DD, different pathways have been explored: for example, it is possible that other factors may play a causal role in the disorder (Figure 1.7), or that the phonological deficit observed is not causally connected to DD, and therefore dyslexia is caused by another cognitive deficit (Figure 1.8).

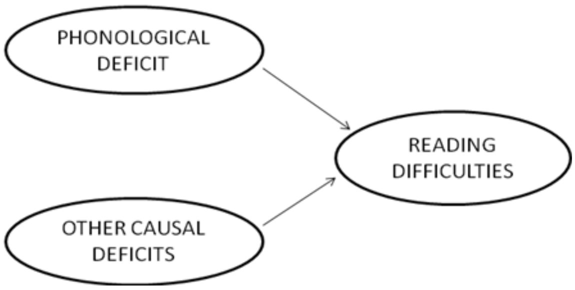


Figure 1.7

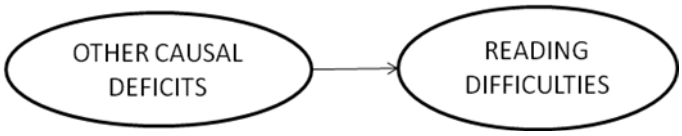


Figure 1.8

Learning to read undoubtedly involves visual perception: for decoding written text it is necessary to discriminate between visually similar shapes and to perceive visual pattern that have to be associated with the corresponding sound. Therefore, it is not surprising that interpretations of DD based on visual perceptual problems have been the earliest and highly influential theories in the last century until the 1970s and 1980s, when linguistic-based explanations of the disorder emerged and began to compete with visual deficit explanations (Lyon, Fletcher, & Barnes, 2002; Snowling, 2000; Vellutino, 1979, 1987; Vellutino et al., 1994). Indeed, the first definition of dyslexia was "word blindness" (Kussmaul, 1877), a clear reference to the sense of sight. Examples of explanations implicating deficiencies in the visual system, in particular in visual perception, are the optical reversibility theory by Orton (1925) and Hermann's (1959) spatial confusion theory, but hypothesis regarding visual perceptual impairment came from several studies (Drew, 1956; Ingram, 1963; Lovell, Shapton, & Warren, 1964; Vernon, 1957). Boder (1973) classified dyslexics in "dyseidetic" (good phonological abilities but a deficit in gestalt word recognition), "dysphonetic" (difficulties in phoneme-grapheme connection due to a deficit in the processing of speech sounds) and mixed category, but her scheme led many professionals to persist in thinking to dyslexia primarily in terms of a visuo-spatial deficit. However, in most of studies the precise nature of the visual perceptual deficit was rarely made explicit (Stanovich, 1988). Interest in this aspect of DD has declined following the publication of Vellutino's (1979) manuscript, in which he concluded that visual-perceptual deficits do not really play a significant role in DD, and emphasized the role of speech-related problems. In fact, to challenge visual-perceptual theories, were designed research paradigms that analyzed visual processing in reading controlling for verbal abilities.

With these paradigms, few significant differences between poor and good readers were found on visual perception skills (Fletcher, Foorman, Shaywitz, & Shaywitz, 1999; Frost, 1998; Vellutino, 1979, 1987; Vellutino & Scanlon, 1982). Despite the robust results regarding the central role of phonological-based abilities in causing and correlating with DD, some scientists have continued to work on visual perceptual problems experienced by some dyslexics. However, as pointed out by Watson and Willows (1995) these visual perceptual difficulties have often been considered together with verbal and/or phonological deficits, rather than isolated impairments associated with DD (Figure 1.7).

Partially different theories are those that associate reading difficulties to visual-attentional deficits. Lennerstrand and colleagues (Lennerstrand, Ygge, & Jacobsson, 1993) suggested that dyslexia may involve "insufficient over the attentional system, which in turn leads to insufficient control over saccadic eye movements in reading" (p. 238). More recently, a set of Italian studies (Facoetti & Molteni, 2001; Facoetti, Turatto, Lorusso, & Mascetti, 2001; Facoetti et al., 2006; Ruffino et al., 2010) showed evidence of an asymmetric control of visual spatial attention, considered by these Authors the main deficit underlying dyslexia. In particular, they identified a pattern of left inattention and right over-distractibility, that was attributed to a reduced right parietal lobe functioning in dyslexic children during visual information processing (Facoetti & Molteni, 2001) and considered a confirmation of the magnocellular theory of dyslexia (Stein, 2001; Stein & Walsh, 1997; see also Boden & Giaschi, 2007; Hansen, Stein, Orde, Winter, & Talcott, 2001; Romani et al., 2001; Skottun, 2000), in particular of the attentional variant proposed by Hari and Renvall (2001). According to the most recent theorization of the magnocellular theory of dyslexia there are two direct causes of reading retardation: phonological and visual deficits. Stein (2001) assumes that phonological deficits arise from an auditory impairment, which has the same biological origin as the visual impairment, namely, a magnocellular dysfunction which is responsible for timing events when reading. According to this theory, dyslexia is therefore caused by a general sensorimotor syndrome. However, a set of studies reported findings inconsistent with a deficit specific to the magnocellular system (Amitay, Ben-Yehudah, Banai, & Ahissar, 2002; Ramus et al., 2003). Furthermore, while intervention studies have confirmed the role of phonological skills in learning to read (see Snowling & Hulme, 2011 for a review), comparable evidence regarding the role of visual-perceptual and visual-attentional deficits is lacking (see Gori et al., 2013 for a possible exception).

1.3.4 The multiple cognitive deficit model

Pennington (2006) delineated the limits of single cognitive deficit hypotheses. For example, a single cognitive deficit that can explain symptoms of all cases with DD has not be identified. In particular, not all children with dyslexia present a phonological deficit (Pennington et al., 2012; Valdois et al., 2011) or, to cite another theory, a visual perceptual problem (Fletcher et al., 1999; Vellutino et al., 2004). Conversely, as showed by cross-sectional (Bekebrede, van der Leij, Schrijf, & Share, 2010; Tunick, 2004) and longitudinal (Snowling, 2008) studies, not all individuals that exhibit phonological deficits have or develop dyslexia in their future. The same appears for perceptual visual and attentional deficits (e.g. Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Another important issue is that single cognitive deficit hypotheses are hardly compatible with the phenomenon of comorbidity. DD co-occurs more often than expected by chance with other developmental disorders such as Specific Language Impairment (SLI - Aram, Ekelman, & Nation, 1984; Bishop & Adams, 1990; Bishop & Snowling, 2004; Catts, 1993; Catts, Fey, Tomblin, & Zhang, 2002; Rutter & Mawhood, 1991; Scarborough, 1990; Snowling, Bishop, & Stothard, 2000), Attention Deficit Hyperactivity Disorder (ADHD - Dykman & Ackerman, 1991; Gilger, Pennington, & DeFries, 1992; Semrud-Clikeman et al., 1992; Willcutt & Pennington, 2000a) or learning deficits as dyscalculia (Ackerman & Dykman, 1995; Badian, 1999; Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Dirks, Spyer, van Lieshout, & de Sonneville, 2008; Landerl & Moll, 2010; Lewis, Hitch, & Walker, 1994); the explanations of DD in terms of a single cognitive deficit requires a distinct justification for each pair of comorbid disorders.

Pennington (2006) proposed a multiple cognitive deficit model for understanding developmental disorders (Figure 1.9), inspired to the complex disease model in medicine (Sing & Reilly, 1993) and to the quantitative genetic model in behavioral genetics (e.g., Plomin, DeFries, McClearn, & Rutter, 1997). It is organized in four levels (etiologic, neural, cognitive, and symptoms) and its main points are the following:

1. the etiology of complex behavioral disorders is multifactorial and involves the interaction of multiple genetic and environmental risk and protective factors;

2. these risk and protective factors alter the typical development of some cognitive functions, producing the behavioral symptoms that define disorders such as developmental dyslexia;

3. no single etiological factor is sufficient for a disorder, and more of them may be necessary;

4. consequently, comorbidity among complex behavioral disorders is to be expected because of shared etiologic and cognitive risk factors;

5. the liability distribution for a given disorder is often continuous and quantitative, rather than being discrete and categorical, so that the threshold for having the disorder is arbitrary (for example, the cut-off of - 2 standard deviations in reading tasks for classifying reading speed as deficient).

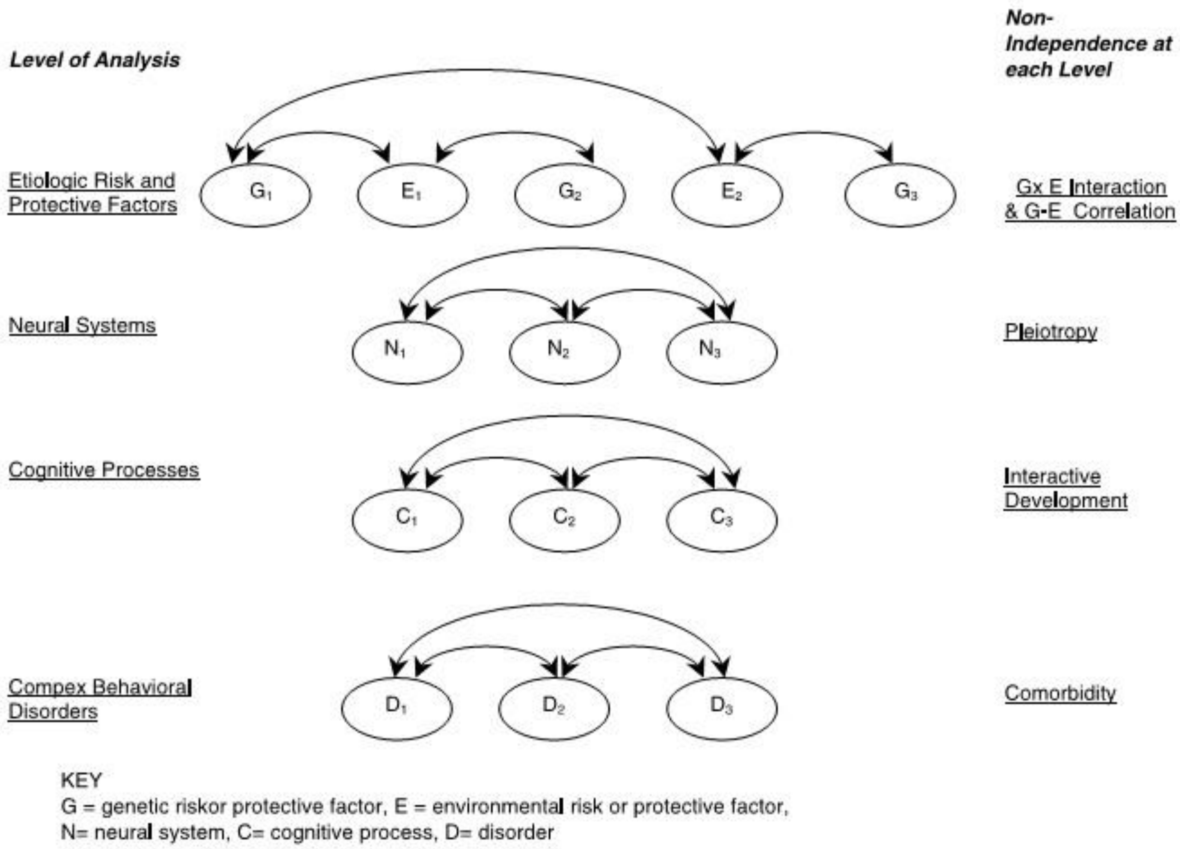


Figure 1.9 – Multiple deficit model. From: "From single to multiple deficit models of developmental disorders." by B. F. Pennington, *Cognition*, *101*(2), p. 404.

A recent study compared single vs multiple cognitive deficit models in predicting dyslexia (Pennington et al., 2012). In particular, it considered the single phonological deficit model similar to the one proposed by Ramus et al. (2003) and a single deficit model that considered other deficits besides phonological awareness (processing speed, naming speed, language skill) as sufficient to cause DD. One of the multiple models tested is constituted of a phonological core necessarily in combination with an additional deficit; the second multiple model predicts that a single deficit is not sufficient to cause dyslexia and at least two deficits are needed. Finally, Authors tested an hybrid model, according to which subgroups of individuals with dyslexia will fit each of the four models above. Findings from this study showed roughly equal proportions of cases explained by multiple and single deficit models, whereas the model that provided the best overall fit to the data was the hybrid one, that implied multiple possible pathways to DD, some involving single deficits and some involving multiple deficits. This result means that the relation between predictors analyzed and reading skill (only fluent reading, not comprehension) are probabilistic and not deterministic. Considering the clinical practice, it implies that clinician should not strictly require a child with dyslexia to fit a particular deficit profile or even to have any cognitive deficits among the constructs considered in the study. However, it has confirmed the important role of the predictors analyzed. In particular, Pennington et al.'s (2012) results reject a strict, single deficit version of the phonological hypothesis, but showed that phonological awareness deficits had the highest sensitivity of any single cognitive deficit. In conclusion, this study showed that the cognitive predictors analyzed are not necessary or sufficient for making a diagnosis of DD; however, they have a substantial sensitivity for the diagnosis and clinician should therefore consider these deficits as reliable cognitive risk factors of dyslexia.

1.4 Cultural and linguistic influences

A primary factor that has been identified to affect reading acquisition in both typical and atypical development is the type of orthography that the child is acquiring. In particular, the consistency of orthographic mapping between written symbols and units of sounds varies in function of the language (Seymour, 2005; Seymour, Aro, & Erskine, 2003). Therefore, orthographies could strictly follow the alphabetic principle, having 1:1 relationships between letters and phonemes (for example, Finnish) or, at the other extreme of the continuum, have a large number of inconsistencies and irregular relationships between graphemes and phonemes (for example, English). As illustrated by Seymour (2005; see also Share, 2008; Ziegler & Goswami, 2005), the process of learning to read in consistent writing systems as Italian or German is easier than learning to read opaque systems with a high proportion of irregular spellings, such as English or French. For example, Seymour et al. (2003) analyzed reading development in 13 different alphabetic orthographies across Europe, showing as at the end of first grade reading accuracy was already close to ceiling in transparent orthographies, including Italian. On the contrary, children acquiring more opaque orthographies were still making lots of mistakes. Beyond reading proficiency and strategies based on orthographic consistency, also the role of different cognitive processes underlying reading acquisition has been investigated. For typical reading development, there is evidence that most predictors of reading performance are relatively universal across alphabetic languages, although their precise weight is modulated by the orthographic transparency (Caravolas et al., 2012; Furnes & Samuelsson, 2011; Moll et al., 2014; Vaessen et al., 2010; Ziegler et al., 2010) Despite studies on dyslexia are currently developed in several alphabetic and non-alphabetic languages, at date most of the scientific background on DD is still build on the English orthography, and the branch of research that focus on cognitive correlates and causes of dyslexia in different orthographies is quite recent. Indeed, the orthography that the child is acquiring is currently considered a central environmental factor that influences both typical and atypical reading acquisition; in particular the transparency of the relationship between orthographic symbols and the language sounds is a key element of written language processing, also in DD (e.g. Landerl, Wimmer, & Frith, 1997; see Caravolas, 2005 for a review). A recent study (Landerl et al., 2013) has gone beyond the question of the impact of transparency variability on reading acquisition in dyslexic children, investigating to what extent the cognitive mechanisms underlying reading acquisition in dyslexia might vary as well. The study involved 1114 dyslexic children and 1138 controls aged 8 to 12, speaking six different languages with a broad range of consistency (Finnish, Hungarian, German, Dutch, French, English). Main results were that PA, measured with phoneme deletion, and RAN are both powerful concurrent predictors of developmental dyslexia across orthographies, but their impact was stronger in opaque (English and French) than in more transparent (Finnish and Hungarian) orthographies. They also investigated the role of verbal short term and working memory, and of verbal abilities, finding significant but minor effect across orthographies. The Authors concluded that the orthographic complexity modulates some aspects of dyslexia symptomatology.

1.5 Developmental Dyslexia in the Italian orthography

In a regular orthography such as Italian, even children who start reading acquisition with poor phonological skills may become able to catch the mapping rules between graphemes and phonemes, and learn to read correctly. The simple orthographic representation of the phonological structure of Italian may help children to overcome early deficits, as well as the aid of formal reading instruction strongly phonics-based can do (Landerl et al., 2013). In fact, it was showed that Italian children read around 94% of words and 82% for pseudo words correctly at the end of first grade (Cossu, Gugliotta, & Marshall, 1995).

However, children with dyslexia learning to read in transparent orthographies are still presenting a relevant difficulty, which is primarily a deficit in reading speed (de Jong & van der Leij, 2003; Wimmer, 1993; Zoccolotti et al., 1999). One way to investigate the nature of the deficit in DD is to use eye movements recording during text reading. De Luca and colleagues (De Luca, Di Pace, Judica, Spinelli & Zoccolotti, 1999) used this technique with Italian skilled readers and children with DD, finding a different pattern of eye movements: whereas the control group took a few saccades to scan the lines of text, dyslexics made a large number of small saccades, making a larger number of fixations for long words, independently from word frequency. The finding of this word length effect for word with either high or low frequency was interpreted by the Authors as the use of sub-lexical strategies in DD. The length effect was further investigated also for single words and pseudo words reading (De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002): eye movements of children with DD suggested sub-lexical processing for both words and pseudo words, whereas typical readers showed to access lexically to words and used sub-lexical strategies only for pseudo words. These results were replicated using analysis of vocal reaction times in naming words and pseudo words (Judica, De Luca, Spinelli, & Zoccolotti, 2002; Zoccolotti et al., 2005; Zoccolotti et al., 1999). Studies on typical reading processes in the Italian orthography indicated that sub-lexical strategies dominates during first grade (Orsolini, 2000; Orsolini, Fanari, Tosi, de Nigris, & Carrier, 2006; Zoccolotti et al., 2005), but are replaced by lexical processing by the end of the first school year. It was consequently hypothesized that Italian children with DD are blocked to an early stage of analytical processing of words, and fail in the transition from a sub-lexical to a lexical strategy (Zoccolotti et al., 2005). Therefore, whereas early alphabetic decoding is acquired quite adequately by most of the children with DD, they remain anchored to a sub-lexical strategy and the result is a rather accurate but slow reading (Tressoldi, Stella, Faggella, 2001; Zoccolotti et al., 1999). The hypothesis of a deficit in lexical processing with consequent over-reliance on the non-lexical route was rejected by Barca and colleagues (Barca, Burani, Di Filippo, & Zoccolotti, 2006), that specifically analyzed the use of lexical route in Italian children with DD, investigating two marker effects: word frequency, consisting in the advantage of high-frequency words over low-frequency ones, and the effect of contextual grapheme-to-phoneme conversion rules, consisting in slower reading times for words containing letters which pronunciation is determined by context-sensitive rules and depends on the letters that follow, for example the letter “g” in “gomma” (gum) and in “giro” (turn). They found that both the effects analyzed had an impact on reading in dyslexic children as well as for the control group. The Authors interpreted this result as the use of lexical reading also in children with DD. Recently, similar results were obtained, showing word frequency and lexicality (the advantage of words over pseudo words) effects in Italian children with DD, both in reading aloud and lexical decisions (Paizi, De Luca, Zoccolotti, & Burani, 2013). Also in this case, the Authors rejected the hypothesis of over-reliance on non-lexical processing; furthermore, they specified that the pattern they have found is inconsistent with the explanation of DD in regular orthographies in terms of surface dyslexia, as it has been theorized within the classical dual-route framework (e.g. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). Paizi et al. (2013) also found a single global factor that accounts for a large portion of the difference in reading speed between dyslexics and controls; they concluded that this global factor represents a level of pre-lexical graphemic analysis that precedes sub-lexical or lexical processing. However, it has been shown that also basic phonological processing, such as orthography-phonology conversion and blending, is altered in Italian dyslexic children at primary school (Orsolini, Fanari, Cerracchio, & Famiglietti, 2009).

The largest study to date that specifically analyzed the cognitive profile of Italian children with DD, showed that most of them have a pervasive phonological deficit involving phonological awareness, memory and fluency abilities (Menghini et al., 2010). In a few cases were reported deficits exclusively in the visuo-spatial domain (see also Del Giudice et al., 2000). Furthermore, a study that examined children with surface dyslexia found that all participants had a difficulty with tasks tapping basic perceptual processing, including rapid scanning of stimuli (Zoccolotti et al., 1999).

1.6 Socio-emotional and behavioral correlates of Developmental Dyslexia

A considerable amount of psychological studies describes learning disorders as an important risk factor for current and future psychological discomfort, probably related to academic difficulties during school years (Cunningham & Stanovich, 2001) but also to lower educational attainment and earnings in adulthood (Blackorby & Wagner, 1996; Savolainen, Ahonen, Aro, Tolvanen, & Holopainen, 2008). A growing body of literature suggests that children with specific learning disorders often exhibit internalizing symptoms such as anxiety and depression, low self-esteem, somatic complaints or emotional withdrawal (Arnold et al. 2005; Bäcker & Neuhäuser, 2003; Boetsch, Green, & Pennington, 1996; Carroll, Maughan, Goodman, & Meltzer, 2005; Dahle & Knivsberg, 2013; Dahle, Knivsberg & Andreassen, 2011; Goldston et al., 2007; Hall, Spruill, & Webster, 2002; Heiervang, Lund, & Jim, 2001; Ingesson, 2007; Willcutt & Pennington 2000b). With internalizing problems we refer to behaviors such as withdrawal from social activities, sadness and loneliness; furthermore, they include fear, anxiety, suicidal ideation, depression and somatic complaints like headaches and stomach pain (Achenbach & Rescorla, 2001). Mugnaini and colleagues (Mugnaini, Lassi, La Malfa, & Albertin, 2009) provided a review that specifically examined studies on internalizing symptoms in DD. They showed that dyslexia is a specific risk factor for increased internalizing, anxious and depressive symptoms at all ages; psychosocial dysfunction was also dependent on the severity of the reading problem, on late diagnosis, on the presence of a borderline IQ and on further learning and psychological disorders: in particular, comorbidity with ADHD is often associated with higher risks of psychopathology and emotional discomfort. Furthermore, the association with mathematical disorder seems to be an additional risk factor for lower global self-esteem, experience or perception of a lower social support and higher depression symptoms (Martinez, 2006; Martinez & Semrud-Clikeman, 2004). Also being female resulted associated to higher risk of emotional suffering (see also Alexander-Passe, 2006; Willcutt & Pennington, 2000b). Mugnaini et al. (2009) finally illustrated that high IQ, high socioeconomic status and the long-lasting remedial work at school are relevant factors for positive outcome in terms of psychiatric symptoms in dyslexic adults. Only a few study did not find any significant difference between children with dyslexia and controls (e.g. Lamm & Epstein, 1992; Miller, Hynd, & Miller, 2005).

Some studies showed as children with dyslexia also have difficulties with peer relationships and deficits in social competence (Dahle et al., 2011; Gadeyne, Ghesquiere, & Onghena, 2004; Elbaum & Vaughn, 1999). In their meta analysis, Kavale and Forness (1996) have found that about 75% of students with learning disabilities can be differentiated from typically developing peers through measures of social competence. However, this review used the general category of “learning disability” to describe the sample, and it is not specified how their result are valid specifically for children with a specific learning disorder in reading. A study that analyzed protective factor in children with DD showed that they have lower levels of peer acceptance than controls, and that high levels of peer acceptance contributed uniquely to reading fluency after controlling for previous risk due to poor reading and other control variables (Kiuru et al., 2013). This result is in line with theoretical perspectives on social motivation (e.g., Deci & Ryan, 2000; Skinner, Kindermann, Connell, & Wellborn, 2009) that suggest how the role of supportive interpersonal relationships can serve as a resource for promoting students’ academic skills.

Finally, also externalizing behavioral problems have been found to be associated to learning disorders such as dyslexia (Bäcker & Neuhäuser, 2003; Dahle & Knivsberg, 2013; Heiervang et al., 2001; Trzesniewski, Moffitt, Caspi, Taylor, & Maughan, 2006). Externalizing behavior includes aggression and rule-breaking, lying, stealing, cheating and threatening people. Children with externalizing behavior may also have bad temper, lack of the feeling of guilt after doing something wrong or, in extreme cases, abuse of alcohol or drugs (Dahle et al., 2011). However, Willcutt and Pennington (2000b; see also Carroll et al., 2005) showed that externalizing symptoms including aggression, conduct problems or delinquency were not specifically related to DD, but characterized the behavioral profile of individuals with both DD and ADHD. On the contrary, relations between DD and internalizing symptoms remained significant also when comorbidity with ADHD was controlled for.

These findings raise important questions about the increased vulnerability of children with DD to psychiatric disorders. The available literature suggests that dyslexia is related to emotional distress, and is a risk factor for being involved in vicious circles where failure, demoralization, poor metacognitive awareness and lack of interest for school duties grow exponentially (Morgan & Fuchs, 2007; Mugnaini et al., 2009). Although most of the results presented are not directly interpreted as causal connection between DD and consequent internalizing and externalizing manifestations (longitudinal studies are needed for such interpretation), it seemed likely that literacy difficulties might act as a risk factor for increased levels of both generalized and school-related symptoms. However, some Authors suggested that the association between literacy disorders and depressed mood or anxiety diagnoses could be partially due to the mediation of attentional problems (Carroll et al., 2005).

1.7 The current studies

My thesis aims to investigate cognitive, emotional and physiological correlates of the process of reading aloud, considering both typical readers and children with Developmental Dyslexia. DD is considered on a continuum with typical reading ability because it has been proved that specific psychological, neural, and genetic features of this developmental disorder also correlate with reading performance in typical readers (Gabrieli, 2009). It means that knowledge on reading acquisition could be used to frame discoveries about dyslexia which, *vice versa*, may offer insights into mechanisms of normal reading acquisition (Hulme & Snowling, 2009). The present work is composed of three studies, that involved around 780 children from primary and middle schools.

The first two studies examined the role of several cognitive abilities in relation to reading fluency, considering children with typical development (Chapter 2) and with Developmental Dyslexia (Chapter 3), specifically for the transparent Italian orthography. Main aim of these studies is to test the contribution to reading fluency of verbal related and visual-spatial related skills, identified in the past literature as potential cognitive factors associated to typical or atypical reading. In particular, Chapter 2 (Tobia & Marzocchi, 2013) describes a cross-sectional study that analyzes the predictors of reading fluency in primary school, investigating differences in the pattern of predictors for beginners (1st and 2nd grade) and expert readers (3rd to 5th grade). Chapter 3 focuses on group differences in the cognitive underpinnings of reading fluency, comparing dyslexic children with chronological-age and reading-age matched controls. Furthermore, Chapter 3 provides an examination of the cognitive deficits that characterized every single dyslexic child involved in the study. The third study (Chapter 4) is an experimental investigation of the autonomic response to reading tasks in children with DD and typical readers. This study also analyses the relationship between the physiological activation and some socio-emotional variables measured through questionnaires administered to children themselves and to their parents. Finally, in Chapter 5 a synthesis of the key findings is presented and their theoretical and practical implications are discussed.

"We are not concerned with the very poor. They are unthinkable, and only to be approached by the statistician or the poet."

