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Behavioral and Cortical Indices of Typical and Atypical Development of Reading and Spelling Skills in Children: Evidence from Different Orthographies

Dissertation

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1. Referent: Prof. Dr. Thomas Elbert
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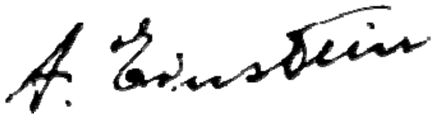
“Try not to become a man of success but rather try to become a man of value”



Diagnosed as Media-dyslexic child

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Konstanz 22.3.2010, Wessam Mohamed

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Summary

Literacy acquisition is among the most highly-developed functions of the human brain and can only be achieved by the systematically-designed learning process known as education. Reading and spelling are complex processes, yet the majority of children learn them effortlessly. For researchers, it is always puzzling why some children are impaired although they are normal in all other respects and go on to develop dyslexia (reading and/or spelling disorders). Researchers have also attempted to determine if reading and spelling are two sides of the same coin: in the acquisition of literacy