E.M. Forster

CHAPTER 2 - Predictors of reading fluency in Italian orthography: Evidence from a cross-sectional study of primary school students

2.1 Introduction

In recent decades, children's reading development and reading difficulties have been extensively investigated in most languages and in various orthographies. There is substantial evidence that learning to read transparent writing systems is easier than learning to read opaque systems, such as English or French (Seymour, 2005). Therefore, some authors have argued that English-based research might have overestimated the role of phonological processes in reading development (Share, 2008). However, Ziegler et al. (2010) have found that most of the predictors of reading that they investigated were relatively universal across several alphabetic languages (Finnish, Hungarian, Dutch, Portuguese and French), although each predictor’s contribution varied as a function of orthographic transparency. An analysis of the recent literature suggests that several potential abilities seem to co-determine reading ability. Furthermore, the processes that contribute to reading performance change as proficiency increases (Bowey, 2005), and the same processes could contribute in different ways at different ages. It is also important to distinguish the influence of reading predictors on good readers and on children with reading difficulties; predictors that are salient for good readers may exert little influence on poor readers’ performance (Bowey, 2005). The influence of reading predictors is complex and seems to vary according to 1) orthographic transparency; 2) level of reading automation, which could indicate the activation of different cognitive mechanisms; and 3) being good or poor readers. Furthermore, reading can be measured by two indices: accuracy and fluency. Fluency is considered a better index of reading skills in more transparent orthographies because readers of these orthographies attain high accuracy rates early in the process of learning to read (Seymour, Aro, & Erskine, 2003).

2.1.1 Phonological awareness (PA)

A large body of evidence suggests that phonological awareness (PA), the ability to represent and manipulate the sound units of spoken words, is a key component of reading development and of individual differences in children's early reading skills for both normal and poor readers (e.g., Muter, Hulme, Snowling, & Stevenson, 2004; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wimmer, Landerl, Linortner, & Hummer, 1991; Ziegler et al., 2010). This ability is developmentally fundamental for learning the association between sounds and letters and for subsequently associating letter strings and words. This letter-sound association gradually becomes less effortful and demanding; skilled readers perform it rapidly and automatically (Hulme & Snowling, 2009). Consistent with this view is the finding that a phonological deficit existing at the time that reading emerges seems to directly cause a reading deficit. Furthermore, reading impairment is predicted by the severity of the phonological deficit (Hulme & Snowling, 2009). In addition, some studies have shown that the role of PA is not the same in all orthographies. For example, in children learning to read relatively transparent languages, some authors have found that the reliability of PA as a predictor decreases after the second grade (de Jong & van der Leij, 1999; Leppänen, Niemi, Aunola, & Nurmi, 2006; Vaessen & Blomert, 2010; Wimmer, Mayringer, & Landerl, 2000) or has only a marginal relationship to reading performance (Aarnoutse, van Leeuwe, & Verhoeven, 2005; Holopainen, Ahonen, & Lyytinen, 2001). Studies directly comparing predictors across orthographies have reported contradictory results: some of them have found that the effect of PA is weaker in more consistent languages (Furnes & Samuelsson, 2010; Georgiou, Parrila, & Papadopoulos, 2008; Mann & Wimmer, 2002), whereas others have suggested a similar predictive power in English and Czech (Caravolas, Volin, & Hulme, 2005; Vaessen et al., 2010), Norwegian and Swedish (Furnes & Samuelsson, 2009), Spanish and Slovak (Caravolas et al., 2012), and Dutch (Patel, Snowling, & de Jong, 2004). These results suggest that PA is predictive of reading ability, although there is no universal agreement on the degree of its contribution in more consistent orthographies.

Furthermore, previous findings (Caravolas et al., 2005; Caravolas & Bruck, 1993) have shown that children learning to read in transparent orthographies generally had better PA skills than children learning to read English or other opaque orthographies. In other words, they obtained higher scores in tasks such as phoneme and syllable blending, segmentation and deletion. These results suggest a reciprocal relationship between PA and learning to read (Perfetti, Beck, Bell, & Hughes, 1987). Duncan et al. (2013) has reported that this advantage also depends on the speech rhythm and phonics instruction received in the early stages of the process of learning to read. In accordance with this observation, Caravolas et al. (2005) hypothesised that the measures of PA used in some studies could be subject to ceiling effects, which could cause a decrease in predictive power that would explain the failure to find robust effects of PA in consistent orthographies (see also Ziegler, 2010). In fact, by comparing reading performance in Czech and English on difficult tasks with highly similar demands, the authors were able to show a similar contribution of PA to reading in both languages. However, Vaessan et al. (2010) have shown that, in consistent orthographies, reading performance is usually measured as reading fluency, whereas most English-language studies are based on reading accuracy measures. Because PA is typically evaluated by accuracy, its influence on reading fluency in transparent orthographies might therefore appear to be attenuated.

2.1.2 Rapid automatized naming (RAN)

Automatic processing efficiency is another factor closely related to reading ability in both early (Badian, 2000; Cronin & Carver, 1998; de Jong & van der Leij, 1999) and late stages (Cronin & Carver, 1998; Di Filippo et al., 2005; Wagner, Torgesen, & Rashotte, 1994; Warmington & Hulme, 2012) of reading development, even after the effects of phonological ability have been controlled for. The role of automatic lexical access in RAN tasks has been investigated by measuring the speed with which children can name a visually presented series of common items (objects, colours or digits) (Wolf, Bally, & Morris, 1986). Several studies examining relatively transparent languages have shown that RAN is a more powerful predictor of early reading development than PA (Furnes & Samuelsson, 2010; Landerl & Wimmer, 2008; Lervåg, Bråten, & Hulme, 2009; Mann & Wimmer, 2002), or it becomes more powerful in expert readers (e.g., Vaessen & Blomert, 2010). Few studies have directly compared the role of RAN across orthographies. Georgiou et al. (2008) have found that colours-RAN significantly predicts reading fluency in Greek but not English. Mann and Wimmer (2002) showed a similar pattern of results among German and American children. In contrast, Ziegler et al. (2010) have found that the predictive power of objects-RAN on reading fluency is weak and not significantly modulated by orthographic transparency. Vaessen et al. (2010) proposed that such studies have failed to find similar effects of RAN across orthographies because the research investigating reading in opaque orthographies usually analyses accuracy scores; RAN, however, is measured using speed parameters. Therefore, the relationship between reading and RAN might be underestimated (see also Georgiou, Parrila, & Liao, 2008). This explanation, which is based on measurement-parameter incompatibility, is similar to the explanation given by the same authors to explain the weak relationship found between PA and reading fluency in transparent orthographies. Another explanation has been proposed by Georgiou et al. (2008), who suggest that the role of different RAN components (e.g., pause time and articulation) may govern the RAN-reading relationship across languages.

Multiple interpretations of the relationship between RAN and reading ability have been proposed. Bowers and Wolf (1993), for example, have suggested that slow naming speed could reflect a deficit in the ability to form orthographic representations of phonological elements. Assuming that a RAN deficit was problematic only when combined with a phonological deficit, they also hypothesised that slow naming speeds reflected a double deficit (Wolf & Bowers, 1999). Furthermore, they proposed an interaction between PA and RAN in predicting reading skills. However, this hypothesis seems to lack theoretical motivation and strong empirical validation (Bowey, 2005). Other researchers proposed that RAN reflects the efficiency with which phonological representations are retrieved (Bowey, 2005; Snowling & Hulme, 1994) or general cognitive speed (Kail & Hall, 1994). Recently, a variation on these proposals has been proposed by Lervåg and Hulme (2009). After performing a 3-year longitudinal study on Norwegian children, whom they observed from kindergarten through 2nd grade, they proposed that RAN relies on the same mechanisms as object recognition and naming. These processes, which involve left hemisphere brain circuits, are recruited to function as critical components of a child's developing visual word recognition ability. Several studies have sought to emphasise that the role RAN plays in digit- and letter-naming is different than the role it plays in colour- and object-naming. In fact, Cronin and Carver (1998) have shown that children's RAN of letters and digits significantly improves during the 1st grade as children become more familiar with alphanumeric item names. These results suggest that, in young children, the naming speed of letters and digits is confounded with knowledge of these items (Share, 1995). Pennington and Olson (2005) questioned the independence of PA's and RAN's influence on reading from a genetic perspective. In response, a study by Compton et al. (Compton, Davis, DeFries, Gayan, & Olson, 2001) showed significant correlations among PA, RAN and reading measures and also found that the correlation between reading and RAN was significant, even when the genetic influence of PA was controlled for.

2.1.3 Verbal short-term memory (VSTM)

Several studies have also found verbal short-term memory (VSTM) to be a predictor of word reading. For example, digit or word span have been shown to contribute significantly to reading performance in both typical (Dickerson Mayes, Calhoun, Bixler, & Zimmerman, 2009; McDougall, Hulme, Ellis, & Monk, 1994) and atypical (Miller-Shaul, 2005; Torgeson, Rashotte, Greenstein, Houck, & Portes, 1988) readers of opaque orthographies. In contrast, studies that have considered orthographically consistent languages suggest that VSTM plays only a marginal role for readers of these languages (Caravolas et al., 2012; Georgiou et al., 2008; de Jong & van der Leij, 1999; Nikolopoulos, Goulandris, Hulme, & Snowling, 2006; Wagner et al., 1994). This was also true for dyslexic children, who performed similarly to their reading age controls (e.g., de Jong, 1998).

Bowey (2005) proposed four interpretations of the link between phonological memory and reading. First, phonological memory could facilitate children's learning of the association between graphemes and phonemes. Second, it could allow them to store letter sounds in memory during the blending process. Third, it could reflect the quality of phonological representations. Finally, phonological memory may be mediated by verbal ability but make no specific contribution to word reading. McDougall et al. (1994) deeply analysed the relationship between VSTM and reading, concluding that VSTM is intimately related to both phonological skills and speech processing mechanisms.

2.1.4 Vocabulary

It has been argued that the predictive power of vocabulary on word reading may be significant (Nation & Snowling, 1998; 2004; Ouellette & Beers, 2010; Plaut, McClelland, Seidenberg, & Patterson, 1996), but several studies on young readers did not confirm this hypothesis (Muter et al., 2004; Ricketts, Nation, & Bishop, 2007; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Willows and Ryan (1986) have suggested that young readers become increasingly sensitive to semantic and syntactic features during their primary school years. Corroborating this hypothesis, Vellutino and colleagues (Vellutino, Tunmer, Jaccard, & Chen, 2007), using the Vocabulary and Similarities tasks from the WISC-R (Wechsler, 1974), found a stronger effect of semantic knowledge on context-free word identification in younger (2^{nd} and 3^{rd} graders), rather than older (6^{th} and 7^{th} graders), children. Vocabulary's capacity to predict reading ability may therefore shift between early and middle childhood (Muter et al., 2004). Furthermore, as Ouellette (2006) has demonstrated, vocabulary could influence reading skills to different degrees. For example, vocabulary knowledge seems to be more important for reading comprehension than for decoding (Muter et al., 2004; Nation & Snowling, 2004; Snow, Tabors, Nicholson, & Kurland, 1995). However, vocabulary knowledge could be particularly important in text reading because knowing the meaning of the words could help readers to understand the context and, consequently, to predict subsequent words, enabling them to read faster.

2.1.5 Visual search and visuo-spatial attention

Visual deficits are often used to explain poor reading ability and dyslexia. For example, several studies have found evidence of differences in visual search ability between poor and good readers (Casco & Prunetti, 1996; Casco, Tressoldi, & Dellantonio, 1998). These studies are based on the theory that reading difficulties arise from a deficit in visual selective attention (Slaghuis, Lovegrove, & Davidson, 1993; Valdois, Bosse, & Tainturier, 2004). Another theory, proposed by Facoetti and colleagues (Facoetti & Molteni, 2001; Facoetti et al., 2006), suggests that dyslexia is caused by a selective disorder of spatial attention characterised by left inattention and right over-distractibility. The question of whether visuo-spatial attention deficits are causally linked to dyslexic reading disorders has been thoroughly examined (e.g., Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Goswami, 2011; Vidyasagar & Pammer, 2010), but less is known about the effect of visuo-spatial attention on typical readers. Several studies have analysed the role of visual variables in predicting normal reading ability, finding significant effects in some instances (Brunswick, Martin, & Rippon, 2012; Ferretti, Mazzotti, & Brizzolara, 2008; Plaza & Cohen, 2007). Theories proposing that reading problems are caused by visual deficits have been widely criticised. As reported by Vellutino et al. (2004) in their review of dyslexia research, most of the studies comparing poor and normal readers across a broad age range have found few significant differences between normal and poor readers on measures of visual processing (visual memory, visuo-spatial attention, visual discrimination) when the influence of verbal coding was controlled for. In general, many researchers hypothesise that visual analysis of written words is mediated by language systems and especially by phonological processes (e.g., Frost, 1998; Share, 1995). Furthermore, sustained and executive attention deficits observed in dyslexic children were found to be mediated by the children’s phonological impairment (Marzocchi, Ornaghi, & Barboglio, 2009).

2.1.6 Reading strategies in Italian

Orsolini and colleagues (Orsolini, Fanari, Tosi, de Nigris, & Carrier, 2006) performed a longitudinal study on 28 Italian children from kindergarten through 2nd grade. The children’s word reading was tested three times: after 3 months and 7 months of reading instruction (1st grade) and in 2nd grade. The results showed that phonological reading develops from the conversion of small orthographic units (e.g., single graphemes) and advances to the recognition of whole words. By the end of 1st grade, the children's reading ability was homogenous, characterised by the ability to map a whole string onto a word form. Furthermore, the authors found length and frequency effects in the 1st graders, suggesting that both phonological decoding and lexical reading contribute to reading ability, even in 7-year-olds (see also Zoccolotti, De Luca, Di Filippo, Judica, & Martelli, 2009). In general, these findings indicate that proficient Italian readers begin to use lexical strategies after a few months of reading instruction, initially combining this strategy with phonological decoding, as suggested by the evidence of length and frequency effects in early readers. In later years, the lexical route becomes more efficient, as has been revealed by studies showing an increase in the differences between word and non-word reading (lexicality effect) and the gradual decrease of the difference between high and low frequency word reading when compared to non-word reading (Zoccolotti et al., 2009).

2.1.7 Aim of the study

The present cross-sectional study examines the contribution of several cognitive abilities to reading fluency in Italian primary school students. It also investigates differences in the ability of these aptitudes to predict reading fluency in younger (1^{st} and 2^{nd} graders) compared to older (3^{rd}, 4^{th} and 5^{th} graders) children. Based on the literature, we expect to find that

1) verbal-related skills (PA, RAN, VSTM and vocabulary) will be more powerfully predictive than variables containing a marked visual component (visual search, verbal-visual recall and visuo-spatial attention);

2) the effect of PA and RAN will be stronger than that of VSTM and vocabulary, for which the literature shows weaker evidence. However, based on the reading strategies in Italian described by the literature, we expect to find a significant effect of vocabulary in expert readers.

3) the effect of PA decreases with age and that RAN and vocabulary generally have a stronger effect in older children.

Gender differences are not expected to affect the predictive power of the variables.

2.2 Methods

2.2.1 Participants

Seven hundred and forty-five Italian children in grades 1 through 5 were recruited from 13 primary schools in Northern Italy. Children diagnosed with dyslexia (n = 20) were excluded from the study. Furthermore, 19 children with reading accuracy standard scores < -3 SD were eliminated from the sample. In addition, 48 children were excluded because their reading fluency was below the -1.5 SD cut-off established by the Italian norms (Cornoldi, Tressoldi, & Perini, 2010) of the MT Reading Test (Cornoldi & Colpo, 1998). Finally, seven children whose reading fluency was too fast (3 SDs above the mean) were considered outliers and were excluded from the sample. The final number of participants was 651 (51.3 % girls), of whom 114 were in the 1^{st} grade (49 % girls), 114 in the 2^{nd} grade (49.1 % girls), 198 in the 3^{rd} grade (55.6 % girls), 104 in the 4^{th} grade (43.3 % girls) and 121 in the 5^{th} grade (57 % girls). The gender information was missing for 60 participants; the percentages reported for gender are adjusted to account for this missing data. No measure of IQ was used to select the sample.

2.2.2 Measures

<u>Reading ability</u>

Reading ability was examined using a standardised Italian text-reading test (MT Reading Test; Cornoldi & Colpo, 1998). Participants were asked to read a text aloud within a 4-minute time limit. Only the fluency (syllables/second) score was analysed. The number of errors was not considered due to the ceiling effect of reading accuracy; 93.5 % of the sample obtained a standard score ± 1 SD. Reading fluency raw scores were converted to *z* scores according to the Italian norms (Cornoldi et al., 2010). Because the children were tested at different times during the school year, the text administered within each grade could vary. In fact, the MT Reading Test provides two different passages for Grade 1 (mid and end of the year), three passages for Grades 2 and 3 (beginning, mid and end of the year) and two passages for Grades 4 and 5 (beginning and end of the year).

Vocabulary

A vocabulary subtest from the Italian version of the WISC-III (Wechsler, 2006) was administered.

This task measures lexical knowledge and, more specifically, the ability to retrieve a word's meaning and provide an accurate definition. Participants were asked to orally define 30 stimulus words presented by the examiner; the words increased in difficulty and abstraction as the test progressed. Each child received a score of zero, one or two points for each item based on the quality of the definition given. The score can range from 0 to 60.

Phonological awareness (PA)

Phonological awareness was measured using the phoneme- and syllable-blending subtests of the PRCR-2 learning prerequisites battery (Cornoldi, Miato, Molin, & Poli, 2009). In the blending phonemes subtest, the examiner enunciated a word's individual phonemes one at a time and then asked the child to produce the entire word. The task was composed of 14 words ranging between 4 and 10 phonemes. One point was given for each correct blend of phonemes. The score can range from 0 to 52. In the blending syllables subtest, the examiner enunciated a word's individual syllables and asked the child to produce the entire word. The task was composed of 10 three-syllable words. Two points were given for producing the entire word and one point for blending at least two syllables. The maximum score is 20.

Rapid automatised naming (RAN)

RAN was assessed using the colour-naming and picture-naming tasks included on De Luca and colleagues' RAN Battery (De Luca, Di Filippo, Judica, Spinelli, & Zoccolotti, 2005). Two 5x10 stimuli matrices were used for each task (colour- and picture-naming). The time required for the child to name all of the items in each matrix was recorded. Recording began when the child started to name the first item and ended when the child named the last item. Then, the two time intervals recorded for each type of matrix were summed to yield a colour-naming score and a picture-naming score, both expressed in seconds. The decision to use only colour- and picture-naming to evaluate automatic processing efficiency was based on evidence suggesting that letter- and digit-naming performance can be confounded with letter/digit knowledge (Share, 1995).

Verbal short-term memory (VSTM)

Verbal short-term memory was measured by four memory-span tasks. In these tasks, the examiner presented two lists, one of digits (WISC-III subtest; Wechsler, 2006) and one of syllables (Carenini, Gremizzi, & Marzocchi, 2006). Each syllable list contained between 2 and 7 items; each digit list contained between 2 and 9 items. The child was asked to repeat each group of items forward and backward. Testing was stopped when both trials of a given length were repeated incorrectly. For each task, the number of correct trials was calculated.

Visual search

A cancellation test was administered to evaluate visual search ability. In this test, designed specifically for this study, the child was asked to cancel 1 of 9 stimuli as quickly and accurately as possible. The stimuli were non-verbal shapes similar to letters in dimension and orientation and were produced with equal quantities of ink. A trial matrix and three test matrices were presented to the child. The stimuli's distance and dimensions differed among the test matrices. In the practice trial, the target stimuli were presented 20 times in a row and the child was asked to cancel all of them; the time required to complete this task was used as a baseline. False positives, omissions and the difference between the time needed to complete the test task and the baseline (correct time) were measured separately for each matrix. The mean of the three correct times was the variable considered in the analysis.

Verbal-visual recall

Two 4x4 matrices were created using 32 pictures selected from the 260 proposed by Snodgrass & Vanderwart (1980). The pictures selected represented common and early-acquired words (between 2.7 and 3 years old); the two matrices were balanced in terms of the age of acquisition of the words represented by the selected pictures (Nisi, Longoni, & Snodgrass, 2000). The examiner named the pictures, and the child was asked to recall them randomly after one minute of exposure. One point was given for each correct recall, and points were summed separately for the two matrices; the mean score of correct recalls for each matrix was then calculated. The maximum score is 16 (the mean performance of both matrices).

Visuo-spatial attention

The attention-orienting task proposed by Facoetti and Molteni (2001) was administered. The child sat in front of a monitor screen. The fixation point was a cross presented in the middle of the screen at a visual angle of 0.5°. The target was a white dot of 0.5° (SOA: 500 msec). This target could appear at three different distances (3°, 6°, or 9° visual angles) from the fixation point along the horizontal axis. It could also appear in the left or in the right visual field. The child was instructed to press the space bar on the keyboard as fast as possible at the onset of the target, and the reaction times were recorded. The mean score of the reaction times for each distance per side was calculated (six mean scores: 3°, 6° and 9° visual angles on the right; 3°, 6° and 9° visual angles on the left).

2.2.3 Procedure

The tests were administered to each child individually in a quiet room at his/her school and in one-hour sessions. The order in which the single subtests were presented was counterbalanced across participants.

2.2.4 Statistical Analysis

Comparisons by gender and grade were carried out using a 2x5 (from 1st to 5th grade) ANOVA design on individual scores (reading fluency, vocabulary, phoneme blending, visual search, verbal-visual recalland visuo-spatial attention) or on composite measures obtained from different tasks evaluating the same construct. The composite scores were obtained by calculating the mean scores of all RAN and VSTM measures. When the ANOVA tests yielded a main effect of gender, single *t*-tests were run to analyse gender differences at each grade level.

A hybrid model (Goldberger & Duncan, 1973) combining confirmatory factor analysis (CFA) with path analysis and containing a maximum-likelihood (ML) estimator was applied using MPlus (Muthén & Muthén, 1998-2010). The model was run on the *z* scores calculated for each grade group to control for age effect. The *z* scores for reading fluency referred to the Italian norms (Cornoldi et al., 2010). The decision to use norm-based *z* scores for reading fluency arose from the need to control for grade and for the text read by each group of children. The model was run separately on 1st and 2nd graders and 3rd, 4th and 5th graders to analyse the effect of age on the predictive power of the cognitive abilities previously tested. The CFA identified RAN, VSTM and visuo-spatial attention latent variables. A path analysis was used to examine the relationships between the dependent variable (norm-based reading fluency *z* scores) and the potential predictors. Variables that had low correlations (r = < .2) with reading fluency were excluded by the hybrid models. Vocabulary, visual search, verbal-visual recall and visuo-spatial attention were excluded by the model that considered 1st and 2nd graders; visual search and visual memory were excluded by the model that considered 3rd, 4th and 5th graders. Multiple indices were used to evaluate model fit: the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), the Tuker-Lewis Index (TLI) and the Standardised Root Mean Squared Residual (SRMR). An RMSEA result of no greater than 0.06, CFI and TLI results of 0.95 or better and an SRMR result of less than 0.08 suggest good model fit for the ML estimator (Hu & Bentler, 1999). All of the analyses, with the exception of the hybrid model, were conducted using SPSS 15.0 (SPSS Chicago, IL).

2.3 Results

The results are presented in three sections. First, we report the descriptive statistics for the cognitive ability and reading measure raw scores and their interrelations. In the second section, gender and grade difference comparisons are provided. Finally, we present the results obtained using the hybrid model to examine the predictive power of the cognitive abilities.

The descriptive statistics of the cognitive and reading variables for grades 1 through 5 are shown in Table 2.1. The syllable-blending task showed a ceiling effect (83 % of participants obtained the maximum score) and was therefore not further analysed.

The correlations among the variables are given in Table 2.2. The correlations for Grades 1 and 2 are presented separately from those for Grades 3, 4 and 5.

		Mean (standard deviation)							
Tasks	Range	1st	2nd	3rd	4th	5th	Total sample	Skewness (s.e. .096)	Kurtosis (s.e. .191)
Reading fluency (syll/sec)	.18 –5.84	.92 (.53)	1.86 (.72)	2.93 (.81)	3.40 (.76)	3.71 (.70)	2.61 (1.21)	-.101	-.871
Reading fluency (norm-based z-score)	-1.46 – 2.67	-.42 (.66)	.02 (.93)	-.13 (.69)	-.03 (.67)	-.01 (.60)	-.12 (.73)	.642	.354
Vocabulary	5 – 50	18.44 (7.15)	21.36 (7.33)	29.41 (7.95)	32.65 (7.80)	35.93 (6.20)	27.81 (9.68)	-.216	-1.042
Phoneme blending	5 – 52	29.75 (13.28)	29.75 (10.79)	41.08 (9.08)	37.78 (10.36)	43.15 (8.05)	36.97 (11.64)	-.581	-.531
Syllable blending	8 – 20	19.35 (1.67)	19.41 (1.39)	19.67 (1.07)	19.77 (.61)	19.89 (.40)	19.62 (1.14)	-4.927	32.687
RAN colors (sec.)	40.12 – 265	123.08 (31.39)	106.59 (21.80)	91.64 (24.49)	86.26 (16.88)	78.55 (17.19)	96.47 (27.59)	1.686	5.157
RAN pictures (sec.)	56 – 259.72	121.21 (30.26)	109.66 (23.44)	93.21 (17.92)	88.12 (15.72)	80.93 (17.03)	97.90 (25.30)	1.748	6.136
RAN colors+pictures	52.09 – 221.00	122.14 (28.39)	108.12 (21.09)	92.42 (20.27)	87.19 (15.46)	79.74 (16.35)	97.18 (25.28)	1.549	4.206
Digit forward	4 – 15	6.43 (1.49)	6.58 (1.64)	7.48 (1.82)	7.72 (1.94)	7.91 (2.10)	7.29 (1.90)	.672	.468

continue

Digit backward	0 – 12	3.09 (1.06)	3.45 (1.04)	4.27 (1.36)	4.36 (1.41)	4.69 (1.65)	4.01 (1.45)	.994	2.006
Syllable forward	1 – 12	3.39 (.92)	3.93 (1.04)	4.32 (1.21)	4.53 (1.04)	4.49 (1.30)	4.15 (1.19)	.653	3.144
Syllable backward	0 – 6	2.05 (.65)	2.41 (.75)	2.57 (.86)	2.78 (.82)	2.87 (.97)	2.54 (.86)	.911	1.642
Memory total	2 – 9	3.74 (.71)	4.09 (.81)	4.66 (.90)	4.85 (.94)	4.99 (1.17)	4.49 (1.02)	.752	1.068
Visual search	-38.45 – 127.8	44.33 (16.66)	45.36 (15.62)	33.03 (10.71)	31.01 (11.35)	27.70 (10.16)	35.30 (14.91)	.893	4.768
Verbal-visual recall	0 – 15.5	8.60 (2.07)	9.10 (2.09)	10.46 (1.96)	10.76 (1.94)	11.44 (1.59)	10.13 (2.18)	-.265	.451
Visuo-spatial attention (msec.)*	216 – 881.88	399.13 (82.85)	415.51 (107.27)	350.14 (82.70)	328.98 (70.92)	296.48 (67.93)	358.99 (93.34)	1.393	2.735

Table 2.1 - Mean raw scores and standard deviations for the cognitive processes evaluated, on the total sample and on the sample divided per grade level.
N = 651
* N = 612

A) Grade 1& 2	1.Reading fluency (syll/sec)	2	3	4	5	6	7	8	9	10	11	12	13
2.Vocabulary	.191												
3.Phoneme blending	.253	.201											
4.RAN colors	-.466	-.167 [a]	-.214										
5.RAN pictures	-.356	NS	-.233	.725									
6. RAN mean	-.443	-.153	-.241	.930	.927								
7.Digit forward	NS	.195	.344	NS	NS	NS							
8.Digit backward	.192	.177	NS	-.138 [a]	NS	-.132 [a]	.392						
9.Syllable forward	.155 [a]	.210	.150 [a]	NS	-.130 [a]	NS	.366	.296					
10.Syllable backward	.182	.223	NS	-.152 [a]	-.141 [a]	-.158 [a]	.246	.245	.396				
11. Memory mean	.215	.278	.275	-.131 [a]	-.170	-.162	.810	.690	.701	.567			
12.Visual search	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
13. Verbal-visual recall	.181	.237	.168 [a]	-.227	-.225	-.243	NS	NS	NS	NS	NS	NS	
14.Visuo-spatial attention	NS	NS	NS	.144 [a]	.185	.177	NS	NS	NS	NS	NS	NS	NS

continue

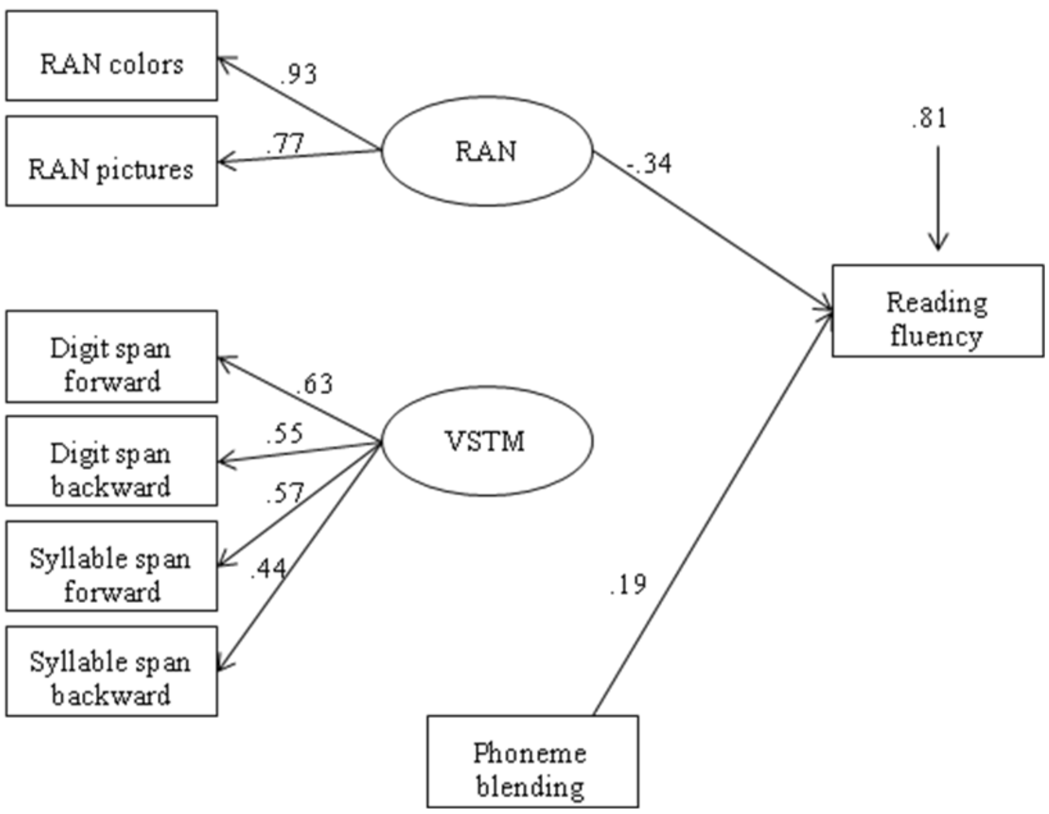
B) Grade 3, 4 & 5	1.Reading fluency (syll/sec)	2	3	4	5	6	7	8	9	10	11	12	13
2.Vocabulary	.379												
3.Phoneme blending	.328	.267											
4.RAN colors	-.319	-.209	-.188										
5.RAN pictures	-.365	-.236	-.224	.825									
6. RAN mean	-.357	-.232	-.215	.960	.951								
7.Digit forward	.224	.286	.272	-.136	-.174	-.162							
8.Digit backward	.279	.245	.236	-.227	-.274	-.261	.424						
9.Syllable forward	.191	.221	NS	NS	NS	NS	.408	.249					
10.Syllable backward	.206	.233	.124[a]	-.138	-.146	-.148	.344	.341	.326				
11. Memory mean	.314	.344	.241	-.206	-.240	-.232	.760	.705	.691	.705			
12.Visual search	-.165	NS	-.126	.180	.229	.212	NS	-.128	NS	NS	NS		
13. Verbal-visual recall	.168	.163	.192	-.210	-.280	-.255	NS	.168	NS	.126	.114[a]	NS	
14.Visuo-spatial attention	-.316	-.136	-.225	.182	.259	.231	NS	-.140	.162	NS	NS	.230	-.161

Table 2.2 – Pearson correlations for grade 1 and 2 (A) and for grade 3, 4 and 5 (B)
All the correlations are significant at $p < .01$;
[a] = significant at $p < .05$; NS = non significant

Eight 2x5 ANOVAs were performed on all of the variables considered in the present study: reading fluency, PA, RAN, vocabulary, VSTM, visual search, verbal-visual recall and visuo-spatial attention. A significant main effect of gender was found only for visuo-spatial attention (*F*(1,542) = 8.754, p < .01), with males responding more quickly than females. Single *t*-tests showed that males performed significantly better than females only in Grades 3 (*t*(143.857) = -1.978, p = .05) and 4 (*t*(69.298) = -3.604, p = .001). Otherwise, significant grade differences were found for all of the variables considered. A general linear improvement was found for reading fluency (*F*(4,581) = 264.296, p < .001), vocabulary (*F*(4,581) = 105.159, p < .001), phoneme blending (*F*(4,581) = 37.712, p < .001), RAN (*F*(4,581) = 70.655, p < .001), VSTM (*F*(4,581) = 34.351, p < .001), visual search (*F*(4,581) = 47.493, p < .001), verbal-visual recall (*F*(4,581) = 40.742, p < .001) and visuo-spatial attention (*F*(4,542) = 31.084, p < .001). Bonferroni post-hoc analyses showed significant improvements in reading fluency for each grade. Students performed similarly on vocabulary, phoneme blending and visual tasks in 1st and 2nd grade, but a significant improvement was shown in 3rd grade. Finally, RAN and VSTM showed significant improvement up to 3rd grade. For phoneme blending, RAN, VSTM and all of the visual variables, the improvement became less pronounced in older children (the improvement between 3rd and 5th grade is significant; the improvement between 3rd with 4th and 4th with 5th grades is not). None of the interactions between gender and grade were significant.

Figure 1 describes the simplified model fitted to the data obtained from two separately considered groups: 1st and 2nd graders and 3rd, 4th and 5th graders. The values presented are standardised parameters. The first model (Figure 1*A*) shows only two significant predictors of reading fluency in younger children: RAN and PA. This model accounts for approximately 19 % of the variance. Figure 1*B* describes the model fitted to the older children's data. In this case, all of the variables considered significantly predict reading fluency, and the model accounts for 25 % of the variance. Both models have good fit indices according to the requirements proposed by Hu and Bentler (1999). Correlations between the unique variances of some variables, chosen using MPlus's (Muthén & Muthén, 1998-2010) modification indices, were allowed. Such minor structural modifications can improve model fit by increasing the proportion of explained variance without changing the key conclusions about the adequacy of a hypothesised structure in the description of the data (Bollen, 1989). The correlations suggested by the modification indices are reported in Figure 2.1.

A



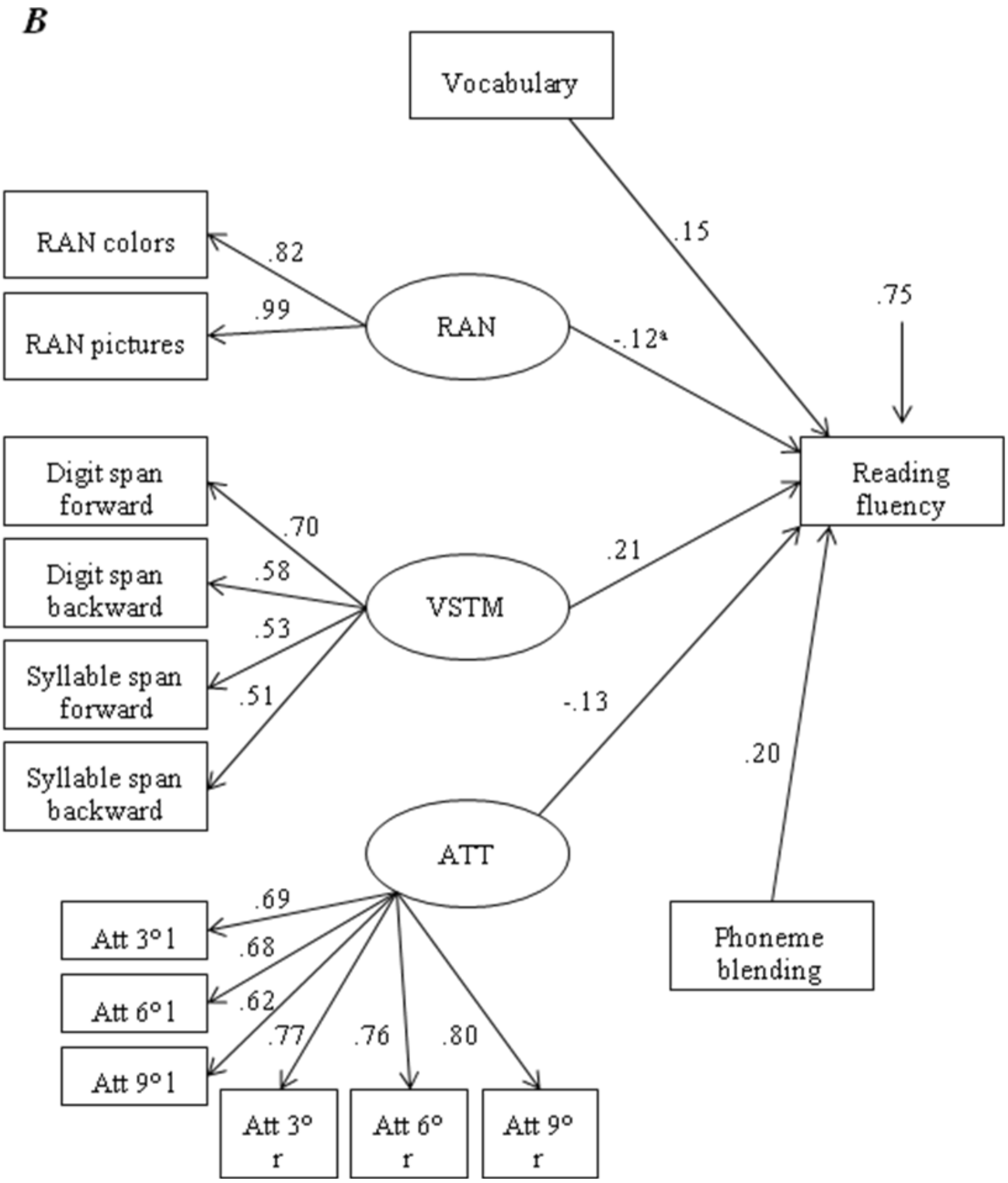


Figure 2.1 - Hybrid models predicting reading fluency on children at 1st and 2nd grade ***(A)*** and on 3rd , 4th and 5th grade ***(B)***.
RAN = rapid automatised naming; VSTM = verbal short-term memory ; ATT = visual attention; l = left; r = right.
Arrows represent significant relationships at p<.01; (a p = .015); missing arrows represent non significant relationships. The arrow above the "Reading fluency" square represents the residual variance for the dependent variable.
Correlations are omitted for clarity of presentation.
Fit indices are as follows: ***(A)*** RMSEA = .035 (90 % CI = .000 - .076); CFI = .988; TLI = .977; SRMR = .032 ***(B)*** RMSEA = .038 (90 % CI = .025 - .050); CFI = .975; TLI = .967; SRMR = .048.
Correlations between unique variances suggested by modification indices: ***(A)*** Phoneme blending with Digit span forward and VSTM ***(B)*** VSTM with vocabulary and phoneme blending.

2.4 Discussion

This study aimed to identify concurrent predictors of reading fluency in Italian primary school students. According to the orthographic depth continuum described by Seymour et al. (2003), Italian is a shallow language, indicating that the correspondence between the phonemes of spoken words and graphemes is direct and unequivocal (Frost, Kats, & Bentin, 1987). We tested the contribution to reading fluency of well-investigated cognitive processes, including phonological awareness (PA) and rapid automatised naming (RAN), and more controversial variables, such as verbal short-term memory (VSTM) and vocabulary. To participate in the debate about the extent of the role of visual variables in reading performance, we also considered , visual search, visuo-spatial attention and a multimodal recall task, verbal-visual recall, as possible contributors to reading fluency. We decided to focus our study on children with typical reading development because of the important distinction between predictors of good and poor reading. Our dependent variable was reading fluency because reading accuracy, as previous findings on transparent orthographies have indicated (e.g., Landerl & Wimmer, 2008; Zoccolotti et al., 2009), shows a ceiling effect.

2.4.1 Concurrent predictors of reading in Italian

Our model was tested using two data sets: 1st and 2nd graders and 3rd, 4th and 5th graders. All of the fit indices showed a good fit. The results are partially consistent with our predictions: we confirmed that individual differences in PA and RAN predict reading fluency. Furthermore, as we hypothesised, VSTM and vocabulary were weak but significant predictors. We also found that the role of predictors changes as readers become more skilled, but the nature of this change differs from that predicted in our hypothesis. Although reading is an automatic process in skilled readers, in non-expert readers it depends on the effortful coordination of perceptual and linguistic processes. Based on previous literature (e.g., de Jong

& van der Leij, 1999; Leppänen et al., 2003; Schatschneider et al., 2004), we hypothesised a decreasing effect of PA and an increasing effect of RAN with reading development. This hypothesis is based on a consideration clearly expressed by Vaessen et al. (2010):

> "A recent study of Vaessen and Blomert (2010) demonstrated that the shift from phonological decoding to automatic word recognition is accompanied by a concomitant gradual shift in the relative importance of the cognitive skills underlying reading. Phonological awareness was related to word reading fluency until the sixth grade, but its contribution to reading fluency was much stronger in beginning phases of reading development, when children rely heavily on phonological decoding strategies. In contrast, the contribution of rapid automatized naming was modest in beginning readers but gradually increased as a function of reading experience." (p. 828)

However, our data showed a different pattern: the RAN coefficient was approximately half the value in the model based on data obtained from older children than the value obtained for younger children. In contrast, PA was substantially similar in the second model. Moreover, RAN was shown to be a stronger predictor than PA in younger children. This result corroborates previous findings that RAN is more important than PA in predicting early reading in transparent orthographies, such as Dutch and Norwegian/Swedish (e.g., de Jong & van der Leij, 1999; Furnes & Samuelsson, 2010). However, the predominance of RAN fades for 3rd-5th graders. In this group, PA and VSTM are the most important independent predictors of reading fluency. The significant role played by PA in both models is consistent with past studies (Caravolas et al., 2005; Vaessen et al., 2010; Ziegler et al., 2010) in which this variable was a strong predictor of individual differences in reading skills across several languages. In accordance with Caravolas et al. (2005), we measured PA using a phoneme blending task, which is considered a representative task for primary school children (Schatschneider, Francis, Foorman, Fletcher, & Mehta, 1999). The task was sufficiently sensitive and did not reveal a ceiling effect. This could explain the robust effect found for PA in primary school. Explaining the decreasing effect of RAN between the two models is more complicated because most of the literature has only analysed reading predictors in children up to 2nd grade. Our results for early readers agree with those found by de Jong and van der Leij (1999) for Dutch children or Furnes and Samuelsson (2010) for Norwegian/Swedish children: RAN is the best predictor of reading fluency for a transparent orthography. If we consider Lervåg and Hulme's (2009) interpretation of this result, this suggests that the neural circuits involved in object identification and naming are "recycled" to support visual word recognition and naming. The significant effect of RAN in younger children therefore implies that, parallel to phoneme-grapheme decoding, Italian children in Grades 1 and 2 quickly introduce another reading strategy based on entire-word recognition. This result reflects the outcomes of previous studies on reading strategies in Italian (Orsolini et al., 2006; Zoccolotti et al., 2009). In this study, 1st graders were not tested before January, and it is therefore possible that children were already able to recognise strings corresponding to high-frequency words and to use this strategy to supplement phonological decoding.

Our results differ from studies that have shown an increasing effect of RAN, a stronger effect of RAN than of PA (Landerl & Wimmer, 2008), or both (Vaessen & Blomert, 2010; Vaessen et al., 2010) in expert readers. However, to explain the weaker effect of RAN in expert readers (3rd through 5th graders), we should also consider the interference of other variables that, according to the results, were significant predictors of text reading fluency. In addition to RAN and PA, we found a significant effect of vocabulary, VSTM and visuo-spatial attention. We believe that the effect of vocabulary can be attributed to the type of reading task chosen; when reading a text, the effect of vocabulary is stronger than in a single-word reading task because the sentence structure and the context of the passage provide clues to the reader. Because older children know a greater number of words, as indicated by the linear increase of vocabulary scores, they could use this lexical knowledge to anticipate the next word in a sentence they are reading. Furthermore, the vocabulary subtest is highly correlated with verbal intelligence and abstraction abilities (Orsini & Picone, 2006; Wechsler, 2006), both of which are important resources for text reading. In addition, the role of VSTM, which was found to be significant in some studies considering both typical and poor reading in inconsistent orthographies (Dickerson Mayes et al., 2009; McDougall et al., 1994; Miller-Shaul, 2005; Torgeson et al., 1988) but was only marginally significant in studies on transparent orthographies (e.g., Georgiou et al., 2008; de Jong & van der Leij, 1999), had a significant effect on reading fluency in our older sample. In this study, VSTM was considered a latent variable and was measured using four tasks that combined two types of stimuli (digits and syllables) and two sets of instructions (forward and backward recall). This strategy differs from that used in previous studies examining transparent orthographies, making comparison difficult. Furthermore, most of the previous studies tested only younger children. Considering the nature of the reading task administered, VSTM may have supported the role of vocabulary in anticipating upcoming words in a sentence by maintaining the previous words in short-term memory. This interpretation associates the significant predictive power of VSTM with the specific measure used in this study (passage reading fluency) without generalising to word or pseudo-word reading fluency or reading accuracy.

We also found that visuo-spatial attention significantly predicts reading fluency in older children. Some authors firmly assert that visual attention difficulties greatly influence the performance of poor readers and dyslexics (e.g., Facoetti & Molteni, 2001). In a recent study, Franceschini et al. (2012) documented the predictive power of visuo-spatial pre-reading measures on text reading in Grades 1 and 2, introducing new considerations into the debate on reading predictors. However, the nature of the sample (typical readers) and of the visuo-spatial perception task used in this study render our results irrelevant to this debate. Furthermore, we considered RTs, which could reflect a more general measure of automatic processing speed in the visual motor domain because there is a relationship between the processing speed of visuo-spatial stimuli and reading fluency in Italian. The significant predictive power of visuo-spatial attention for 3^{rd}-5^{th} graders should be further analysed in both typical and atypical readers using a broader set of tasks to identify the various effects of visuo-spatial perception.

To explain the results obtained for expert readers, it is important to recognise the complex scheme of abilities involved in text reading fluency. The decreasing effect of RAN could be caused by the emergence of vocabulary and VSTM as significant predictors during this developmental stage of reading. While the PA effect confirms the use of decoding strategies, which are thought to be used to read low-frequency words, left-hemisphere naming circuits also support rapid naming of visually recognised words. In parallel, vocabulary and VSTM abilities allow readers to take advantage of the text's meaning and syntactic structure to anticipate upcoming words. It is possible that anticipation based on sentence structure and meaning sometimes negates the need for RAN.

Finally, all of the other visual processing variables were omitted from the hybrid models because of their low correlations ($r = < .2$) with the reading fluency z scores. This result agrees with the results of previous studies that have cast doubt on the role of visual processes as independent predictors of reading (e.g., Vellutino et al., 2004).

2.4.2 Age and gender differences in the variables considered

All of the cognitive processes examined showed a clear developmental trend. In particular, reading fluency and vocabulary showed a linear, significant improvement across the five grades, replicating the results of previous studies (e.g., for typical readers of Italian orthography: Tressoldi, Stella, & Faggella, 2001; e.g., for WISC Vocabulary subtest: Orsini & Picone, 2006). In contrast, phoneme blending and all of the visual variables yielded similar scores in Grades 1 and 2, although they did not reach a floor effect (see Table 2.1 for raw scores, ranges and means). Finally, RAN and VSTM showed a significant improvement up to 3rd grade and continued to improve in the following years at a slower rate, a result partially demonstrated in past studies (e.g., for RAN: De Luca et al., 2005; e.g., for VSTM: Gathercole, Pickering, Ambridge, & Wearin, 2004). Generally, these results describe a linear improvement during primary school for all of the cognitive processes examined. Though each of the processes follows a different trend, the improvement continues up to 5th grade, indicating that these abilities are still developing in 10-year-old readers.

There was no significant effect of gender on the tested parameters, with one exception: males performed better than females in the visuo-spatial attention task in Grades 3 and 4. This result is consistent with other studies suggesting that gender differences in visuo-spatial cognition exist (e.g., Feng, Spence, & Pratt, 2007; Voyer, Voyer, & Bryden, 1995). Despite this exception, the manifestation of this effect only in the 3rd and 4th grades and not before or later is an unusual development pattern that requires further and specific investigation.

2.4.3 Limitations of this study

An important limitation of this study is its cross-sectional nature, which prevents it from establishing causal links in reading development. A longitudinal study would be the best way to create reading development prediction models. We could then develop a latent variable measured by different types of PA tasks, as we had initially planned. In particular, it would be better to administer more complex PA tests using phonemes rather than syllables. This would facilitate a more reliable analysis of meta-phonological competence in school-aged children. Finally, the models we tested accounted for a low proportion of the variance in reading fluency, indicating that there are other important cognitive processes not considered in this study that are related to reading development in primary school.

2.4.4 Conclusions

The current study has confirmed that PA and RAN are influential predictors of reading fluency in Italian orthography for good readers throughout primary school. Furthermore, two additional verbal abilities and the attention function play a significant role in the reading abilities of third, fourth and fifth graders: vocabulary, VSTM and visuo-spatial attention. This result is in partial agreement with previous studies that used word and non-word reading tasks to investigate Italian reading strategies. The additional elements that emerged in our study seem to depend on the nature of the reading task used: text reading is a complex task that involves not only word-level decoding and lexical strategies but semantic and syntactic processes that may support fluent reading. We speculate that this model could be generalised to text reading in various alphabetic orthographies, although the weight of each predictor would be modulated by orthographic transparency.

"We are absurdly accustomed to the miracle of a few written signs being able to contain immortal imagery, involutions of thought, new worlds with live people, speaking, weeping, laughing. [...] What if we awake one day, all of us, and find ourselves utterly unable to read?

I wish you to gasp not only at what you read but at the miracle of its being readable."

Vladimir Nabokov

CHAPTER 3 - Cognitive profiles of Italian children with Developmental Dyslexia

3.1 Introduction

Learning to read fluently is an extremely complex operation that requires the integration of multiple cognitive processes: it requires visual recognition of letters; phonological skills to sound out written syllables and phonemes using grapheme-phoneme mapping; memory and lexical skills to quickly recognise words; and knowledge of syntactic and semantic rules to access meanings. Despite its complexity, most children easily learn to read and spell in the early years of schooling. However, small numbers have extraordinary difficulty in learning to read because of a congenital disorder that affects the cognitive traits necessary for reading proficiency (Pennington & Olson, 2005). Developmental dyslexia (DD) is a specific deficit that affects reading ability in the presence of an IQ in the average range and that cannot be accounted for by sensory or neurological damage or by poor educational opportunities (American Psychiatric Association, 2000; World Health Organization, 2004).

Despite the universal neurocognitive basis, behavioural manifestations of DD have a culturally based variability (Caravolas, 2005; Paulesu et al., 2001; Ziegler & Goswami, 2005). The type of orthography that the child is acquiring is a primary cultural factor that influences reading acquisition in both typical and atypical development. In fact, the consistency of orthographic mapping between written symbols and units of sounds varies with the language (Seymour, 2005; Seymour, Aro, & Erskine, 2003). As illustrated by Seymour (2005; see also Share, 2008; Ziegler & Goswami, 2005), the process of learning to read in consistent writing systems such as Italian or German is easier than learning to read opaque systems with high proportions of irregular spellings, such as English or French. Based on this observation, we might expect that children with DD would be advantaged by a writing system that provides regular relationships between letters and phonemes (Hulme & Snowling, 2009; Ziegler & Goswami, 2005). Some studies support this hypothesis (see Landerl, 2006 for a review).

Recently, a great deal of research has been generated on this topic. A specific question that has emerged is whether the cognitive skills necessary for reading acquisition vary among different orthographies or whether they are mainly similar (e.g., Caravolas et al., 2012; Moll et al., 2014; Vaessen et al., 2010; Ziegler et al., 2010; for Italian orthography: Di Filippo et al., 2005; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Tobia & Marzocchi, 2013). As a neuro-developmental disorder, DD affects the cognitive abilities that underlie reading skills. Although the characteristics of the behavioural expression of dyslexia are generally well accepted, DD's underlying neurocognitive deficits remain a matter of debate: it has been considered that the neurocognitive processes underpinning reading ability may be differently involved in producing symptoms of DD, depending on orthographic transparency (Landerl & Wimmer, 2000; Landerl, Wimmer, & Frith, 1997; Landerl et al., 2013).

3.1.1 Cognitive deficits in developmental dyslexia

Currently, there is strong and highly convergent evidence that the key deficit in DD lies within the language system and that, in particular, it involves a lower-level component, phonology, which has been defined as the ability to access the underlying sound structures of words (Ramus et al., 2003; Scarborough, 1990; Snowling, 2000; Swan & Goswami, 1997). The results from different populations with dyslexia showed that they frequently perform below the level of typical readers on phonological awareness, a term used to refer to the wide range of skills involved in discriminating and manipulating the sounds of speech (Adams, 1994; Bowey, 1994; Wagner & Torgesen, 1987), and it has been clearly demonstrated that phonological deficits represent the most reliable and specific correlate of DD in children (Beaton, 2004; Blachman, 2000; Fletcher et al., 1994; Morris et al., 1998; Ramus, 2003;

Snowling, 2000; Snowling & Hulme, 2012a; Stanovich & Siegel, 1994; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Vellutino & Scanlon, 1987). Furthermore, several studies have confirmed that training and interventions designed to facilitate phonological awareness and letter-sound mapping have a positive effect on reading ability (Hatcher, Hulme, & Ellis, 1994; Scanlon, Vellutino, Small, Fanuele, & Sweeney, 2005; Vellutino et al., 1996; for a recent review: Snowling & Hulme, 2011). Finally, evidence of a phonological deficit in dyslexia comes also from electrophysiological, anatomical and neuroimaging studies (Blau, van Atteveldt, Ekkebus, Goebel, & Blomert, 2009; Dougherty et al., 2007; Paulesu et al., 2001; Rumsey et al., 1992; for a review: Habib, 2000; Ramus, 2004). Poor phonological awareness, reflected by tasks such as syllable or phoneme segmentation and blending, may therefore hinder the acquisition of the alphabetic principle and lead to reading difficulties (Frith, 1985; Snowling, 1995). However, as was originally noted by Tunmer and colleagues (Tunmer, Herriman, & Nesdale, 1988), “phonological awareness is necessary but not sufficient for acquiring phonological recoding skill” (p. 150). The phonological deficit hypothesis (Frith, 1997; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; Snowling, 1987; Wilding, 1989, 1990), which holds that DD results from an underlying phonological impairment, accounts for a wide range of behavioural symptoms associated with dyslexia. It refers to the role of phonological awareness but also to other speech-based functions: in particular, phonological deficits could also involve lexical retrieval and verbal short-term memory (Wagner & Torgesen, 1987).

Evidence of slow lexical retrieval in children with dyslexia has been found in a large number of studies (Ackerman & Dykman, 1993; Denckla & Rudel, 1976; de Jong & van der Leij, 2003; Landerl et al., 2013; Wimmer, 1993; Wolf & Bowers, 1999; Wolf, Pfeil, Lotz, & Biddle, 1994; for a review: Wolf, Bowers, & Biddle, 2000), using rapid automatised naming (RAN) tasks, which measure the speed with which children can name a visually presented series of common items, such as objects, colours, letters or digits (Wolf, Bally, & Morris, 1986). Although RAN and phonological awareness correlate with each other, there is evidence that the two skills utilise distinct processes (Bowers & Wolf, 1993; Compton, Defries, & Olson, 2001; Kail & Hall, 1994; Lervåg and Hulme, 2009; Wolf et al., 2000), and they can consequently contribute independently to DD (Manis, Doi, & Bhadha, 2000; van Bergen et al., 2011; Wimmer, Mayringer, & Landerl, 2000; Wolf et al., 2000; for a review: Vellutino et al., 2004). The double-deficit hypothesis (Wolf & Bowers, 1999) suggests that deficits in phonological processing and RAN are separable causes of reading difficulties and that deficits in phonological processing and RAN combined have an additive negative influence on reading performance above and beyond that of a single deficit.

Difficulties with verbal memory have been reported in many studies on children with DD (Avons & Hanna 1995; Landerl et al., 2013; McDougall, Hulme, Ellis, & Monk, 1994; Miller-Shaul, 2005; Ramus & Szenkovits, 2008). In particular, impairment on tasks that require implicit phonological processing, such as those evaluating verbal short-term memory, has been identified most clearly in transparent orthographies such as Italian or German (Wimmer, Mayringer, & Landerl, 1998; Vellutino et al., 2004). Given the well-demonstrated difficulties of dyslexics with phonological awareness, whether verbal short-term memory deficits are connected to poor phonological processing—and, if so, how—has been discussed. An alternative explanation is that basic short-term memory processes are impaired in children with DD. The first hypothesis is supported by two main findings: first, most studies that have reported memory deficits only considered verbal material and not visuo-spatial stimuli (McDougall et al., 1994; Swanson, Ashbaker, & Lee, 1996; Winner et al., 2001); second, some studies have reported that poor readers appear to be less susceptible than controls to the phonological similarity effect (Brady, Shankweiler, & Mann, 1983; Mann, Liberman, & Shankweiler, 1980), which suggests more difficulty in retrieving phonologically similar words or pseudo-words (Baddeley, 1986). This result has been interpreted as indicating the inefficient use of phonetic coding in short-term memory (Brady et al., 1983) or as evidence of degraded phonological representations in people with dyslexia (Ramus & Szenkovits, 2008). However, this last evidence has been questioned by some authors who found no differential phonological similarity effect when comparing children with DD with control groups (Ramus & Szenkovits, 2008; Swanson & Ramalgia, 1992). The second hypothesis, which considers verbal short-term memory deficits to be the result of impaired basic short-term memory processes operating on phonological representations (Ramus & Szenkovits, 2008), is supported by these latter results. Phonological awareness and verbal short-term memory have been sometimes shown to make independent contributions to reading abilities (Dickerson Mayes, Calhoun, Bixler, & Zimmerman, 2009; Hansen & Bowey, 1994; Tobia & Marzocchi, 2013), although the amount of variance explained by verbal memory, after controlling for the effect of phonological awareness, has been found to be small or not significant (Bowey, Cain, & Ryan, 1992; Landerl et al., 2013; McDougall et al., 1994; Rohl & Pratt, 1995).

As shown in past studies, phonological deficits can range in severity across individuals in a continuous way, and their impact on reading outcomes can increase or decrease depending on additional co-occurring risk or protective factors both constitutional and environmental (Bishop & Snowling, 2004; Moll, Loff & Snowling, 2013; Peterson, Pennington, Shriberg, & Boada, 2009).

In addition to phonology-based deficits, some studies have provided evidence for further cognitive impairments associated with DD. In particular, there is evidence that children with DD also experience difficulties in visual-attentional tasks (Eden, Stein, Wood, & Wood, 1995; Eden, VanMeter, Rumsey, & Zeffiro, 1996) such as visual search (Casco, Tressoldi, & Dellantonio, 1998; Vidyasagar & Pammer, 1999), visual recognition (Geiger et al., 2008) and low-level visual information processing (Slaghuis, Lovegrove, & Davidson, 1993).

Finally, some authors have strongly criticised the central role of phonological deficits in DD, associating this developmental disorder mainly with visual attentional deficits and considering both correlation and causality (Franceschini et al., 2012; Hari & Renvall, 2001; Kevan & Pammer, 2008; Stein, 2001; Vidyasagar & Pammer, 2010). For example, a set of Italian studies (Facoetti & Molteni, 2001; Facoetti, Turatto, Lorusso, & Mascetti, 2001; Facoetti et al., 2006; Ruffino et al., 2010) showed evidence of the asymmetric control of visual spatial attention, considered by these authors to be the main deficit underlying dyslexia. However, an Italian study that attempted to replicate Facoetti and colleagues' experiment failed to find the same results (Marzocchi, Ornaghi, & Barboglio, 2009).

One way to better understand the role of the different neurocognitive abilities in DD is to analyse the recurring cognitive profiles of dyslexic children. From this framework stems the idea that a similar behavioural outcome, consisting of reading difficulties, could be attributable to different underlying disorders. The main evidence for different DD profiles comes from studies that found good phoneme awareness skills, considered the most consistent predictor of DD, in some dyslexic children (Broom & Doctor, 1995; Castles & Coltheart, 1996; Brunsdon, Coltheart, & Nickels, 2005; Goulandris & Snowling, 1991; Hanley & Gard, 1995; Hanley, Hastie, & Kay, 1992; Valdois et al., 2003; Zoccolotti et al., 1999), which opens the field to the idea of multiple subtypes of dyslexia. The best-known example of the theorisation of DD's multiple causes is the distinction between phonological and surface dyslexia, characterised by deficits in phonic and lexical reading strategies, respectively (Castles & Coltheart, 1993; Coltheart, Masterson, Byng, Prior, & Riddoch, 1983; Ziegler et al., 2008). Another example is the above-mentioned double-deficit hypothesis (Wolf & Bowers, 1999). In those cases, both the proposed profiles involve problems in the language domain (see also Di Betta & Romani, 2006). However, the existence of two main clusters of deficits in dyslexia, one involving language-based deficits and another that considers visual-attentional impairments, has also been hypothesised (Ans, Carbonnel, & Valdois, 1998; Bosse, Tainturier, & Valdois, 2007; Del Giudice et al., 2000; Valdois et al., 2003; Valdois, Bosse, & Tainturier, 2004).

3.1.2 Cognitive profile of Italian children with Developmental Dyslexia

Most studies that have examined Italian children with dyslexia have focused on the characteristics of their reading deficits and on their reading strategies. In particular, some studies have analysed the transition from alphabetic decoding to sub-lexical and then lexical strategies, hypothesising that Italian children with dyslexia have a deficit in lexical processing (De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002; Zoccolotti et al., 1999; Zoccolotti et al., 2005). However, this hypothesis is not fully supported by more recent findings (Barca, Burani, Di Filippo, & Zoccolotti, 2006; Paizi, De Luca, Zoccolotti, & Burani, 2013).

A small number of studies have specifically investigated the cognitive profiles of Italian children with dyslexia. For example, Del Giudice and colleagues (2000) identified 43 children in the 2^{nd} and 3^{rd} grades who tested as having reading difficulties during a school screening for dyslexia. The children were retested one year later, and only 9 of them still presented a significant reading impairment; at that time, a portion of the sample showed deficient performance on only one section of the reading tasks, and the remaining children showed no deficits. Participants were administered a test battery that was specific to the visuo-spatial domain. The results showed that children with a long-lasting reading deficit exhibited normal performances on spatial cognition tasks. Only one child showed deficits in the visuo-spatial domain, and the authors suggested the existence of a visuo-spatial subtype for DD.

Zoccolotti et al. (1999) analysed several cognitive skills of four Italian boys aged 11 to 15 with a diagnosis of DD who were characterised by a reading performance typical of surface dyslexia. Only one participant showed poor phonemic skills, and all of the sample reached average scores in general intelligence, verbal short-term memory and complex visuo-spatial abilities. However, all participants showed a decline in tasks that required basic perceptual processing, including rapid scanning of stimuli and matching with targets.

More recently, Menghini and colleagues (2010) compared the performance of 60 dyslexic children and adolescents aged 8 to 17 and 65 age-matched normally reading participants on tests analysing phonological abilities, visual processing, selective and sustained attention, implicit learning, and executive functions. The results showed that children with dyslexia had a pervasive phonological deficit involving phonological awareness, memory and fluency abilities. Furthermore, visuo-spatial and motion perception abilities were also impaired, as were attention and executive functions. In contrast, their performance on the implicit memory learning task was similar to that of the control group. Children who exhibited an exclusively phonological deficit made up 18% of the dyslexics, whereas only 1.6% showed a selective deficit in attention or motion perception abilities. Finally, 1.6% of participants exhibited no deficit, and 76.6% of dyslexics showed other deficits in addition to the phonological problem. The authors interpreted their results as evidence supporting the multiple-deficit model of dyslexia proposed by Pennington (2006), according to which DD is a complex disorder that causes similar reading deficits in different individuals presenting heterogeneous impairments in neuropsychological functioning.

More recently, Pennington et al. (2012) tested the capacity of single- and multiple-cognitive-deficit models for predicting dyslexia. The model that provided the best overall fit to the data was the hybrid model that implied multiple possible pathways to DD, some involving single deficits and some involving multiple deficits. The authors' interpretation was that the relationship between the analysed predictors (phonological awareness, language skills and RAN) and reading fluency were probabilistic and not deterministic. However, the study confirmed the important role of the predictors analysed; in particular, it was shown that phonological awareness had the highest sensitivity in predicting DD (see also Moll et al., 2013).

3.1.3 Aim of the study

The main aims of the present study are (1) to examine the role of several specific verbal and non-verbal cognitive functions in Italian children with developmental dyslexia and (2) to investigate the presence of multifactorial deficits in Italian children with DD, considering phonological (phonological awareness, RAN and verbal short-term memory), visual-attentional (visual search, visual memory and visuo-spatial attention) and mixed profiles.

In particular,

(1) we expect to find poorer phonological abilities (phonological awareness, RAN and verbal short-term memory) in dyslexic children compared with controls. Furthermore, we expect to find a milder impairment in visual-attentional skills (visual search, visual memory and visuo-spatial attention) and globally preserved lexical knowledge.

(2) considering past literature that analysed the cognitive profiles of DD (e.g., Menghini et al., 2010; Ramus et al., 2003), we expect to find a core phonological deficit, operationalised by difficulties with phonological awareness, RAN and verbal short-term memory, despite ranging in severity across individuals. We expect that in some cases, these difficulties will combine with deficits in the visual-attentional cognitive processes analysed (visual search, visual memory and visuo-spatial attention). Finally,

we expect to find a very low proportion, if any, of dyslexic children who show exclusively visual-attentional deficits.

Furthermore, an attempt will be made to replicate the results obtained by Facoetti and Molteni (2001) in their study on the gradients of visuo-spatial attention in dyslexic children (see also Marzocchi et al., 2009).

3.2 Methods

3.2.1 Participants

The total sample consisted of 160 children divided into three groups: children with DD, chronological age-matched controls (CA) and reading age-matched controls (RA).

Forty children with diagnoses of DD were recruited. A portion of them (n = 20) were referred by a rehabilitation centre, and the remainder (n = 20) were recruited through an advertisement sent by email to parents of children with DD who were members of an Italian association on learning disabilities[1]. All children were from northern Italy and were native Italian speakers. They had all received a formal diagnosis of DD made in agreement with the definitions given by the International Classification of Diseases Version 10 (ICD-10; World Health Organization, 2004): they presented IQ within normal limits, the absence of sensory deficits or emotional disorders and age-appropriate education. To be selected for the present study, children with a diagnosis of DD had to show a performance more than 1.5 standard deviations (concerning speed) below the mean of the normative data in at least two parameters among text (Cornoldi & Colpo, 1998), lists of single words and lists of pseudo-words (Sartori, Job, & Tressoldi, 2007). Using this criterion, eight participants with a diagnosis of DD were excluded. The final sample of children with DD therefore comprised 32 participants (28.1 % females; mean age = 9.76 years, standard deviation (SD) = 1.30).

[1] Thanks to the Association of parents, teachers and friends of dyslexia (AGIAD)

The control groups contained children with typically developing reading skills, considering both correctness and speed, and with Italian as their first language, all recruited from primary and middle schools in northern Italy (Tobia & Marzocchi, 2013). For each dyslexic child, we selected two participants from the same grade who were close in age and who showed typical reading development on the passage reading task (reading speed z score > - 1 SD and reading errors performance category corresponding to "criterion fully met" or "sufficient performance"; Cornoldi & Colpo, 1998). This group of children constituted the CA control group and included 64 children (35.9 % females; mean age = 9.82 years; SD = 1.44). An independent sample t-test showed no significant age differences between the DD and CA groups ($t(94) = -.194$, $p > .05$).

Next, for each child with a DD diagnosis, we also selected two younger participants with similar reading speeds on the passage reading task and good reading skills for their ages (reading speed z score > - 1 SD and reading errors performance category corresponding to "criterion fully met" or "sufficient performance"; Cornoldi & Colpo, 1998). The RA group was composed of 64 children (34.4 % females; mean age = 7.38 years; SD = .80). An independent sample t-test confirmed similar reading speed scores for the DD and RA groups ($t(94) = -.031$, $p > .05$).

A Chi-square test indicated that the composition of the CA, RA and DD groups was balanced by gender ($\chi^2(2)= .601$, $p > .05$).

3.2.2 Measures

Reading ability

All participants read a passage from the MT Reading Test (Cornoldi & Colpo, 1998), a standardised Italian text-reading test that provides different passages for each school grade. Children were asked to read a text aloud within a 4-minute time limit. Syllables per second were calculated, and raw scores were converted to *z* scores based on recent Italian norms (Cornoldi et al., 2010).

Furthermore, a test of reading words and pseudo-words, the “Battery for the evaluation of dyslexia and spelling disorder” (Sartori et al., 2007), was administered to the group of children with DD for a further measure of reading fluency. Children were asked to read four lists of 28 concrete and abstract words with high or low frequency and three lists of 16 pseudo-words that were similar to real Italian words. Raw scores were converted into *z* scores according to the Italian norms (Sartori et al. 2007). The cut-off criterion for the DD group was a reading speed inferior to - 1.5 standard deviations below the mean on at least two tasks among text, word and pseudo-word reading.

Vocabulary

Participants were administered the vocabulary subtest from the Italian version of the WISC-III (Wechsler Intelligence Scale for Children - Third Edition; Wechsler, 2006). Children were asked to provide up to 30 definitions for words of increasing difficulty and abstraction; for each description they received a score from 0 to 2, based on their definition’s quality. The test measures word knowledge, word meaning retrieval and the ability to provide a clear definition. The maximum score was 60.

Phonological awareness (PA)

Two subtests included on the PRCR-2 learning prerequisites battery (Battery for the early identification of reading and writing difficulties; Cornoldi, Miato, Molin, & Poli, 2009) were administered: phoneme- and syllable-blending. For the first task, children were asked to produce an entire word that blended 4 to 10 phonemes, enunciated one at a time by the examiner. The task was composed of 14 words; one point was given for each correct blend of phonemes, and the total score could range from 0 to 52. On the blending syllables subtest, the examiner pronounced words' individual syllables and asked the child to produce the entire word. The items were 10 three-syllable words. Two points were given for producing the entire word and one point for blending at least two syllables. The score ranged from 0 to 20.

Furthermore, a syllable deletion task was administered (CMF Test; Marotta, Trasciani, & Vicari, 2004): the child was asked to repeat 15 words omitting the first syllable. One point was given for each correct deletion, and the total score, ranging from 0 to 15, was calculated.

Rapid automatised naming (RAN)

The colour-naming and picture-naming tasks from De Luca and colleagues' RAN battery (De Luca, Di Filippo, Judica, Spinelli, & Zoccolotti, 2005) were administered. The tasks both consisted of two 5 × 10 stimuli matrices and required the children to name each item aloud. The time taken by the child to name all of the items in each matrix was recorded; then the two time intervals recorded for each type of matrix were summed to yield a colour-naming score and a picture-naming score, expressed in seconds. Furthermore, the number of errors was registered.

Verbal short-term memory (VSTM)

The digit span subtest from the WISC-III (Wechsler, 2006) and a syllable memory task (Carenini, Gremizzi, & Marzocchi, 2006) were administered to measure verbal short-term memory. On these tasks, the examiner orally presented lists with increasing numbers of items (digits or syllables): each syllable list contained between two and seven items, and each digit list contained between two and nine items. The children were asked to repeat each group of items, one set forward and another set backward. Testing was stopped when both trials of a given length were repeated incorrectly. For each task, the number of correct trials was registered. The score could range from 0 to 30 for digits and from 0 to 24 for syllables.

Visual search

A cancellation test was intentionally designed for this study and administered to evaluate visual search ability. Children were asked to cancel one of nine stimuli as quickly and accurately as possible. The stimuli were non-verbal shapes similar to letters in dimension and orientation and were produced with equal quantities of ink. A trial matrix and three test matrices, with different stimulus distances and dimensions, were presented to each child. In the practice trial, the target stimulus was presented 20 times in a row, and the child was asked to cancel all of the shapes; the time required to complete this task was used as a baseline. False positives, omissions, and the difference between the time needed to complete the test task and the baseline (correct time) were measured separately for each matrix. The mean of the three correct times and the mean number of false positives and omissions were calculated.

Verbal-visual recall

Two 4 × 4 matrices were created using 32 black and white pictures selected from a set by Snodgrass and Vanderwart (1980). For each matrix, the examiner initially named the pictures and then the child looked at the pictures for one minute. When time had run out, children were asked to recall the pictures randomly. The illustrations selected represented common and early-acquired words (between 2.7 and 3 years old), balanced between the two matrices in terms of age of acquisition of the words represented (Nisi, Longoni, & Snodgrass, 2000). One point was given for each correct recall, and the mean of points of the two matrices was then calculated. The maximum score was 16. Although a verbal component was included in the present task, we considered it part of the visual-attentional domain: the request was to memorise items mainly through visual exposure.

Visuo-spatial attention

The attention-orienting computer test proposed by Facoetti and Molteni (2001) was administered. The child sat in front of a monitor screen at a distance of approximately 40 cm. The fixation point was a cross presented in the middle of the screen, and the target was a white dot that could appear at three different distances (3°, 6°, or 9° visual angles) from the fixation point along the horizontal axis. Furthermore, it could appear in the left or the right visual field. The stimulus onset asynchrony was 500 msec. The child was instructed to press the space bar on the keyboard as quickly as possible at the onset of the target; reaction times and errors were recorded. Considering the asymmetrical spatial distribution of visual attention identified by Facoetti and Molteni (2001) with this experiment, the mean score of the reaction times was calculated separately for the left and right visual fields (right RT mean score: 3°,6°, and 9° visual angles on the right; left RT mean score: 3°,6°, and 9° visual angles on the left).

3.2.3 Procedures

Children with DD referred by the rehabilitation centre were seen at the clinic, whereas dyslexic children recruited through the email advertisement were tested in a quiet child laboratory at the university. The testing session lasted for roughly one and a one-half hours, including pauses. Parents signed the consent form and were then asked to wait in a separate room.

Controls were individually tested in a quiet room at their schools, during school hours, in a 1-hour session. Teachers collected the consent forms.

3.2.4 Statistical analysis

Initially, to analyse in-depth the visuo-spatial attention task, we used the procedure used by Facoetti and Molteni (2001: a repeated measure ANCOVA was performed on mean RTs, with eccentricity of target (3, 6 and 9°) and visual field (left and right) as the within-subject factors and group (DD, CA and RA) as the between-subject factor. Age was the covariate.

A preliminary analysis was conducted to reduce the number of dependent variables: an ANCOVA or MANCOVA for each single task was performed to analyse differences between the three groups (DD, CA and RA), using age as a covariate. Therefore, we ran ANCOVAs for the following tasks: vocabulary, phoneme blending, syllable blending, syllable deletion, verbal-visual recall and verbal short-term memory. We then performed MANCOVAs for the RAN task (RAN speed and errors), visual search (mean correct time, number of false positives and omissions) and visuo-spatial attention total mean RT. Variables for which the main effect of group was significant in the preliminary analysis were then entered into a unique MANCOVA. This multivariate procedure allowed the investigation of the effect of the group independent variable on the means of several interrelated dependent variables by taking into account their joint distribution (Norusis, 2004).

For all analyses of covariance performed, eta-squared (η^2) values were computed as measures of effect size for each dependent variable. Cohen's (1988) guidelines for interpreting eta-squared values are the following: .01 is the cut-off point for a small effect, .06 is the cut-off for a moderate effect and .14 is the cut-off for a large effect. Independent-samples t-tests corrected for multiple comparisons with the Bonferroni procedure were also run.

Finally, to determine the profile of children with DD involved in the present study, the number of deficits on specific tasks was counted, using a criterion of – 1.5 SD below the mean as the cut-off for impaired function. Furthermore, a z-score ranging between – 1 and – 1.5 SD was classified as borderline. The normative sample used to calculate the standard scores was that of a previous study (N = 651; Tobia & Marzocchi, 2013) for primary school pupils, whereas for middle school, we intentionally collected data from 18 typically developed children from the 6th to 8th grades. A unique exception was the Vocabulary task, for which the norms provided in the manual (Orsini & Picone, 2006) were used; this decision was made because, only in this case, the normative sample described in the manual was larger than ours. First, seven of the tasks administered were divided into two different domains: phonological, which included RAN, VSTM and phonological awareness, and visual-attentional, which included visual search, verbal-visual recall and visuo-spatial attention. Vocabulary was considered individually. Next, we counted the number of dyslexic children who had a deficit (< – 1.5 SD) only in the phonological domain, only in the visual- attentional domain, or in both. A one-way ANOVA was performed to analyse reading speed and accuracy differences among the four groups.

3.3 Results

Table 3.1 shows descriptive statistics for the reading variables. Scores on some measures were not normally distributed (Table 3.2); consequently, the analyses were run on both the raw and transformed scores. Because the results were highly similar, the raw scores are presented.

Task	DD Mean (SD)	CA Mean (SD)	RA Mean (SD)	Skewness (SE = .192)	Kurtosis (SE = .381)	Pairwise comparisons
Reading text sill/sec	1.69 (.55)	3.89 (1.00)	1.69 (.54)	.869	.219	DD = RA < CA
Reading text – speed z-score	-2.00 (.59)	.36 (.67)	-.16 (.46)	-.583	.416	CA > RA > DD
Reading text errors	9.75 (10.44)	2.44 (1.56)	2.94 (2.03)	6.116	50.813	DD > RA = CA
Reading words – speed z-score	-2.95 (1.79)	-	-	-.776 (SE = .361)	1.278 (SE = .709)	-
Reading pseudo – speed z-score	-2.31 (1.14)	-	-	-.426 (SE = .361)	.361 (SE = .361)	-

Table 3.1 – Descriptive statistics for reading variables.

Task	DD Mean (SD)	CA Mean (SD)	RA Mean (SD)	Skewness (SE = .192)	Kurtosis (SE = .381)	Pairwise comparisons (covariate = age)
Vocabulary	34.69 (6.70)	34.95 (8.83)	23.66 (7.64)	-.213	-.484	DD = CA > RA
Phoneme blending	33.19 (11.07)	43.33 (6.75)	33.67 (10.63)	-.469	-.718	DD = RA < CA
Syllable blending	19.78 (.61)	19.89 (.44)	19.11 (1.58)	-2.965	9.159	-
Syllable deletion	12.09 (3.96)	13.42 (2.91)	11.82 (3.57)	-1.383	.841	-
RAN total time	101.20 (21.11)	82.83 (20.41)	106.06 (20.00)	.720	1.624	DD > RA, CA; RA = CA
RAN errors	1.70 (1.58)	1.01 (1.24)	1.19 (1.54)	2.069	5.665	DD > RA = CA
Verbal short-term memory (VSTM)	4.63 (1.16)	5.44 (1.25)	4.05 (.77)	.834	.737	DD = RA < CA
Visuo-spatial attention left mean RT	366.49 (99.99)	305.45 (53.50)	368.47 (88.24)	1.533	2.853	RA = DD > CA; RA = CA
Visuo-spatial attention right mean RT	343.51 (82.68)	293.15 (57.82)	396.87 (117.50)	1.590	3.632	RA = DD > CA; RA = CA
Visuo-spatial attention total mean RT	372.17 (72.49)	318.20 (71.34)	404.75 (111.55)	1.287	1.597	DD > CA = RA DD = RA
Verbal-visual recall	9.81 (1.86)	10.99 (2.05)	9.64 (2.05)	-.014	-.263	DD < CA = RA DD = RA
Visual search total correct time	34.92 (9.52)	29.61 (12.15)	40.60 (15.40)	.977	2.779	-
Visual search errors	.78 (3.46)	.11 (.47)	.10 (.55)	11.195	133.196	-
Visual search omissions	1.05 (1.30)	.77 (.99)	1.08 (1.02)	1.564	1.931	-

Table 3.2 – Descriptive statistics and results of the pairwise comparison for variables resulted significantly different between groups.

The repeated measure ANCOVA performed on the RTs obtained for the visuo-spatial attention task showed no significant main effect of eccentricity of target or of the visual field and no significant interactions. The group main effect was significant ($F(2,152) = 5.059$, p <

.01, η^2 = .06). Multiple comparisons performed with the Bonferroni procedure showed generally slower RTs for children with DD. Additionally, the covariate that resulted was significant ($F(1,152) = 8.675$, $p < .01$, $\eta^2 = .05$). Considering these results, the following analyses including the visuo-spatial attention task were performed on the RT total mean score and not on the right and left mean scores separately.

Correlations among all of the tasks are presented in Table 3.3. The ANCOVAs and MANCOVAs, performed as separate preliminary analyses on each task, led to the selection of variables for which the main effect of group was significant ($p < .05$). These tasks were therefore analysed with a unique MANCOVA as dependent variables; for all, the main effect of group was significant: vocabulary ($F(2,155) = 4.626$, $p < .05$, $\eta^2 = .06$), RAN speed ($F(2,155) = 9.015$, $p < .001$, $\eta^2 = .10$) and RAN errors ($F(2,155) = 4.680$, $p < .05$, $\eta^2 = .06$), phoneme blending ($F(2,155) = 13.660$, $p < .001$, $\eta^2 = .15$), verbal-visual recall ($F(2,155) = 4.262$, $p < .05$, $\eta^2 = .05$), verbal short-term memory ($F(2,155) = 9.131$, $p < .001$, $\eta^2 = .10$) and visuo-spatial attention total mean RT ($F(2,155) = 4.675$, $p < .05$, $\eta^2 = .06$). The results of the multiple comparisons corrected with the Bonferroni procedure are presented in Table 3.2. The covariate age was significant for all of the variables excluding phoneme blending and verbal-visual recall: vocabulary ($F(1,155) = 25.293$, $p < .001$, $\eta^2 = .14$), RAN speed ($F(1,155) = 39.480$, $p < .001$, $\eta^2 = .20$) and RAN errors ($F(1,155) = 6.044$, $p < .05$, $\eta^2 = .04$), verbal short-term memory ($F(1,155) = 9.556$, $p < .01$, $\eta^2 = .06$) and visuo-spatial attention total mean RT ($F(1,155) = 9.553$, $p < .01$, $\eta^2 = .06$).

	1.Reading text sill/sec	2	3	4	5	6	7	8	9	10	11	12
2.Vocabulary	.524**											
3.Phoneme blending	.529**	.281**										
4.Syllable blending	.244**	NS	.168*									
5.Syllable deletion	.278**	.196*	.236**	NS								
6.RAN total time	-.629**	-.391**	-.398**	NS	-.156*							
7.RAN errors	-.198*	NS	NS	NS	NS	.199*						
8.Verbal short-term memory (VSTM)	.578**	.486**	.362**	NS	NS	-.493**	NS					
9.Visuo-spatial attention total mean RT	-.394**	NS	-.192*	-.360**	NS	.297**	.237**	-.191*				
10.Verbal-visual recall	.357**	.249**	.262**	NS	NS	-.374**	NS	.412**	-.238**			
11.Visual search total correct time	-.454**	-.281**	-.246**	NS	-.183*	.328**	NS	-.332**	.325**	-.205**		
12.Visual search errors	NS	NS	NS	NS	-.306**	NS	NS	NS	NS	NS	NS	
13.Visual search omissions	-.175*	NS	-.220**	NS	-.161*	.320**	NS	-.233**	NS	-.268**	NS	NS

Table 3.3 – Pearson correlations among single tasks

** = p < .01

* = p < .05

The percentages of children with DD who, for each task, showed a deficit (<– 1.5 SD), were in the borderline range (score between – 1 and – 1.5 SD) or had typical performance are presented in Figure 3.1. None of the dyslexic children exhibited deficits on the vocabulary task; thus, it was not included in the following observations. The analysis of children's cognitive profiles showed that 25% of the children with DD had no remarkable deficits in the abilities analysed in the present study. Twenty-five percent of the children showed deficits exclusively in the phonological domain, whereas only 3 children (9.4%) had a deficit exclusively in the visual- attentional domain. Finally, most children with DD (40.6%) had a profile that included deficits in both verbal and non-verbal domains.

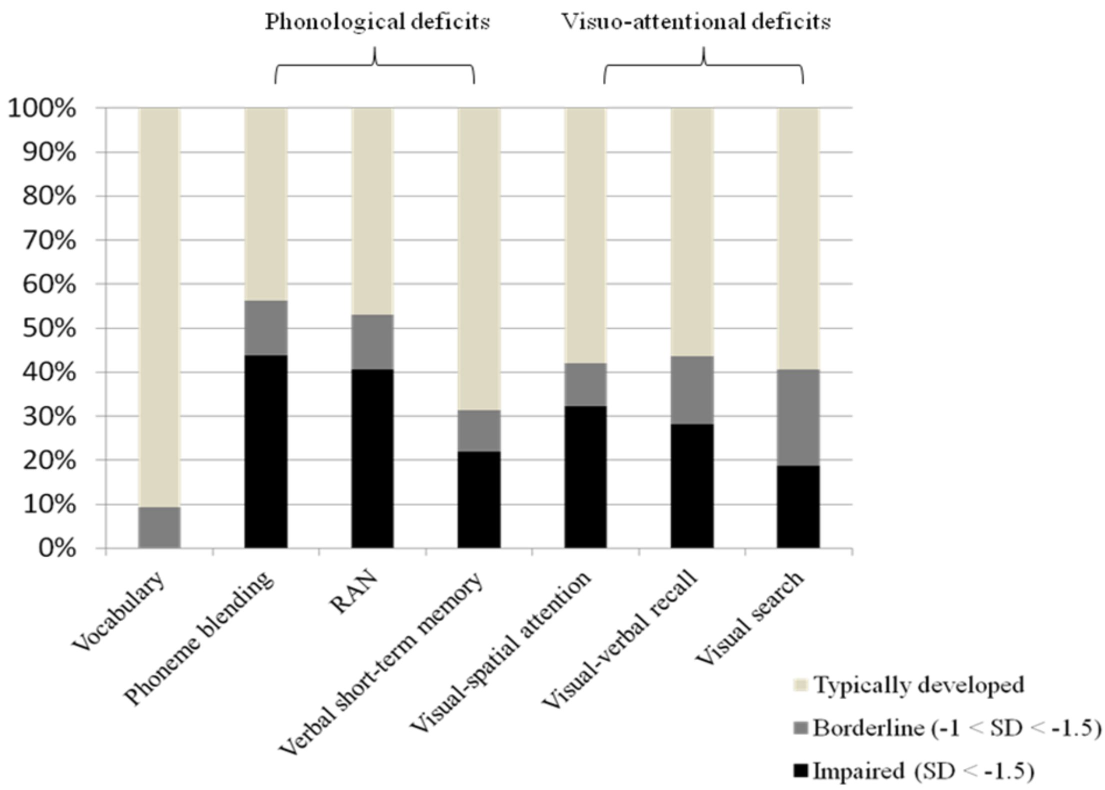


Figure 3.1 – percentage of children with DD that showed a deficit (< - 1.5 SD), a borderline level (-1 < SD < -1.5) or a typical performance in each task.

Figure 3.2 summarises the individual data across the different domains. A one-way ANOVA showed no differences in reading speed and reading errors among the four groups of dyslexics. Considering the 8 dyslexic children with no impairment in the phonological or visual-attentional domains, a further analysis was performed to identify which of them fell into the borderline range for the cognitive tasks administered. Only two had completely preserved skills, whereas three fell into the borderline range for the verbal domain, two for the nonverbal domain, and one showed a mixed borderline profile.

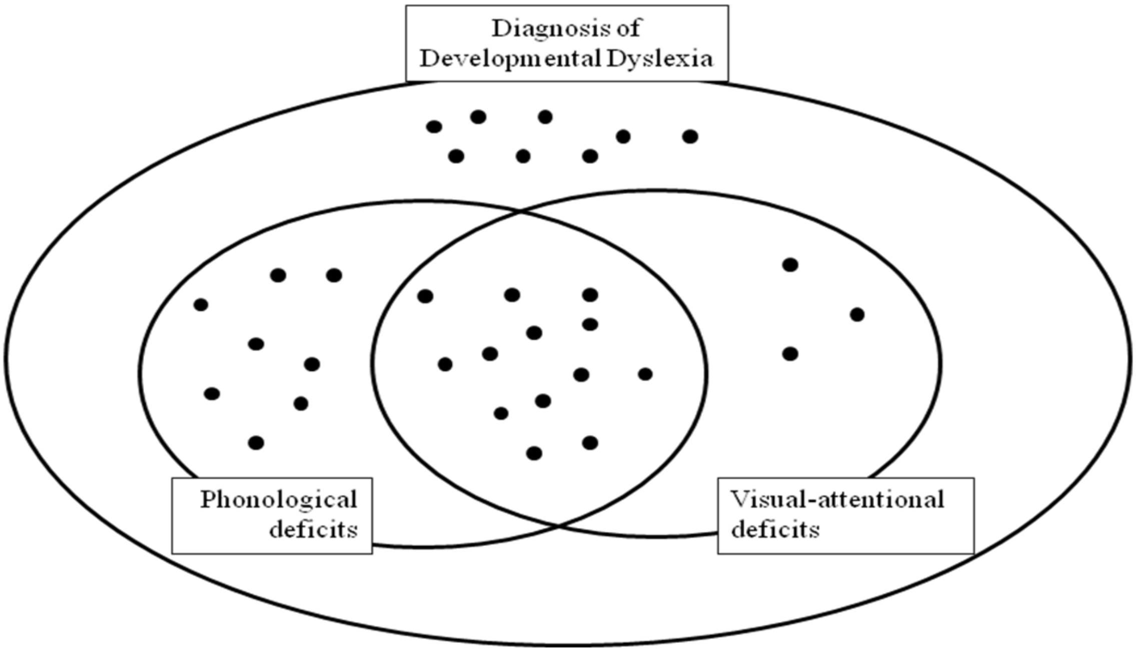


Figure 2 – Distribution of phonological and visuo-attentional deficits (z < -1.5) in the sample of 32 children with Developmental Dyslexia. Each dot represent a child.

3.4 Discussion

The central issue addressed by this study concerns the nature of the cognitive deficits associated with developmental dyslexia in Italian primary and middle school children. It is generally accepted that DD is the consequence of a core phonological disorder and is characterised mostly by an impairment in phonology-based skills such as phonological awareness, RAN and verbal short-term memory (Ramus et al., 2003; Snowling, 2000; Vellutino et al., 2004). However, some studies have found a heterogeneity in the dyslexic population, particularly in cases of dyslexic children without phonological deficits (e.g., Goulandris & Snowling, 1991; Hanley & Gard, 1995; Zoccolotti et al., 1999), suggesting that some patterns of disorders associated with DD might actually reflect a profile in which reading difficulties are independent from phonological problems and related to the visual-attentional domain (Ans et al., 1998; Bosse et al., 2007). To investigate the manifestation of the different cognitive profiles associated with developmental dyslexia in Italian children, the present study examined the phonological (through phonological awareness, RAN and verbal short term memory) and visual-attentional (visual search, verbal-visual recall, and visuo-spatial attention) domains, in addition to the role of lexical knowledge (vocabulary).

Initially, analyses of the visuo-spatial attention task were run to replicate Facoetti and Molteni's (2001) results obtained with the same test. Those authors showed an atypical pattern of RTs in children with DD that was interpreted in terms of left inattention and right over-distractibility. However, this result was not replicated in another Italian study (Marzocchi et al., 2009) that used the same experimental task. In the present study, slower RTs were generally exhibited by children with DD, but no interaction with target eccentricity or visual field was shown. Hence, the asymmetrical spatial distribution of visual attention identified by Facoetti and Molteni (2001) in children with DD was not confirmed in the present study; consequently, in the following analysis, only the total mean RT on the visuo-spatial attention task was considered.

One of the aims of the present study was to investigate the presence of multifactorial deficits in DD by simultaneously testing different cognitive domains and comparing three groups: dyslexic children, typically developing children of the same age (CA) and a control group equated for reading ability by being younger than the dyslexic group (RA).

The first group of analyses, performed separately for each task, led to the exclusion of some variables from the following analysis. These measures (visual search, syllable blending and syllable deletion) were not significantly different among the three groups, meaning that two of the three phonological awareness measures were found to be inappropriate for discriminating between groups. Past literature on phonological awareness suggests that tasks involving the manipulation of large units, such as syllables, are more sensitive measures among preschoolers, whereas tasks at the phoneme level are considered representative measures of phonological awareness for older children (Schatschneider, Francis, Foorman, Fletcher, & Mehta, 1999). This knowledge, together with the high mean scores obtained by the participants in the syllable-blending and deletion tasks, explains the low sensitivity of these measures.

Next, the remaining variables were analysed with a unique multivariate procedure that allowed the investigation of the main effect of the group independent variable on interrelated cognitive processes by taking into account the possible reciprocal correlations between dependent variables. According to Cohen's (1988) guidelines for interpreting eta-squared, phoneme blending was the only variable that showed a large effect size. In particular, children with DD performed at the level of the RA controls, roughly 2 years younger than their chronological ages, and significantly worse than the CA controls. A similar pattern was found for the other measures considered by Wagner and Torgesen (1987) as variables that could be involved in phonological deficits: VSTM and lexical retrieval, measured in the present study with a RAN task. Both of these tasks showed a moderate effect size in the comparison between groups, but pairwise comparisons revealed that whereas on the VSTM tasks, children with DD were similar to RA controls and performed worse than did the CA controls (see Roodenrys & Stokes, 2001 for a similar result), for RAN speed, controlling for age, dyslexic children were slower than both the control groups. Multiple interpretations of RAN have been hypothesised (Bowey, 2005; Lervåg & Hulme, 2009; Wolf & Bowers, 1999). In the present study, RAN is interpreted as an implicit measure tapping the phonological domain (Snowling

& Hulme, 1994; Wagner & Torgesen, 1987) while also considering the high correlation observed with phoneme-blending and VSTM tasks (Table 3.3).

The following profiles' analysis showed that phoneme-blending ability was impaired in roughly 40% of the children with dyslexia, and an additional 12% showed borderline scores. Combining the phonological-domain skills analysed in the present study, approximately 65% of children with DD exhibited a deficit in this domain. However, in most cases, the phonological impairment combined with deficits in the visual-attentional domain. Although visual search ability was similar across participants, a moderate effect size was found in the comparison between groups for visuo-spatial attention, and a small effect size was found for the Verbal-visual recall task. In both cases, the dyslexic children's performance was similar to that the RA controls and lower than that of the CA controls. The analysis of profiles showed that fewer than 10% of children with dyslexia exhibited any impairment that exclusively affected the visuo-attentional domain, but when mixed profiles were also considered, half of the dyslexic children showed a deficit in at least one of the three visual-attentional tasks administered.

Lexical knowledge, measured with the vocabulary task, showed a moderate effect size, but pairwise comparisons showed that children with DD had similar scores to those of CA controls, whereas younger children (the RA group) had lower performance. Lexical knowledge was the only ability that was relatively preserved in all of the dyslexic participants: only in 10% of cases did the children's performance land in the borderline range, and it was never impaired. This result is in line with findings from past studies that connected lexical knowledge, and more general linguistic abilities, to reading comprehension more than reading speed (Muter, Hulme, Snowling, & Stevenson, 2004; Nation & Snowling, 2004; Snow, Tabors, Nicholson, & Kurland, 1995).

Therefore, we analysed the domains in which participants exhibited remarkable impairment, which showed that the majority of children with DD exhibited multiple deficits that included both the verbal and non-verbal domains. As in another Italian study with aims partially analogous to those of the present study (Menghini et al., 2010), we found a predominant but not exclusive phonological deficit in children with DD. Furthermore, in our sample, 40% or so of dyslexic children exhibited a mixed profile, a lower percentage than that found by Menghini et al. (2010). Indeed, those authors found that roughly three-quarters of the sample had multiple deficits, including attentional, executive function and/or visual-spatial tasks. However, the set of tasks and of cognitive processes analysed by Menghini et al. (2010) was largely different from the ones considered in the present study; therefore, the mixed profiles identified in the two studies are not easily comparable.

The heterogeneous cognitive profiles showed by dyslexic children in our sample could be considered in line with the results obtained by Pennington et al. (2012). Within the framework of a multiple-deficit model of dyslexia, these findings are in accordance with the statement that a phonological awareness deficit is neither sufficient nor necessary to cause dyslexia. Broader difficulties in the phonological domain, such as RAN and VSTM deficits, were common, but skills that required visual-attentional processes were also impaired in some cases. A small group of children showed deficits only in the visual-attentional domain. Finally, a proportion of dyslexic participants showed no or mild impairments in the cognitive processes analysed. Nevertheless, reading outcome was similar in all children with dyslexia, independently of the pattern of cognitive deficits.

The results of the present study suggest that investigators should not rely exclusively on conventional test scores to diagnose DD but should also look for converging evidence from the observation of children’s behaviours, as well as their developmental and familial histories. However, even if the cognitive predictors analysed in the present study are not necessary or sufficient for the diagnosis of dyslexia, 75% of our sample showed a deficit in one or more; thus, a clinician can be more confident in the diagnosis if it is also supported by evidence from these cognitive risk factors (Pennington et al, 2012). Finally, considering the similar reading outcomes observed, a more in-depth analysis of cognitive deficits is necessary for planning appropriate intervention or treatment.

The present cross-sectional study had a number of limitations. First, it can only provide suggestions regarding causality: the pattern of plausible predictions observed reflects the bidirectional relationships between the cognitive processes analysed and reading skills rather than causal links. For example, the interpretation of the role of phonological awareness in reading for school-aged children should consider the reciprocal nature of two skills: phonological awareness tasks, including phoneme blending, predict later reading outcomes, but learning to read also improves performance in phonological awareness (Hogan, Catts, & Little, 2005; Moll et al., 2013; Perfetti, Beck, Bell, & Hughes, 1987). Furthermore, co-morbidities were not investigated. Finally, the sample size was small and included a wide age range. Further studies that analyse additional cognitive processes are needed to replicate our findings in larger and more homogenous samples.

"Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life thinking it is stupid."

Albert Einstein

CHPATER 4 - Atypical galvanic skin response in dyslexic children reading aloud

4.1 Introduction

Around 3-6% of children are affected by a specific reading disorder with neurobiological origin, or developmental dyslexia, characterized by difficulties in accurately and fluently recognizing printed words at a level appropriate for the chronological age, despite adequate intelligence and age-appropriate education and an absence of sensory deficits (American Psychiatry Association, 2000; Hulme & Snowling, 2009; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Longitudinal and cross-sectional studies have reported that people with dyslexia are often affected by behavioral, relational, and emotional difficulties, probably originating in the impact of their reading problems on everyday life, which could be confined to the learning context but also extend to other domains of life (e.g., Hall, Spruill, & Webster, 2002; Ingesson, 2007; Karande & Venkataraman, 2012; Tabassam & Grainger, 2002; Undheim, 2003). In particular, learning disabilities are often related to negative emotional manifestations, such as anxiety; it is recognized that reciprocal relationships between anxiety and cognition are common and influential on multiple aspects of life (see Manassis, 2013, for a recent review). In their meta-analysis Nelson and Harwood (2011) considered 58 studies analyzing anxious symptomatology among school-aged students with learning disabilities compared to typically developing peers, and globally found significantly higher mean scores on measures of anxiety in the clinical group. A review that specifically included studies on internalizing correlates of dyslexia (Mugnaini, Lassi, La Malfa, & Albertini, 2009), showed that reading problems contribute in a relevant way to higher anxiety symptoms in students from first grade to university. Anxiety symptoms in children with dyslexia were also investigated through sources other than children themselves, finding significant differences between dyslexics and controls according to their parents (Carroll, Maughan, Goodman, &

Meltzer, 2005; Dahle, Knivsberg, & Andreassen, 2011; Knivsberg & Andreassen, 2008; Snowling, Muter, & Carroll, 2007; Willcutt & Pennington, 2000b) or their teachers (Carroll et al., 2005; Dahle & Knivsberg, 2013; Knivsberg & Andreassen, 2008). Studies that considered the agreement between child-parent reports on socio-emotional and behavioral consequences of specific learning disabilities have found only partial confirmation. For example, Rotsika et al. (2011) showed that mothers of children with specific learning disorders seemed to perceive children’s quality of life in the school context in a more negative way, whereas they overestimated their physical and emotional well-being (see also Ginieri-Coccossis et al., 2012),. This type of result suggests the importance of considering multiple points of views in the evaluation of dyslexic children’s internalizing and externalizing symptoms (e.g., Dey, Landolt, & Mohler-Kuo, 2013). However, not all the studies that investigated internalizing symptoms have found evidence of significant differences between children with dyslexia and typical readers (Lamm & Epstein, 1992; Miller, Hynd, & Miller, 2005).

According to Bandura and colleagues (Bandura, Pastorelli, Barbaranelli, & Caprara, 1999), the perceived difficulties in managing potential threatening events, as reading aloud may be for children with dyslexia, are a source of anxiety. A few studies specifically analyzed the emotional reaction of children and young adults with learning disabilities to academic tasks involving literacy abilities. For example, Carroll and Iles (2006) evaluated anxiety symptoms in undergraduates with a self-report questionnaire, showing higher states of anxiety in dyslexic students just before starting a reading task as compared with a control group. Butkowsky and Willows (1980) measured initial expectancy of success in fifth-graders with good, average, and poor reading ability just before starting a reading task, finding that expectancy decreased with lowered reading ability; furthermore, poor readers showed lower persistence during the task and inferred external causes for successes and internal causes for failures. These results reflect low self-concepts of ability in reading that could be associated with anxiety symptoms, emotional withdrawal, and passivity, and could affect motivation to read (Polychroni, Koukoura, & Anagnostou, 2006; Riddick, Sterling, Farmer, & Morgan, 1999). All these studies used instruments such as self-reports, questionnaires, and interviews to analyze socio-emotional correlates of learning disabilities. However, a few studies employed physiological measures to identify autonomic indicators of stress and anxiety in children with learning disabilities.

Galvanic skin response (GSR) is a low-cost, easy-to-detect, and robust measure to indicate anxiety, cognitive load, and emotional arousal; in fact, brain mechanisms underlying GSR are integrated with those involved in emotional processing (Büchel, Morris, Dolan, & Friston, 1998; Critchley, Elliott, Mathias, & Dolan, 2000; Dykman, Ackerman, Holcomb, & Boudreau, 1983). This technique is an index of changes in the sympathetic nervous system and could be used to monitor quick changes that occur in association with various types of stimuli; it consists of the measurement of conductivity of human skin that varies with changes in skin moisture level, related to the number of active sweat glands (Boucsein, 1992; Nourbakhsh, Wang, Chen, & Calvo, 2012). It is measured through one or two sensors usually attached to the palms of the hands or the bottoms of feet, where the density of sweat glands is the highest (Setz et al., 2010); it is nonintrusive and therefore suitable for use with children. Another physiological measure easy to detect and adapt for children is cardiac responsivity, usually assessed by heart rate (HR), which is the number of beats per unit of time. As with the GSR, it is possible to monitor alterations resulting from stimulation, for example counting the beats or fractions thereof in each second; with these values it is possible to calculate the minute rate equivalent for each successive second (Dykman et al., 1983).

The majority of psychophysiological studies of children with learning disabilities were developed in the 1970s and 1980s, with the primary aim of comparing children who solely had learning disabilities with ones who also showed hyperactivity symptoms and finding significant differences in their autonomic activation, sometimes also including a control group of typical developing children. However, results from these studies were controversial. For example, comparing learning-disabled, hyperactive, and typically developed children's basal levels of physiological functioning, some studies have found generally higher activation in learning-disabled and hyperactive children than in controls (Ackerman, Dykman, & Peters, 1977; Zahn, Little, & Wender, 1978) whereas some of them showed lower skin conductance level (Rugel & Rosenthal, 1974) or similar GSR and HR (Dykman, Ackerman, Oglesby, & Holcomb, 1982; Zahn, Abate, Little, & Wender, 1975).

Findings have also been obtained in studies of autonomic responsivity to various stimuli, most of them showing lower activation in children with learning disabilities compared to controls. For example, Hunter, Johnson and Keefe (1972) studied autonomic responsivity in dyslexic children and controls during a simple reaction time task. The task was composed of three series of stimuli, to test habituation, reaction times, and auditory threshold. Results showed lower basal skin conductance levels and a rapid drop-off of skin conductance level over the trials for dyslexic children, whereas controls appeared to remain alert. The authors interpreted their findings as a difficulty of dyslexic children to maintain a constant attentional level during the task.

Dykman et al. (1982) analyzed heart rate and skin conductance measures recorded during a visual search task in hyperactive, reading-disabled, hyperactive reading-disabled, and typical developing children from primary school. They found a different pattern of HR response to the task, comparing clinical groups to controls, whereas no skin conductance differences reliably separated the groups. HR differences involved the task's intertrial intervals, with the control subjects showing anticipatory heart rate deceleration more consistently than clinical groups. The authors explained this difference as less effort expended by clinical children to remain attentive during the task.

However, some studies found no differences in autonomic responsivity of children with learning difficulties. For example, Bryant (1976) analyzed 60 children from primary school classified for their reading ability (below, average, and above average), recording GSR during a reading-aloud task, and found no significant differences in arousal level among the three groups. Specifically, the author analyzed group differences at the "frustrational level," which is when the child is unable to cope with the reading task and shows signs of tension and discomfort (Ekwall, Solis, & Solis, 1973).

Low physiological activation has been interpreted as a consequence of the activation of the behavioral inhibitory system, which is important in stemming impulsiveness and keeping arousal at appropriate levels to focus attention and carry out intentional behaviors (Gray, 1972; Dykman et al., 1983). However, according to Gray (1972, 1978; see also Fowles, 1980; Fowles, Kochanska, & Murray, 2000), the behavioral inhibition system could also produce withdrawal or anxiety and inhibits behavior in the presence of a threat or risk of punishment.

In summary, most of the studies indicate that during baseline recording of physiological measures such as GSR and HR, children with learning disabilities could already be differently activated compared to controls. A similar alteration was observable when stimuli were given to learning-disabled children and they showed a divergent pattern of physiological activation. However, not all the research developed on this topic led to the same conclusions. The main limitation of these studies was the lack of sample homogeneity, grouping together children with varying degrees and types of learning disability, with or without attention deficit disorders and hyperactivity (Dykman et al., 1983). Furthermore, these studies used different types of stimulation to measure autonomic responsivity, therefore their results are difficult to compare. Finally, the main purpose of this branch of research was to identify physiological anomalies in hyperactive children, paying minor attention to characteristics specifically belonging to children with learning disabilities.

4.1.1 Aim of the study

The primary aim of this study is to investigate psychophysiological manifestations in connection with specific tasks, in children with dyslexia and in a control group of typical readers. In particular, cardiac and electrodermal responses to specific tasks involving reading will be analyzed and compared with control tasks. Considering past literature that analyzed autonomic responses in children with learning disabilities (Dykman et al., 1982; Hunter et al., 1972) and studies that investigated emotional reaction to reading tasks in poor readers (Butkowsky & Willows, 1980; Carroll & Iles, 2006), we expect to find:

1) a weaker activation in children with dyslexia when compared to the control group, associated with reading tasks but not with tasks involving describing illustrated stories;

2) a greater difference between silent reading and reading aloud in dyslexic children, compared to the control group, but a similar activation in all the children when comparing silent and aloud tasks with illustrated stories.

The weaker activation would be interpreted as action of the behavioral inhibition system (Dykman et al., 1983; Fowles, 1980; Gray, 1972; 1978) and would be operationalized by lower levels of GSR and HR.

Furthermore, this study analyzed differences between dyslexic children and controls in components of school wellness, through self-report questionnaires administered to children and their parents. In this case, in accordance with the past literature (e.g., Ginieri-Coccossis et al., 2012; Ingesson, 2007), we expect dyslexic children to have a worse emotional attitude towards school, lower scores on self-efficacy, and poorer relationships with teachers and classmates, compared with controls. We also expect that their parents report more emotional and behavioral problems in their children (e.g., Carroll et al., 2005; Dahle et al., 2011). Finally, exploratory analysis to investigate the relationship between questionnaire scores and physiological measures are performed.

4.2 Methods

4.2.1 Participants

Thirty-two third- through eighth-grade students participated to the study: 16 children (37.5% girls, mean age = 10.41 ± 1.93 years) had a diagnosis of developmental dyslexia (DD), whereas 16 children (50% girls, mean age = 10.79 ± 1.91 years) were in the control group of typical reading children (TR).

All children in the DD group had a formal diagnosis of dyslexia, made in agreement with the definitions given by ICD-10, and at least two parameters among reading speed and accuracy of words and pseudo-words (Battery for the evaluation of dyslexia and spelling disorder; Sartori, Job, & Tressoldi, 2007) that are < - 1.5 SD. Exclusion criterion was the additional clinical diagnosis of attention deficit hyperactivity disorder (ADHD) according to the DSM-IV criterion (American Psychiatric Association, 2000). The control group is composed of typically developed children with Italian as their first language, who attended school regularly and were typical readers (at least three parameters among reading speed and accuracy of words and pseudo-words that are > - 1.5 SD). A chi-square test indicated that the composition of groups is balanced by gender ($\chi 2 = .508$, $p > .05$) and an independent sample t-test showed no significant age differences between the two groups ($t(30) = .559$, $p > .05$).

4.2.2 Measures and material

<u>Experimental tasks</u>

Galvanic skin response and heart rate were recorded using the “Psycholab Satem VD13SV” machine. The measurement unit for the GSR is Microsiemens (μs) and it was monitored through two sensors attached to the fingers on the subject's left hand. The HR, measured in number of beats per minute, was detected with three disposable solid gel adhesive surface electrodes placed on the wrists.

A total of four tasks, plus baseline recording, were administered to all children involved. In the baseline condition, GSR and HR were measured in a one-minute session before the experimental tasks; in this session children were asked to wait a few seconds without doing anything. In order to develop the reading tasks, a set of 42 short sentences (Palladino, 2005) were randomly assigned to two lists of 21 sentences each (Appendix 1). Children were invited to read one list aloud and the other one silently; moreover, for each sentence, they had to indicate if it were true or false. For each list the time limit was five minutes. Finally, 12 illustrated stories taken from the Web, each composed in three or four vignettes, were randomly assigned to two lists of 6 stories (Appendix 2); each list consisted of a total of 21 vignettes and the children were asked to produce a short sentence to describe each vignette. For one list the sentences had to be pronounced aloud, for the other list children were asked to produce them silently. At the end of each brief story (three or four vignettes) the child had to indicate how clear the vignettes were in illustrating the story, on a three-point Likert scale. For each list of stories the time limit was five minutes. The order of the four tasks was counterbalanced across participants; furthermore, the two lists of sentences and illustrated stories were alternated among aloud and silent tasks.

<u>Reading ability</u>

Words and pseudo-words reading tasks from the "Battery for the evaluation of dyslexia and spelling disorder" (Sartori et al., 2007), were administered in order to assess children's reading speed and accuracy. The first reading task consists of four lists of isolated words with different frequency, whereas the pseudo-words reading tasks comprises three lists of pseudo-words with different orthographic complexity. Raw scores were converted to *z* scores according to the Italian norms (Sartori et al., 2007).

<u>School wellness</u>

The Questionnaire on School Wellness (QSW; Tobia & Marzocchi, in preparation) is a questionnaire created to investigate the school experience in children with learning disabilities, considering three different perspectives: children, parents, and teachers. In particular, QSW investigates the emotional and motivational impact of their difficulties within the learning context, by self-report and/or considering parent and teacher observations. Furthermore, it analyzes emotional distress connected to children's difficulties according to parents and teachers. In the present study, the QSW was administered to children (QSW-child version - Appendix 3) and to their parents (QSW-parent version - Appendix 4). The children's version is composed of 27 items and 5 subscales: Gratification obtained by school results (α = .76), Relationship with teachers (α = .78), Relationship with classmates (α = .74), Emotional attitude towards school (α = .62), and Self-efficacy (α = .62). The parents' version includes 36 items and 5 subscales: Personal experience in relation to the child's difficulties (α = .84), Evaluation of learning processes (α = .85), Child's emotional difficulties (α = .72), Child's behavioral problems (α = .68), and Relationship with teachers (α = .82). Cronbach's alphas for the QSW-child version were calculated on a community sample of 250 primary (4^{th} and 5^{th} grades) and middle school students (Tobia & Marzocchi, in preparation). A confirmatory factor analysis (CFA) was also performed to analyze the factorial structure of the questionnaire. Results showed acceptable fit indices (Hu & Bentler, 1999): root mean square error of approximation (RMSEA) = .046, 90% confidence interval (CI) = .037-.056, Comparative Fit Index (CFI) = .93, Tuker-Lewis Index (TLI) = .92. Cronbach's alphas for the QSW-parent version were obtained on a sample of 223 questionnaires administered to parents of children with and without specific learning disabilities (Tobia & Marzocchi, 2011); on the same sample, a CFA showed acceptable fit indices considering the five subscales described (RMSEA = .059, CI = .053-.065, CFI = .91, TLI = .90). Responses were obtained on a 3-point Likert scale ranging from not true (0) to very true (2).

4.2.3 Procedure

Parents were informed of the aim and procedures of the research and signed the informed consent. Children were tested in one 30-minute session in a quiet child laboratory at the university. First, children were familiarized for five minutes with the instrument used to measure GSR and HR, and then baseline was registered. Afterward, the four experimental tasks were administered to the children, during which the GSR and the HR were again recorded. The words and pseudo-words reading tasks were then presented. Finally, children filled in the QSW-child version and a parent filled in the QSW-parent version.

The experiment was approved by the Research Ethics Committee of the university.

4.2.4 Statistical Analysis

Independent sample t-tests were run to analyze differences between the two groups (Dyslexics and Typical Readers) on reading speed and accuracy of words and pseudo-words z-scores.

Physiological recordings from the first minute of each task were isolated for each child to obtain a comparable amount of time for each participant. Then, HR values lower than 50 and higher than 200 beats per minute and GSR values corresponding to 0 were removed to eliminate recording errors. Finally, GSR and HR means were calculated within each condition for every single participant and the GSR and HR means obtained during the baseline condition were subtracted from the ones obtained with the four experimental tasks.

To test our hypotheses, two 2 x 2 x 2 ANOVAs (Group: DD vs. TR; Production: silent vs. aloud; Material: read sentences vs. describing illustrated stories) were run separately for the measures of GSR and HR, with Group as between-subjects factor and Production and Material as within-subject factors. Furthermore, to conduct a deep analysis of differences between the two groups in all conditions, main effects were compared using pairwise comparisons with Bonferroni correction. To support hypothesis 1, we expect to find significantly lower scores of GSR and HR on reading tasks, comparing dyslexic children with the control group, operationalized with significant interactions Material x Group and/or Production x Material x Group. To confirm hypothesis 2 we expect to find an interaction Production x Material x Group and, considering the pairwise comparisons, a significant difference between dyslexic and controls only.

Finally, questionnaire scores and links between these scores and physiological measures were analyzed. Two MANOVAs were run to compare QSW subscales scores obtained by dyslexic children and their parents with the ones obtained by the control group; two ANOVAs were performed to analyze differences in total scores. Then, Pearson correlations were run to investigate connections between the scores of the Questionnaire on School Wellness subscales in its parent's and children's versions, and the physiological measures in each condition.

Since the number of subjects in each group was small, the effect size was computed; to interpret main effects and interactions produced by the ANOVAs and MANOVAs, eta squared (η^2) was calculated, whereas effect size according to Cohen's formula (1988; Cohen's *d*) was computed in order to understand the differences between groups in the pairwise comparisons. Cohen's (1988) guidelines to interpret effect size are the following: considering eta squared, values of .01 are small, .06 are medium, and greater than .14 are large; for the Cohen's *d*, results between 0.2 to 0.4 are considered small, between 0.4 to 0.8 are medium and higher than 0.8 are large.

4.3 Results

Independent sample t-tests indicated significant differences between groups in all the reading variables considered (Table 4.1).

	Dyslexic (n = 16)	Controls (n = 16)		
Task	Mean (SD)	Mean (SD)	T-test	Effect size (Cohen's *d*)
Reading words (speed)	-3.70 (2.20)	0.41 (0.57)	t (17.03) = 7.216, p <.001	2.56
Reading words (accuracy)	-4.01 (4.74)	0.38 (0.76)	t (15.78) = 3.663, p <.01	1.29
Reading pseudo-words (speed)	-2.58 (1.64)	0.29 (0.58)	t (18.70) = 6.617, p <.001	2.33
Reading pseudo-words (accuracy)	-2.49 (1.61)	0.13 (0.60)	t(19.07) = 6.095, p <.001	2.16

Table 4.1 – Descriptive statistics, t-tests and effect sizes for the reading variables analyzed

No significant differences between groups were found in GSR ($t(30) = -.382$, $p > .05$; DD mean = 13.17, SD = 9.43; TR mean = 12.12, SD = 5.76) or HR ($t(30) = .984$, $p > .05$; DD mean = 86.65, SD = 17.04; TR mean = 93.06, SD = 19.73) during baseline recordings. Considering GSR, the only main effect that showed significant results in the 2 x 2 x 2 ANOVA is Production ($F(1, 30) = 7.468$, $p = .01$, $\eta^2 = .181$), with a globally higher activation in the tasks using aloud production. Then, the interaction Production x Material x Group showed significant results ($F(1, 30) = 4.375$, $p < .05$, $\eta^2 = .118$). To conduct a deep analysis of the differences that cause this interaction effect, pairwise comparisons with Bonferroni correction were run. GSR significant differences between groups were identified in the reading-aloud task ($t(30) = 2.264$, $p < .05$; DD mean = -0.59, SD = 6.51; TR mean = 3.84, SD = 4.34; Cohen's d = .80), with dyslexic children showing lower activation (Figure 4.1). No significant main effects or interactions were found in the HR values (Figure 4.2).

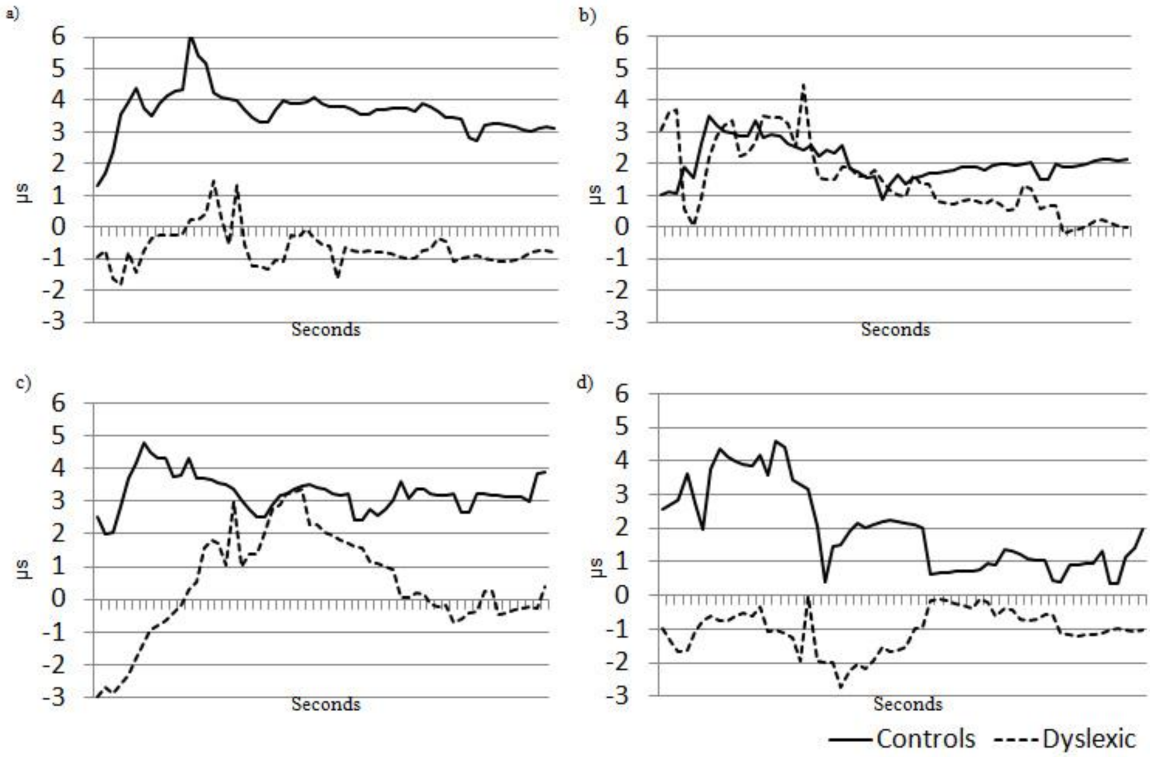


Figure 4.1 - Galvanic skin response (GSR) in the first-minute section of the four experimental conditions: a) reading aloud b) reading silently c) describing illustrated stories aloud d) describing illustrated stories silently.
Baseline GSR have been subtracted.

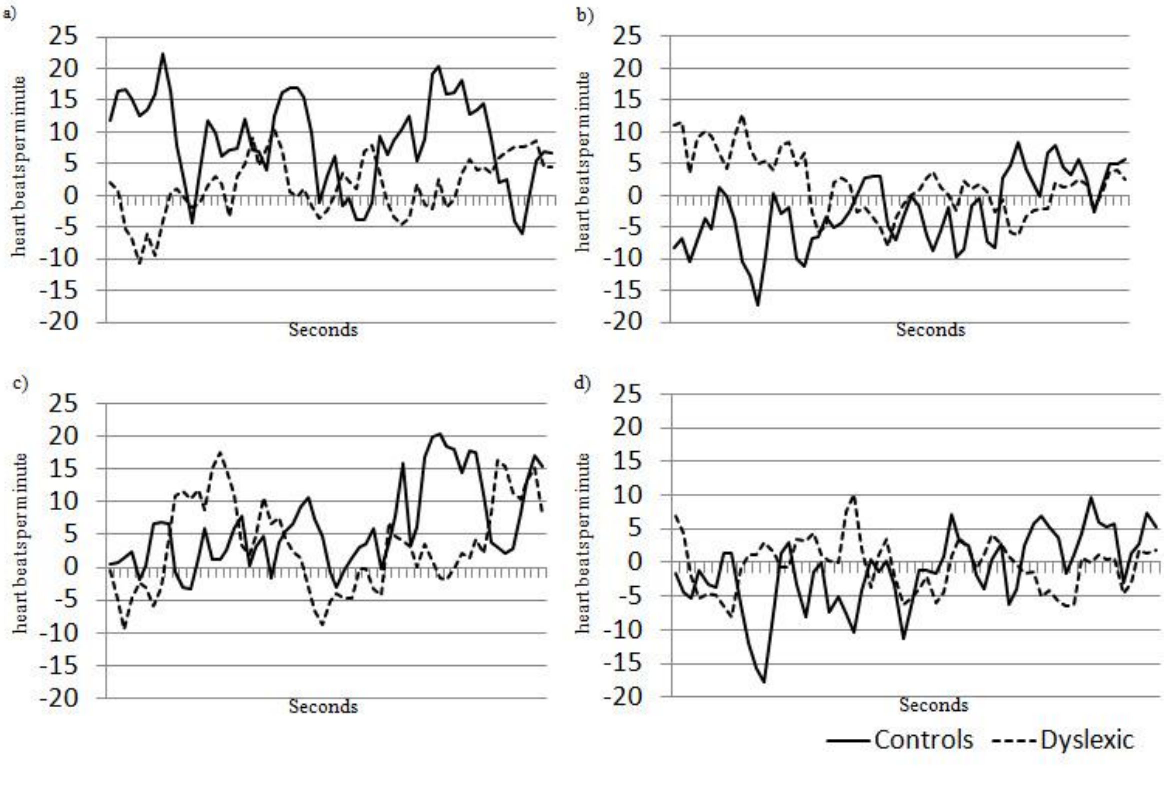


Figure 4.2 – Heart rata (HR) in the first-minute section of the four experimental conditions: a) reading aloud b) reading silently c) describing illustrated stories aloud d) describing illustrated stories silently.
Baseline HR have been subtracted.

Both the MANOVA run on QSW-child version's subscale and the ANOVA run on the total score showed no significant main effect of Group. On the contrary, parent results had a different pattern and showed a significant main effect of Group for the following subscales: Personal experience in relation to the child's difficulties ($F(1, 30) = 9.833$, $p < .01$, $\eta^2 = .247$), Evaluation of learning processes ($F(1, 30) = 136.121$, $p < .001$, $\eta^2 = .819$), and Child's emotional difficulties ($F(1, 30) = 11.306$, $p < .01$, $\eta2 = .274$). A significant main effect of Group was found also for the QSW-parent version's total score ($F(1, 30) = 34.774$, $p < .001$, $\eta^2 = .537$). Descriptive statistics and effect sizes of significant differences are presented in Table 4.2. Pearson's correlations between self- and parent reports showed only a few significant correlations: Child's emotional difficulties reported by parents were negatively correlated with children's ratings on Gratification obtained by school results ($r = -.370$, $p < .05$), Relationship with classmates ($r = -.441$, $p < .01$), and QSW total score ($r = -.377$, $p < .05$); then parent's Relationship with teachers was positively related to children's Relationship with classmates ($r = .356$, $p < .05$) and QSW total score ($r = .329$, $p < .05$); finally parent's evaluation of his/her Child's behavioral problems was negatively correlated with children's QSW total score ($r = -.414$, $p < .01$).

	Task	Dyslexic (n = 16) Mean (SD)	Controls (n = 16) Mean (SD)	Effect size (Cohen's *d*)
QSW – child version	Gratification obtained by school results	1.56 (0.43)	1.28 (0.51)	-
	Relationship with teachers	1.55 (0.38)	1.32 (0.54)	-
	Relationship with classmates	1.50 (0.52)	1.60 (0.52)	-
	Emotional attitude towards school	0.98 (0.47)	1.22 (0.35)	-
	Self-efficacy	1.47 (0.30)	1.37 (0.35)	-
	Total score	7.06 (1.30)	6.80 (1.36)	-
QSW – parent version	Personal experience in relation to the child's difficulties	0.83 (0.44)	0.43 (0.25)	1.12
	Evaluation of learning processes	1.35 (0.38)	0.13 (0.18)	4.10
	Child's emotional difficulties	0.89 (0.47)	0.41 (0.33)	1.18
	Child's behavioral problems	1.02 (0.32)	0.81 (0.35)	-
	Relationship with teachers	1.09 (0.51)	1.30 (0.71)	-
	Total score	3.00 (1.38)	0.49 (0.99)	2.09

Table 4.2 – Descriptives statistics and effect sizes for the subscales and total scores of the Questionnaires for School Wellness (QSW)

The analysis of Pearson correlations showed no significant correlations between physiological measures and the QSW-child version's subscales and total score. However, some significant correlations were found between GSR/HR and some QSW-parent version's subscales and total score: scores in the Child's emotional difficulties subscale are inversely proportional to the GSR showed by children during reading tasks (r = -.443, p < .01 for the reading-aloud task; r = -.372, p < .05 for reading-silently task), and to their HR during the reading-aloud task (r = -.378, p < .05) and describing illustrated stories silently task (r = -.415, p < .05). Scores in the Child's behavioral problems subscale are positively correlated with GSR during the describing illustrated stories silently task (r = .352, $p < .05$). Finally, the QSW-parent version's total score was negatively correlated with HR in the reading-aloud task (r = -.368, $p < .05$).

4.4 Discussion

The main aim of the present study was to analyze physiological reactions to reading tasks considering a sample of dyslexic children and a control group. To measure response to stimuli GSR and HR were analyzed; these measures are robust and suitable for children because they are non-invasive. In particular, baseline skin conductance and GSR during specific tasks are considered to be valid measures of the sympathetic nervous system's functioning (Boucsein, 1992).

A generally higher activation was found for both the tasks involving production aloud. This result is consistent with past studies: Reading aloud and talking, in the absence of emotional content, has been shown to elicit significant sympathetic nervous system activation (Bernardi et al., 2000).

Then, a significant effect was found for the Production x Material x Group interaction: it has a medium effect size and explained the 11.8% of total variance. With further analysis, a significant difference between dyslexic children and typical readers, with large effect size, was found in the GSR stimulated by the reading-aloud task (see Figure 4.1a). Considering the dyslexic group, the discrepancy in the GSR between reading aloud and silently showed significantly larger results compared to the discrepancy between aloud and silent production in the describing illustrated stories task. Finally, this discrepancy showed significantly larger results for dyslexic children compared to the control group. To summarize, the main result of the present study is an atypical activation of skin conductance during the reading-aloud task for the dyslexic children, whereas their level of both GSR and HR showed similar results to the control group during the reading silently and the control tasks. In particular, the difference resulted in an underactivation of children with dyslexia, compared to the control group; their GSR to the reading-aloud task is on average lower than baseline.

The physiological atypical response could be determined by an emotional reaction to a specific self-threatening situation, and be related to high levels of the behavioral inhibition system activity (Fowles, 1980; Fowles et al., 2000; Gray, 1972; 1978). The aim of this system is to avoid behavior that may lead to adverse or painful outcomes, through inhibition of movement toward goals. Furthermore, the activation of the behavioral inhibition system could cause uncomfortable feelings such as anxiety and a sense of frustration, when engaged by the perception of threat (e.g., Gray, 1978). This interpretation leads to the conclusion that reading aloud is perceived as a threat by dyslexic children that activates an autonomic response to avoid negative consequences associated with this critical request. However, this reaction is specific to the reading-aloud tasks and is not evoked by other cognitive requests, even when they implicate silent reading; furthermore, it does not involve baseline recordings, which showed similar results for the dyslexic and control groups. Past studies that reported alterations in basal skin conductance or HR in children with learning disabilities suggested that it was caused by expectations of failure (Dykman et al., 1983) or was a reaction to nonspecific background stimuli experienced in a novel and busy environment such as a laboratory (Zahn, Rapoport, & Thompson, 1980). In the present study, children were all informed they were going to read and describe illustrated stories before starting the baseline recording, and were all tested in the same environment; however, no alterations in skin conductance or HR were observed. Therefore, the present results does not support the assertion that learning-disabled children are "lacking in those specific arousal or emotive supports necessary for sustained attention and learning" (Dykman, Walls, Suzuki, Ackerman, & Peters, 1970), sustained also by Hunter et al. (1972), or that they have an atypical physiological activation that is the result of general attentional problems (Dykman et al., 1983). In a departure from past studies (e.g., Hunter et al., 1972), when comparing different types of tasks we showed that the atypical physiological activation observed in children with dyslexia is task-related and not a general abnormal response to cognitive exercises. In particular, their GSR and HR are similar to typical readers during tasks involving silent reading, reading comprehension, and aloud or silent production of sentences from visual stimuli, whereas there is a specific alteration involving the GSR when they have to respond to the specific cognitive request of reading aloud. This partially explains the reason why some previous studies (Bryant, 1976; Dykman et al., 1982) failed to find significant differences in the GSR between learning-disabled children and controls. We hypothesize that repeated frustrating experiences and persistent struggling with reading have disposed dyslexics to respond physiologically in a different way when placed in a situation demanding specific literacy skills, such as fluent reading aloud. This result supports educational practices that recommend that dyslexic children abstain from reading aloud in class.

Another aim of the present study was to analyze differences between clinical and control groups in variables related to school wellness, such as satisfaction regarding school results, emotional attitude towards school and learning activities, relationship with teachers and classmates, and self-efficacy. In particular, emotional involvement in school and learning activities was the main concern of the present study, investigated through two different informants: children and parents. Questionnaire scores revealed significant differences in the comparison between dyslexic and controls when considering parent reports. A possible explanation of why children with dyslexia showed ratings similar to controls on school wellness variables is that they underestimate the fatigue experienced in the school context to protect themselves from a stressful recognition of it. This interpretation would in some way conform to the activation of the behavioral inhibition system during reading-aloud tasks, in terms of a similar response to avoid threatening stimuli.

QSW-parent version scores also correlated significantly with physiological measures. In particular, parent scores on children's emotional difficulties were correlated with GSR for both the reading tasks and with HR for reading aloud and describing illustrated stories silently. This subscale does not investigate anxiety symptoms specifically and solely, but contains four items that asked parents to rate their children's levels of anxiety, rage, worry, and sadness considering their learning difficulties. Whereas its correlation with physiological measures detected during reading tasks is interpretable in terms of identification by parents of a distress expressed by children through the activation of the behavioral inhibition system, the correlations with HR measured during the describing illustrated stories silently tasks need further investigation.

To summarize, the main findings from the present study are a physiological atypical activation during reading-aloud tasks in dyslexic children and the linear connection that GSR or HR registered during reading tasks has with the parent's evaluation of emotional difficulties presented by his/her children. It seems that, in some way, parents are able to recognize and report an emotional suffering not recognized or reported by their children, but detectable through physiological measures. Furthermore, the low correlations between children and parent reports, and the significant differences between dyslexic and controls found only for the QSW-parent version's scores, suggest low child-parent agreement on school wellness; this is in line with Rotsika et al.'s (2011) study that provided evidence on differences in child–parent ratings of variables such as quality of life in the school context, considering children with a specific learning disability. The main implication of these results is the importance of going beyond children self-reports on their emotional difficulties, and considering the parents' point of view.

Future investigations should incorporate multiple autonomic indicators and combine physiological measures with more specific self- and parent-proxy reports to analyze children's experience during different sets of tasks from different perspectives. In addition, it would be important to investigate experimentally possible factors that could attenuate the physiological effect of the stressful task, in order to intervene on the atypical autonomic activation.

Considering the initial hypothesis, the analyses showed the following results:

1) Children with dyslexia showed a weaker GSR than the control group on the reading aloud task, but not on the reading-silently and on describing illustrated stories tasks; no differences in the HR were found.

2) Children with dyslexia showed a significantly larger discrepancy between silent and aloud tasks considering GSR in reading sentences, compared (a) to the control group and (b) to the discrepancy calculated for the task involving illustrated stories.

Finally, predictions regarding differences between dyslexic students and controls in the questionnaire scores were only partially confirmed, because these differences resulted only for some subscales of the parent questionnaires and did not involve self-reports filled in by children.

"A falling tree makes more noise than a forest that's growing"

Lao Tzu

CHAPTER 5 – General discussion

5.1 Main findings from this dissertation

The series of studies reported in this thesis investigated cognitive, emotional and physiological correlates of reading aloud, in Italian children who are typical readers or have Developmental Dyslexia (DD). In particular, the first two studies examined the role of several cognitive abilities in relation to reading fluency. Results obtained with the study of typical readers in primary school (Chapter 2) showed that concurrent predictors of reading fluency partially change when children become expert readers. Indeed, it was showed that whereas in 1st and 2nd grade text reading fluency is predicted by phonological awareness (PA) and Rapid Automatized Naming (RAN), in 3rd to 5th grade two additional verbal abilities (vocabulary and verbal short-term memory - VSTM) and visuo-spatial attention played a significant role in predicting the dependent variable. However, the variable tested accounted for around ¼ of the variance in text reading fluency, suggesting that there are other important cognitive processes not considered in this study and involved in reading development. In the study reported in Chapter 3, several cognitive abilities were examined, comparing Italian children with DD of primary and middle school with chronological-age and reading-age matched controls. Considering the phonological domain (Hulme & Snowling, 2009; Snowling & Hulme, 1994; Wagner & Torgesen, 1987), dyslexic children were significantly impaired in all the tasks: PA measured with phoneme blending and VSTM was at the level of reading-age matched controls, around two years younger, and significantly worse than chronological-age matched controls; in addition, including age as a covariate, RAN speed was significantly slower than both control groups. A significant deficit was also observed for two of the three measures included in the visuo-attentional domain: dyslexic children showed a deficiency in visuo-spatial attention and verbal-visual recall tasks, in which their performance was significantly poorer than chronological-age matched controls and similar to reading-age matched group. On the contrary, visual search ability was similar across groups. Finally, lexical competence of dyslexic children, measured with an expressive vocabulary test, was appropriate to age. The research presented in Chapter 3 also focuses on the pattern of cognitive deficits exhibited by the 32 Italian children with dyslexia included in the study. Main finding is that a large group of children with DD (40.6 %) exhibited multiple deficits, that included both the phonological and the non-verbal domains. A lower number of children had a deficit exclusively in the phonological or exclusively in the visual-attention based domain (25% and 9.4% respectively). Finally, 25% of children with DD had no remarkable deficits in the abilities analyzed. However, excluding children that fell in the borderline range (between – 1 and – 1.5 standard deviations) for the tasks administered, only two dyslexic children had completely preserved skills.

The last study presented (Chapter 4) focused less on cognitive processes and more on emotional reactions to reading tasks and, generally, to learning situations, in both dyslexic children and typical readers. The analysis of the autonomic response to reading showed that children with DD exhibit a physiological atypical activation during reading aloud tasks, namely a significantly lower Galvanic skin response (GSR). Physiological measures registered during reading silently and control tasks were similar to the ones observed in typical readers. Then, some socio-emotional variables related to the school and to learning settings were analyzed through questionnaires administered to children themselves and to their parents. Self-reports by children were similar in dyslexics and controls. On the contrary, parents of children with DD revealed a worse personal experience in relation to their children's difficulties and reported emotional difficulties in their children. Interestingly, there were significant correlations of GSR and heart rate registered during reading tasks with parent's evaluation of emotional difficulties presented by their children.

5.2 Are underpinnings of reading universal?

Research on reading processes, in both typical and atypical development, have a long history. However, in 2008 Share published a paper criticizing current reading research and practice. Specifically, he affirmed that the large amount of knowledge based on studies on the opaque English orthography, defined as “Anglocentric research agenda”, addressed theoretical and applied issues with limited relevance for a universal science of reading. Share (2008) also criticized the excessive attention to oral reading accuracy, with the consequent neglect of other components of reading, such as silent reading, meaning access and fluency. Finally, he declared that also the central role of PA was determined by the Anglo-centric point of view. In response to Share’s critique, cross-linguistic studies that consider several alphabetic orthographies with different degrees of transparency (e.g. Caravolas et al., 2012; Furnes & Samuelsson, 2011; Moll et al., 2014; Vaessen et al., 2010; Ziegler et al., 2010) and depth analysis of consistent orthographies (e.g. Schulte-Körne, Bruder, Ise, & Rückert, 2012; Spinelli et al., 2009; Wimmer & Schurz, 2010) have been developed. Most of these studies have found that predictors of reading performance were relatively universal across the alphabetic languages analyzed, although their precise weight varied systematically as a function of script transparency (Ziegler et al., 2010). However, only a few studies on cognitive correlates of reading in typical and atypical development included the Italian language (e.g. Del Giudice et al., 2000; Di Filippo et al., 2005; Menghini et al., 2010; Zoccolotti et al., 1999) and most of them involved a small number of children or a restricted group of potential reading predictors. The present thesis analyzed the cognitive profile of typical and atypical Italian readers, considering a set of tasks that investigate both the verbal and non-verbal domains.

The study on Italian typical readers presented in Chapter 2 confirmed the fundamental role of PA for Italian beginner readers, as well as for older children (3^{rd}-5^{th} grade). Furthermore, the significant and independent role of RAN, already identified by another Italian study (Di Filippo et al., 2005) on a smaller and heterogeneous (from 1^{st} to 6^{th} grade) group of children, was confirmed both in beginner and expert readers, despite its role in concurrently predicting reading speed appeared bigger in younger children. Coherently, PA and RAN were globally impaired in Italian children with DD. This set of results is consistent with recent cross-linguistic studies (e.g. Caravolas et al., 2012; Landerl et al., 2013; Moll et al., 2014) and support the hypothesis that PA is a universal predictor of reading, and has a relevant importance across orthographies, including Italian. Landerl et al.'s findings (2013) also suggest that predictive power of PA increases with the degree of orthographic complexity. This claim is in line with the non-exclusive and not massive role of PA found in the relatively simple Italian orthography. According to my results, RAN, considered by some authors the key predictor of typical and atypical reading in transparent orthographies (e.g. Furnes & Samuelsson, 2010; Landerl & Wimmer, 2008; Mann & Wimmer, 2002), has a similar weight compared to PA: for example, PA and RAN deficits or borderline performance occurred respectively in the 56.3% and 53.1% of children with DD.

Another result of the present studies is that variations in PA and RAN skills are not sufficient to explain individual differences in typical and atypical reading. Considering children from 3^{rd} grade, other cognitive processes were implicated. As explicated in the Discussion section of Chapter 2, the nature of the reading task administered (passage reading) could imply the activation of additional cognitive processes, in both the verbal and non-verbal domains, that significantly support reading. Talking about the components of text reading fluency, Fuchs and colleague (Fuchs, Fuchs, Hosp, & Jenkins, 2001) said:

> "Oral reading fluency represents a complicated, multifaceted performance that entails, for example, a reader's perceptual skill at automatically translating letters into coherent sound representations, unitizing those sound components into recognizable wholes, and automatically accessing lexical representations, processing meaningful connections within and between sentences, relating text meaning to prior information, and making inferences to supply missing information." (pp. 239-240).

Despite (or right for) the activation of a complex pattern of supportive cognitive skills, meaningful text reading is an ecological task to evaluate reading ability because of its similarity with learning material used in the school context; moreover, it has been considered the best indicator of overall reading competence (Adams, 1994; Fuchs et al., 2001). Yet, most of studies on reading used word and/or non-word reading tasks, so less is known about the cognitive underpinnings of text reading. The present studies provide some evidence in this direction.

Another important factor is the extent of reciprocal relationships between the neurocognitive processes analysed and children's literacy skills: difficulty in reading reduced motivation to read, and discourages children to practice their reading. Lack of practice prevents the growth of reading skill and, in the meantime, hinders the expansion of reading-related skills, such as lexical knowledge and PA (e.g. Perfetti, Beck, Bell, & Hughes, 1987). Considering the concurrent nature of the relationships between reading fluency and cognitive skills identified in the present studies, this observation should be kept in mind.

5.3 Beyond cognitive processes

A further aim of this dissertation was to investigate in an exploratory way the autonomic response to reading tasks in children with DD and typical readers. This intention derives from the lack of studies that specifically analyzed the emotional and physiological reaction to reading tasks in children with DD, despite Italian educational policies recommend to abstain dyslexic children from reading aloud in class (e.g. ministerial note n° 4099 05.10.2004). The lower GSR observed only in dyslexic children and exclusively for the reading aloud task, was interpreted as an indicator of activation of the behavioural inhibition system, associated to the production of withdrawal or anxiety symptoms (e.g. Gray 1972; 1978). This result is in line with the few studies that analysed emotional reactions to reading in children with dyslexia and controls, showing higher states of anxiety and lower expectancy of success in dyslexic students just before starting a reading task (Butkowsky & Willows, 1980; Carroll & Iles, 2006). However, past studies used self-report questionnaires, that may not reflect what the child really feels: for example, children could underestimate the fatigue experienced in the school context to protect themselves from a stressful recognition of it. A confirmation of this comes from the low child-parent agreement on emotional life in the school context found in some studies (e.g., Rotsika et al., 2011). Another critical factor for self-reporting is that the recording of children's answers clearly can not be done during the reading task. Using physiological measures it was possible to have a direct measure of children's reaction when they were reading a text.

In the study presented in Chapter 4, questionnaires were used to investigate components of school wellness (e.g., relationships with classmates and teachers, self-efficacy, emotional attitude towards school) considering the point of view of both children and parents. Questionnaire scores revealed significant differences in the comparison between dyslexics and controls when considering parent, but not children, reports. This result could be considered in line with the low child-parent agreement found in past studies (e.g., Rotsika et al., 2011). Interestingly, parent's scores correlated significantly with physiological measures: considering the aim of the study, correlations between parent scores on children's emotional difficulties subscale, GSR for both the reading tasks and HR for the reading aloud tasks, are the most relevant. This result was interpreted in terms of identification by parents of a distress expressed by children through the activation of the behavioral inhibition system.

The set of findings presented in Chapter 4 suggests the importance of broadening the focus on the emotional consequences of DD through different instruments, also involving "significant others" such as parents as critical informants.

5.4 Implications for educational and clinical work

It has been known for some decades that it is possible to prevent reading difficulties by structured PA training in preschool or first grade (see Carroll, Bowyer-Crane, Duff, Hulme, & Snowling, 2011; Snowling, 2013; Vellutino et al., 2004). Furthermore, it has been shown that systematic and explicit phonic-based instruction of decoding strategies - and not, for example, teaching based on whole language instruction - yields substantial improvement in reading process and co-determines its automatization (Dehaene, 2007; Foorman & Torgesen, 2001; Jeynes & Littell, 2000). The study presented in Chapter 2 confirmed the importance of didactic strategies based on PA and on explicit teaching of grapheme-phoneme associations also for Italian beginner readers. This study's results also suggest to look specifically to both PA and RAN in screening assessments for children in 1st and 2nd grades. Considering older children, the concurrent predictors of text reading fluency identified reflect the role of additional cognitive processes, despite the contribution of PA and RAN remains significant: in light of these results, screening measures in the later years of primary school should include, in addition to PA and RAN, verbal short-term memory and a measure of visual-spatial attention. Lexical knowledge had a role in explaining reading fluency variations observed in typical readers, but was not impaired in dyslexic children; so it should not be included in a screening battery for dyslexia. Special attention should be paid to the choice of the task for assessing PA: in fact, only phoneme blending was found to be appropriate for discriminating between children with dyslexia and controls (Chapter 3). This finding suggests to prefer tasks involving manipulation of phonemes rather than syllables.

Results obtained on Italian dyslexic children have implications for clinical work in the areas of diagnosis and intervention. In particular, considering the process of diagnosis, my findings suggest to deeply analyze the cognitive profile exhibited by each child, going beyond a functional investigation of reading skills and the verification of the IQ-achievement discrepancy. It was clearly shown by the research presented in Chapter 3 and partially in similar previous studies (Del Giudice et al., 2000; Menghini et al., 2010; Zoccolotti et al., 1999), that in a transparent orthography such as Italian, as well as in less consistent ones (e.g. Pennington et al., 2012), children with DD present different patterns of deficits. In some children only the phonological domain, and on rare occasions exclusively the visuo-attentional area, result impaired, whereas most of dyslexics exhibit a mixed profile, that includes cognitive deficits in several areas. A deep analysis of the cognitive processes that result impaired in each child is particularly important for the implementation of intervention programs, together with the analysis of comorbidities, in order to have theoretically motivated and evidence based interventions. In fact, to date there are studies that proved the efficacy of different types of interventions, but that also showed that no intervention benefits all children, and inevitably there is variation in children's response (Snowling, 2013). For example, it is well established that effective interventions to strengthen decoding abilities involve work on letter-sound knowledge, PA and reading practice (Snowling & Hulme, 2012b). However, interventions that focus only on the phonological processing would be probably less incisive for children that show also some visual-perceptual or attentional problems, compared with children with an exclusively deficit in the phonological domain. Another example comes from the study of Allamandri et al. (2007), that proved the clinical efficacy of five interventions based on training of lexical and sublexical reading, supported by specialized software. Also in this case, a portion of participants was not significantly advantaged by the intervention.

Recently, various types of interventions have been designed and tested, and could be considered as an alternative or integration for children with unusual or mixed cognitive profiles: it is the case, for example, of the “Seeing stars” method by Bell (1997), that focuses on imaging/visualization of single letters, syllables and entire words, or of training paradigms that improves visual attention (e.g. Franceschini et al., 2013). However, it remains important for professionals to critically review the content of available programs, to evaluate the actual possibility of obtaining positive results and ensure their suitability for a specific child (Snowling, 2013); furthermore, characteristics of orthography should be considered in the choice of an intervention program (Bavelier, Green, & Seidenberg, 2013). A careful evaluation and choice of intervention is recommended also considering the potential that a proper intervention can have, going beyond behavioral changes; in fact, functional neuroimaging studies have revealed brain plasticity associated with effective intervention for dyslexia (see Gabrieli, 2009 for a review).

5.5 Future directions

A massive amount of research has been conducted in the lasts decades to discover cognitive, neural and genetic bases of reading processes in typical and atypical development. Future research on reading should focus on interventions based on individual pattern of cognitive strengths and impairments, possibly considering also the emotional difficulties due to struggling in reading. It would be particularly useful to identify behavioral, cognitive and environmental characteristics of children with DD that do not respond to- or sustain the benefits of intervention, in order to understand risk factors for resistance to treatment. All these considerations should be done taking into account also the impact of the orthography’s characteristics on learning to read. Concerning assessment, it would be useful to know if and how the physiological alterations observed in dyslexic children during reading aloud affect reading performance, also examining possible influences over time.

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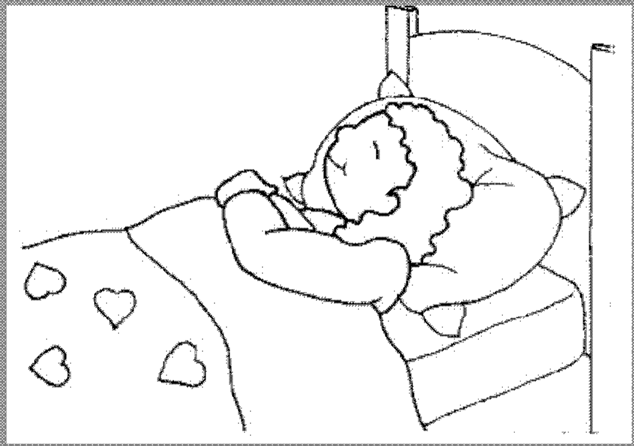
Appendix 1

		V = vero	F = falso
1	Il cane è un animale domestico come il gatto	V	F
2	All’interrogazione l’alunno fa le domande alla maestra	V	F
3	In agosto la gente indossa sciarpa e cappotto	V	F
4	Al tramonto il sole è in alto nel cielo	V	F
5	Per giocare a calcio occorrono gli sci	V	F
6	Il latte e il tè si bevono a colazione con i biscotti	V	F
7	La A e la B sono le prime lettere dell’alfabeto	V	F
8	Le pentole si costruiscono con lana e cotone	V	F
9	La mucca ha cinque zampe e due code	V	F
10	In montagna si usano spesso guanti e sciarpa	V	F
11	Il burro e la marmellata si spalmano sul pane	V	F
12	L’acqua del mare contiene sale	V	F
13	La chiave serve per aprire la porta e si infila nella serratura	V	F
14	I pennarelli si usano per colorare i disegni	V	F
15	Se ci comportiamo male la mamma ci dà un premio	V	F
16	L'Africa è un paese freddo che si trova vicino al Polo	V	F
17	Allo stadio si va per vedere una gara di nuoto	V	F
18	La canna da pesca si usa per prendere le farfalle	V	F
19	L’aereo si alza da terra e vola tra le nuvole	V	F
20	L’insalata è una verdura che cresce nell’orto	V	F
21	Il serpente è un animale che striscia sulla terra	V	F

		V = vero	F = falso
1	Le fiabe sono dei racconti di fantasia	V	F
2	I cervi sono animali che vivono sia sulla terra che nell’acqua	V	F
3	I leoni e gli elefanti si possono vedere al circo	V	F
4	Il dentista è un tecnico che aggiusta le automobili	V	F
5	La bicicletta ha un manubrio, un sellino, e due ruote	V	F
6	Gli uomini camminano con due gambe	V	F
7	Il carnevale si festeggia travestendosi in maschera	V	F
8	La gallina è un animale coperto di pelo	V	F
9	La domenica è un giorno di festa e non si va a scuola	V	F
10	La bicicletta va più veloce dell’automobile e dell’aereo	V	F
11	Gli uccelli hanno ali, piume e becco	V	F
12	Sul camion possono salire persone, animali e cose	V	F
13	Il postino distribuisce lettere e cartoline	V	F
14	Lo squalo vive nell’oceano ed è un pesce	V	F
15	Il cioccolato si mangia sugli spaghetti	V	F
16	Gli occhiali servono per sentire meglio i suoni	V	F
17	I cacciatori uccidono gli animali con il fucile	V	F
18	Allo zoo si possono osservare famosi quadri	V	F
19	Col telefono possiamo veder cartoni animati e film	V	F
20	La sera ci distendiamo nel letto tra le coperte	V	F
21	Il macellaio vende bulloni, viti e martelli	V	F

Appendix 2

1



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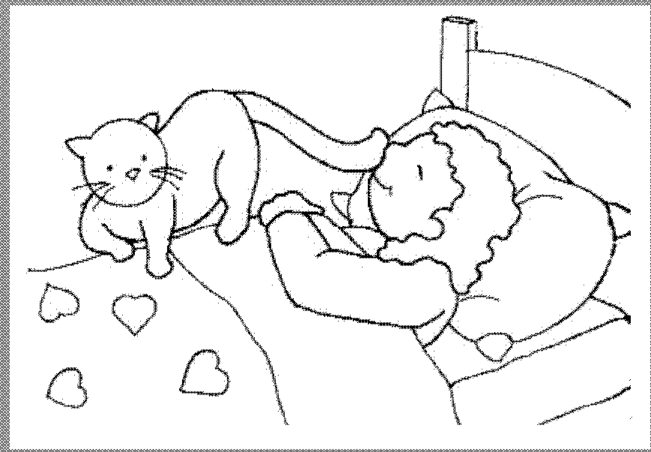

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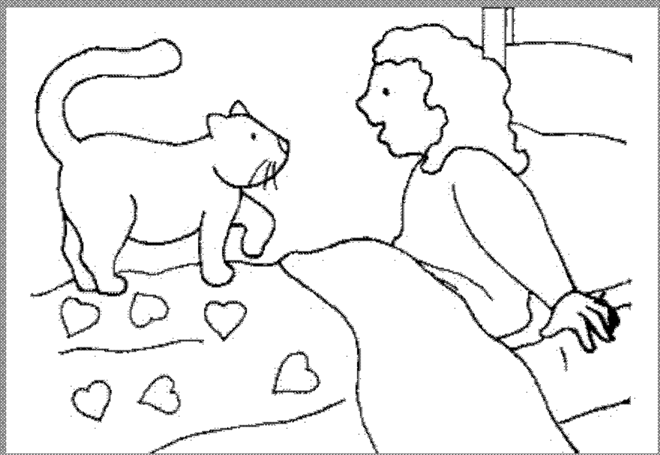


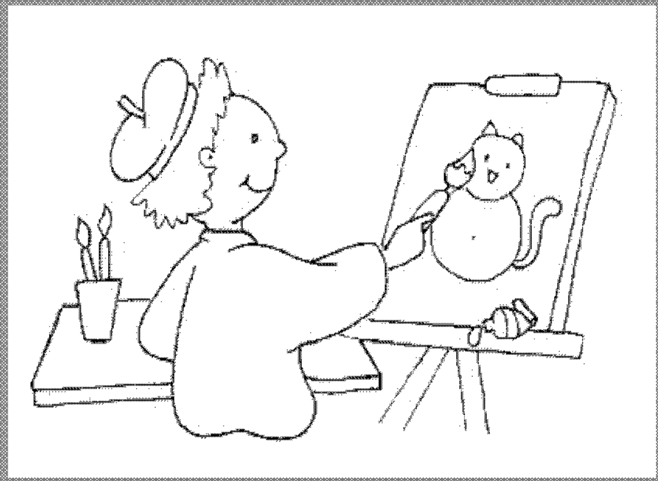
Dai il tuo voto:

□ poco chiaro

□ abbastanza chiaro

□ chiarissimo

1



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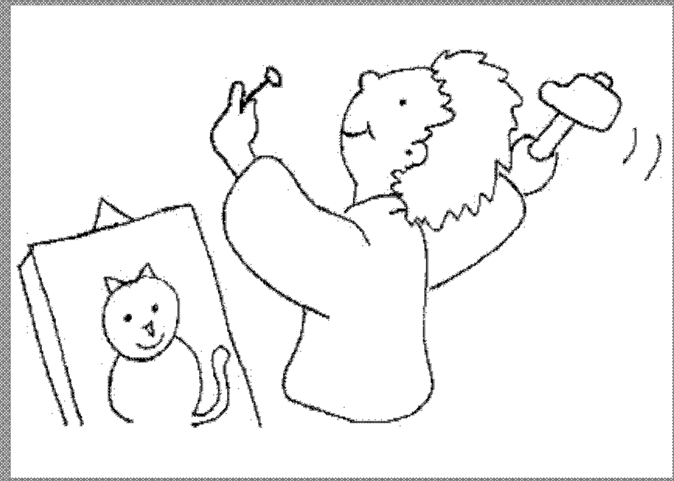

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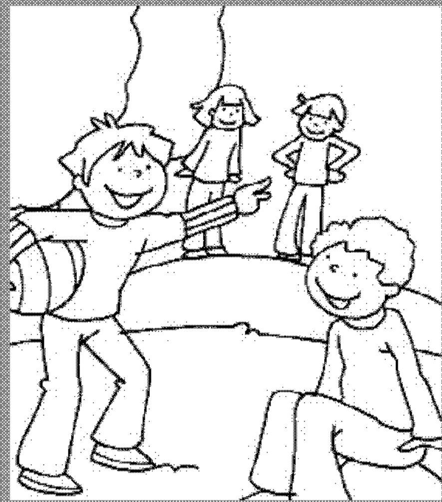
Dai il tuo voto:

- □ poco chiaro
- □ abbastanza chiaro
- □ chiarissimo

1

2



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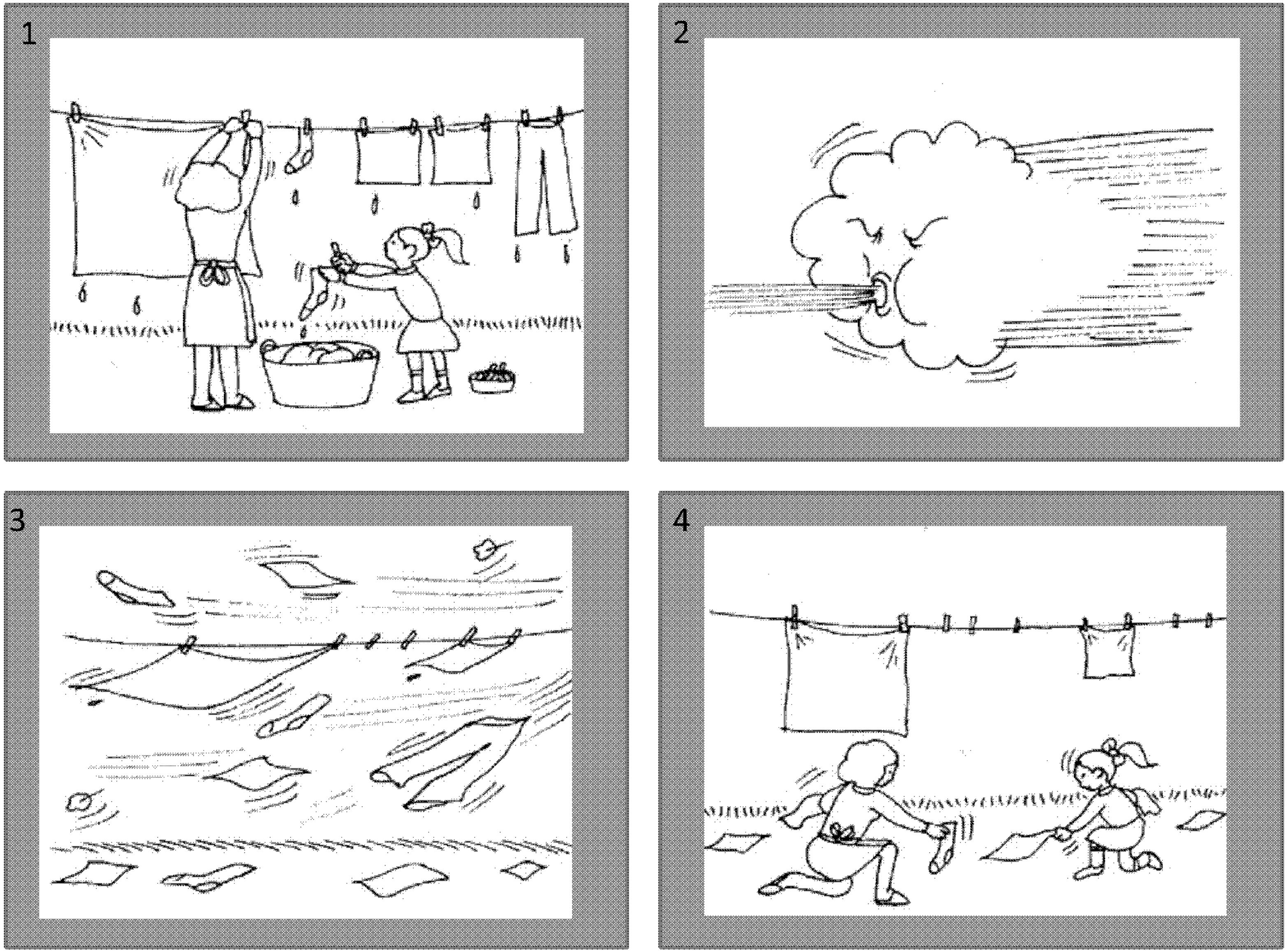
Dai il tuo voto:

□ poco chiaro

□ abbastanza chiaro

□ chiarissimo



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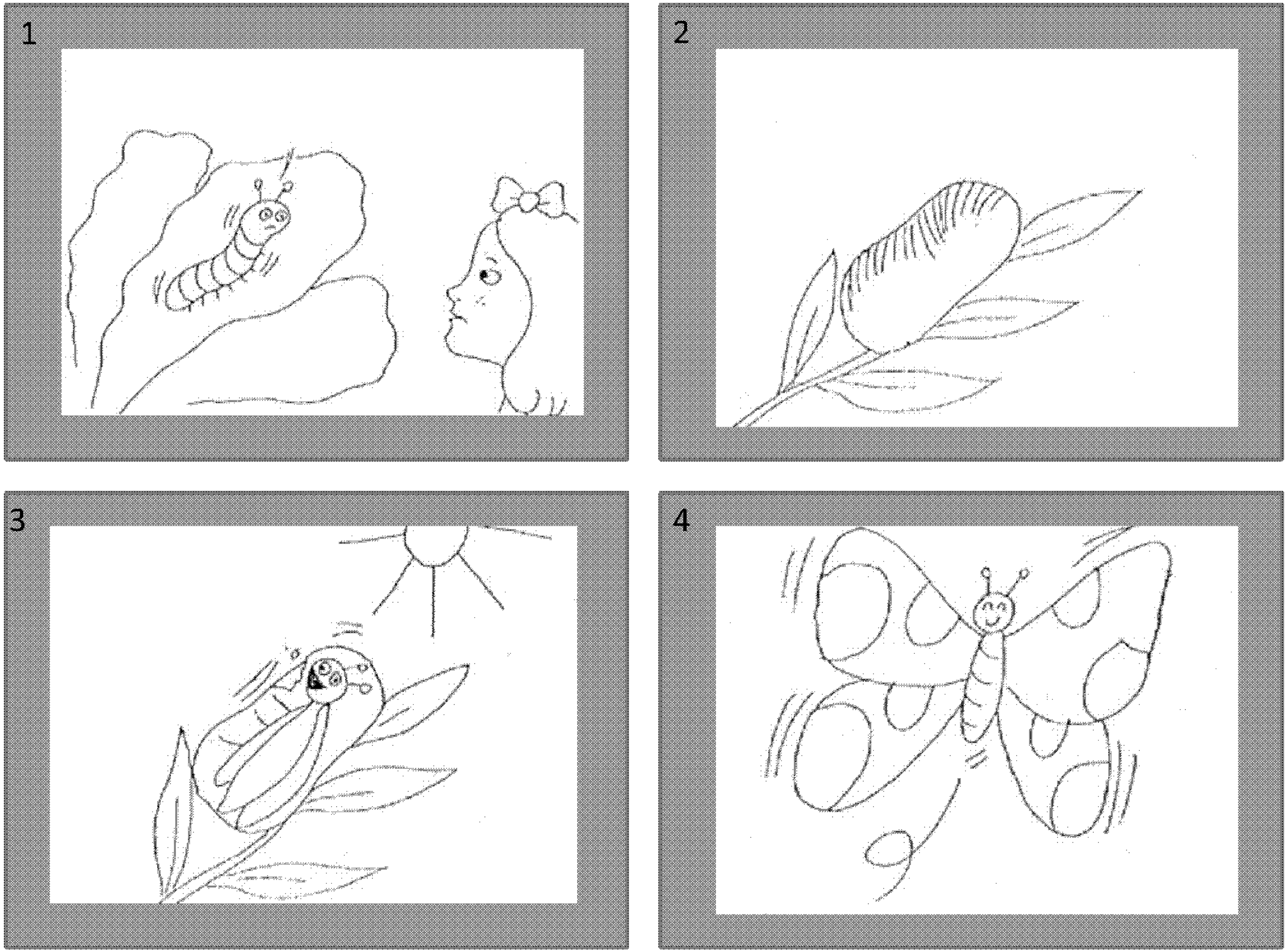
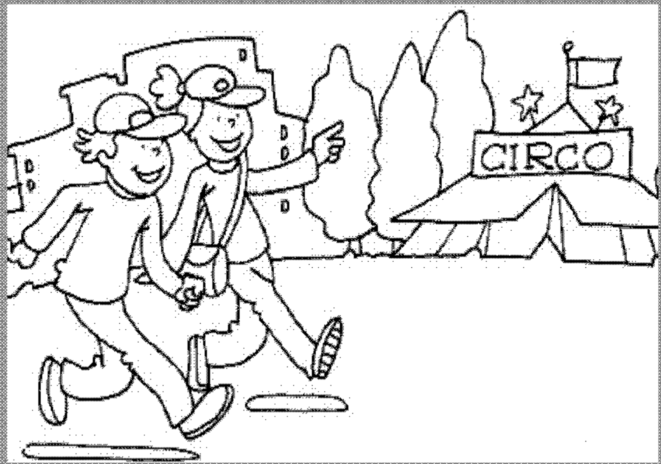


Dai il tuo voto: □ poco chiaro □ abbastanza chiaro □ chiarissimo

1



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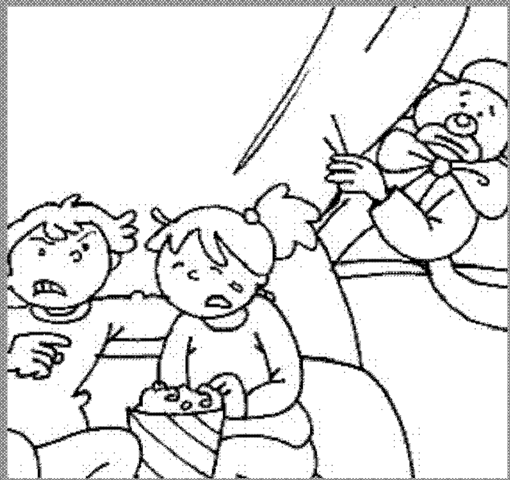

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Dai il tuo voto: □ poco chiaro □ abbastanza chiaro □ chiarissimo

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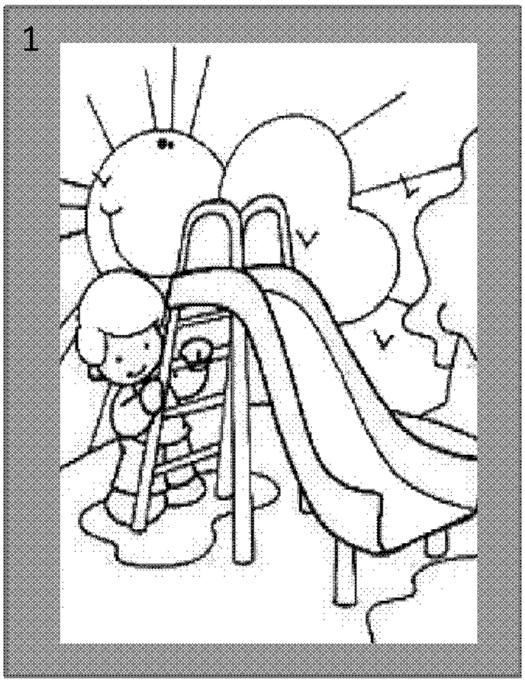

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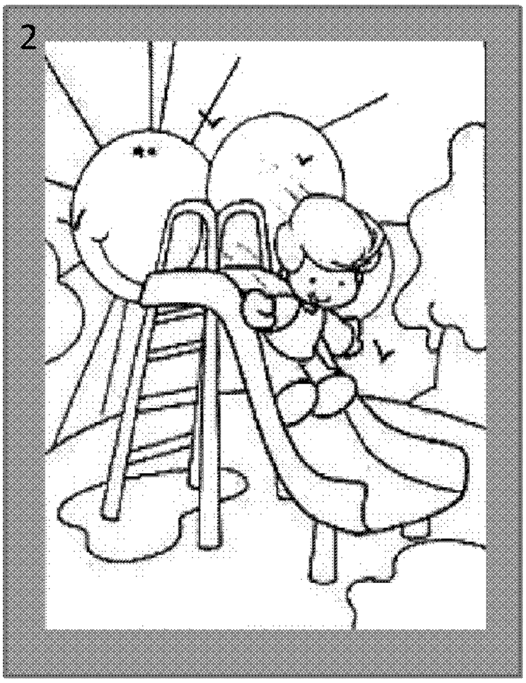

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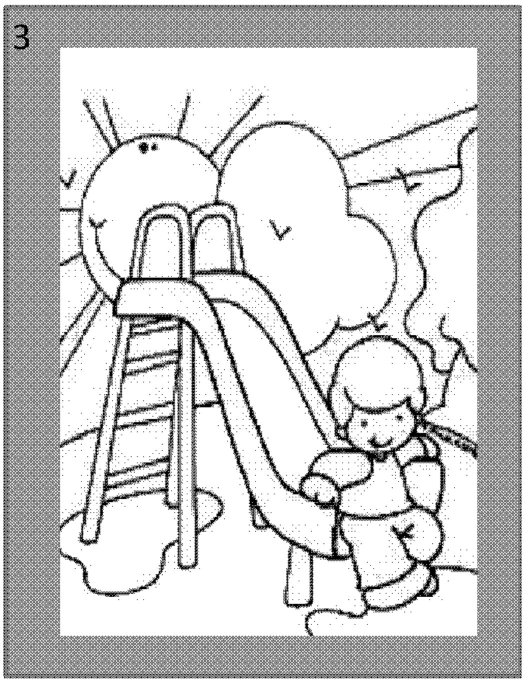

Dai il tuo voto:
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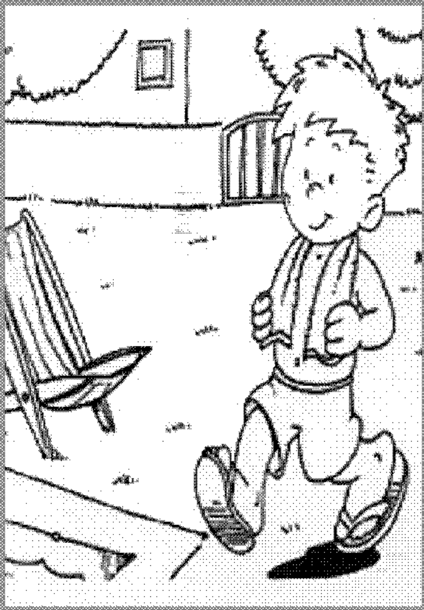
□ abbastanza chiaro
□ chiarissimo

1



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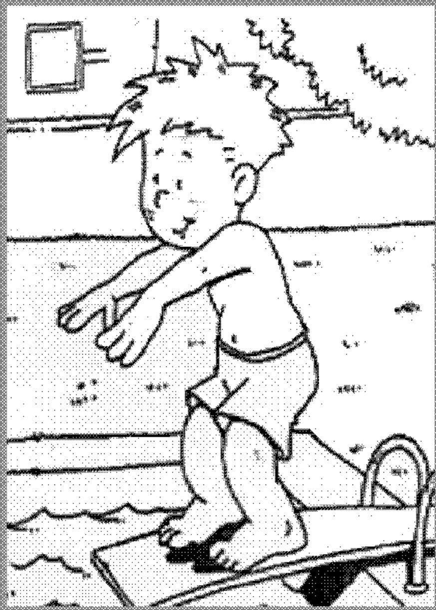

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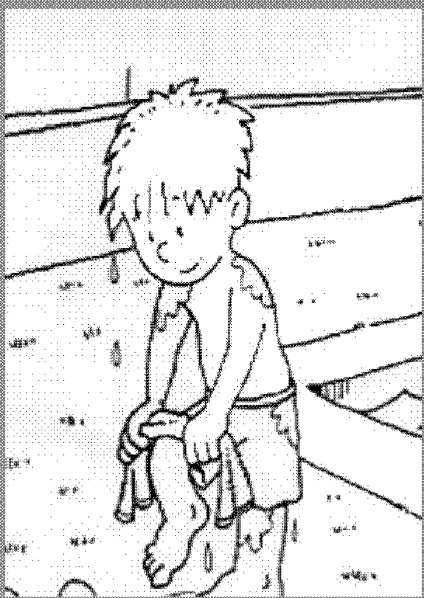

Dai il tuo voto:

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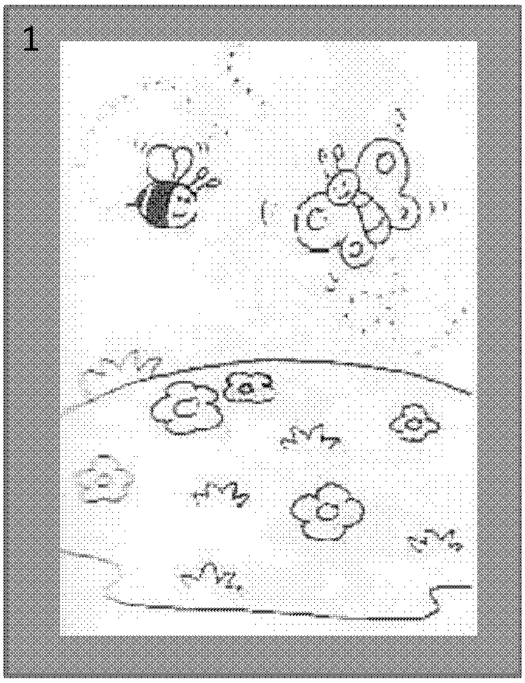
□ chiarissimo

1



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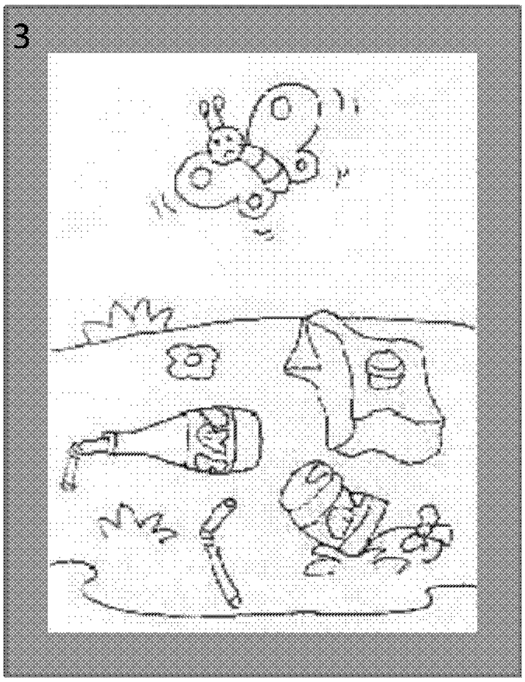

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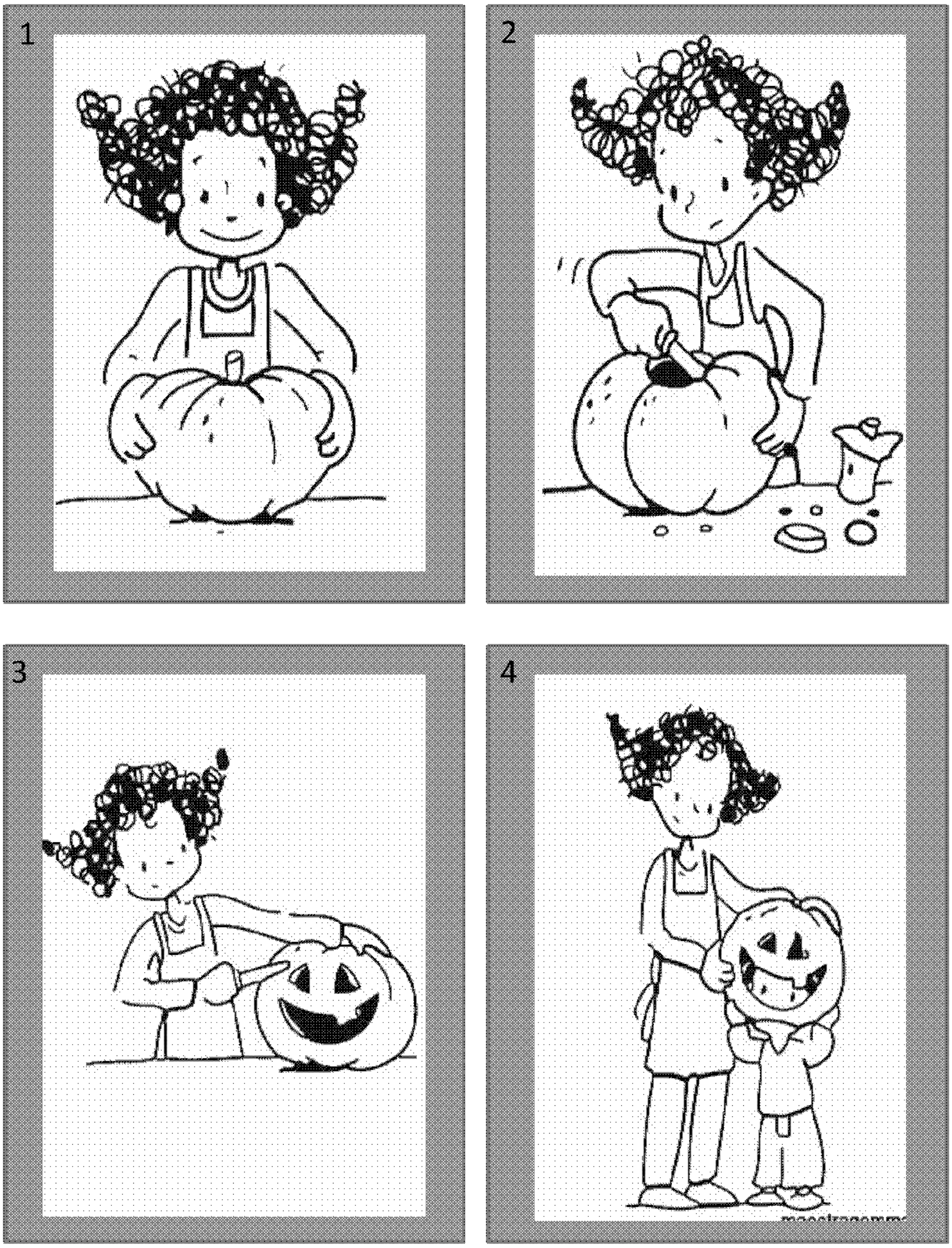
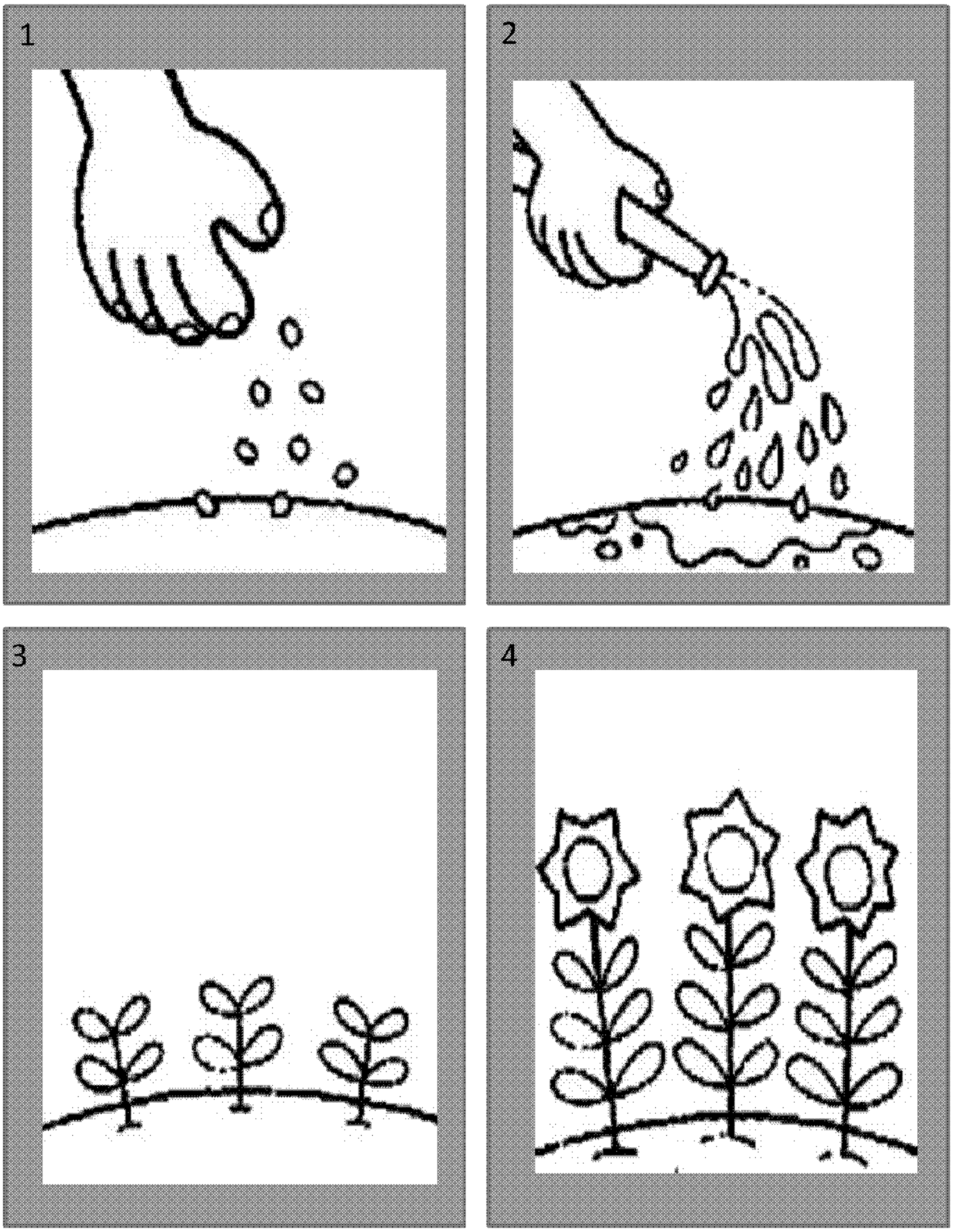
□ chiarissimo



Dai il tuo voto: □ poco chiaro □ abbastanza chiaro □ chiarissimo

Dai il tuo voto: □ poco chiaro □ abbastanza chiaro □ chiarissimo



Dai il tuo voto: □ poco chiaro □ abbastanza chiaro □ chiarissimo

Appendix 3 – QSW-child version

Tobia Valentina & Marzocchi Gian Marco – Università di Milano-Bicocca Gennaio 2013
Questionario Bambino

Leggi attentamente le frasi e poi fai una croce su

0 se secondo te la frase NON E' VERA, 1 se è ABBASTANZA VERA oppure 2 se è VERISSIMA.

Non ci sono risposte giuste o sbagliate, ci interessa quello che pensi tu!

Classe: ______________________________

Data di nascita: ________________________

Maschio ☐ Femmina ☐

	Item	Non vero	Abbastanza vero	Verissimo
1	Sono soddisfatto dei risultati scolastici che ottengo	0	1	2
2	Sono capace di pensare in fretta	0	1	2
3	Vado male in un compito scolastico solamente quando è troppo difficile	0	1	2
4	Ai miei compagni piace lavorare con me	0	1	2
5	Credo di essere un bambino sveglio	0	1	2
6	Sono tranquillo prima di una verifica o un'interrogazione	0	1	2
7	Di fronte agli ostacoli non mi tiro indietro	0	1	2
8	Quando sbaglio credo di essere meno intelligente dei miei compagni	0	1	2
9	Sono agitato quando so di non aver fatto bene un compito	0	1	2
10	In classe ho molti amici	0	1	2
11	Mi sento a mio agio con i miei insegnanti	0	1	2
12	Mi sento in colpa quando non riesco a fare bene un compito	0	1	2
13	Vado bene nei compiti scolastici solo quando qualcuno mi aiuta	0	1	2
14	Ho tanta immaginazione	0	1	2
15	I miei insegnanti mi sanno convincere a impegnarmi al massimo	0	1	2
16	Di solito ho delle buone idee	0	1	2
17	In classe mi sento accettato	0	1	2
18	Mi fido dei miei insegnanti	0	1	2
19	I miei genitori sono contenti di come vado a scuola	0	1	2
20	I miei insegnanti mi aiutano se non capisco qualcosa	0	1	2
21	Con i miei compagni mi diverto	0	1	2
22	Mi vergogno a parlare davanti a tutta la classe	0	1	2
23	I miei genitori credono che nello studio mi impegni al massimo	0	1	2
24	Posso parlare con i miei insegnanti delle mie preoccupazioni e difficoltà	0	1	2
25	I miei insegnanti sono contenti di come vado a scuola	0	1	2
26	Imparo cose nuove con facilità	0	1	2
27	Dei miei compagni mi posso fidare	0	1	2

Grazie mille!

Appendix 3 – QSW-parent version

UNIVERSITÀ DEGLI STUDI DI MILANO
BICOCCA

QUESTIONARIO BENESSERE SCOLASTICO – versione per genitori

Nome: ____________________________ Cognome: _____________________________

Genitore di: ____

La preghiamo di leggere attentamente le frasi e di fare poi una crocetta su:

0 se secondo lei la frase non è vera, 1 se è abbastanza vera e 2 se è verissima.

	Item	Non vero	Abbastanza vero	Verissimo
1	Penso che mio/a figlio/a sia molto preoccupato/a dalle sue difficoltà	0	1	2
2	Gli insegnanti di mio/a figlio/a sono disposti a collaborare con la famiglia per aiutarlo	0	1	2
3	Quando mio/a figlio/a è in difficoltà mi sento in colpa	0	1	2
4	Le difficoltà di mio/a figlio/a mi fanno arrabbiare	0	1	2
5	Mio/a figlio/a è autonomo/a nello svolgere i suoi compiti	0	1	2
6	Tendo ad aiutare troppo mio/a figlio/a	0	1	2
7	Mio/a figlio/a tende a ingigantire le sue difficoltà	0	1	2
8	Mio/a figlio/a ha difficoltà a scrivere	0	1	2
9	Mio/a figlio/a si fa prendere dall'ansia quando ha qualche verifica o interrogazione	0	1	2
10	Mio/a figlio/a ha difficoltà a comprendere ciò che legge	0	1	2
11	Dopo un colloquio con gli insegnanti di mio/a figlio/a sono spesso nervoso/a	0	1	2
12	Tendo a sopravvalutare le difficoltà di mio/a figlio/a	0	1	2
13	Penso che mio/a figlio/a si intristisca a causa delle sue difficoltà	0	1	2
14	Mio/a figlio/a mi parla delle sue difficoltà	0	1	2
15	Mio/a figlio/a è interessato/a a migliorarsi	0	1	2
16	Mio/a figlio/a ha difficoltà a concentrarsi	0	1	2
17	So come aiutare mio/a figlio/a quando è in difficoltà	0	1	2
18	Mio/a figlio/a è pigro/a quando si tratta di fare i compiti	0	1	2
19	Gli insegnanti di mio/a figlio/a conoscono bene quali sono le sue potenzialità	0	1	2
20	Le difficoltà di mio/a figlio/a mi fanno paura	0	1	2

1

Questionario realizzato da:

Valentina Tobia & Gian Marco Marzocchi

21	Mio/a figlio/a ha difficoltà a fare i calcoli	0	1	2
22	Credo che gli insegnanti di mio/a figlio/a abbiano le competenze per aiutarlo/a	0	1	2
23	Le difficoltà di mio/a figlio/a mi intristiscono	0	1	2
24	Il momento dei compiti è fonte di stress per me	0	1	2
25	Mio/a figlio/a ha difficoltà a leggere	0	1	2
26	Mio/a figlio/a si impegna per combattere le sue difficoltà	0	1	2
27	Penso che mio/a figlio/a si arrabbi a causa delle sue difficoltà	0	1	2
28	Mio/a figlio/a è in grado di gestire il proprio materiale scolastico (cartella, diario, astuccio…)	0	1	2
29	Faccio fatica a far lavorare mio/a figlio/a	0	1	2
30	So a chi rivolgermi se mio/a figlio/a ha difficoltà nelle quali io non posso aiutarlo/a	0	1	2
31	Gli insegnanti di mio/a figlio/a conoscono bene quali sono le sue difficoltà	0	1	2
32	Mio/a figlio/a ha difficoltà a produrre dei testi scritti	0	1	2
33	Mio/a figlio/a ha difficoltà a seguire ragionamenti complessi	0	1	2
34	Sono preoccupata/o per il futuro di mio/a figlio/a	0	1	2
35	Penso che mio/a figlio/a si renda bene conto delle sue difficoltà	0	1	2
36	Mi sento solo/a davanti alle difficoltà di mio/a figlio/a	0	1	2

La ringraziamo per la sua collaborazione

Questionario realizzato da:

Valentina Tobia & Gian Marco Marzocchi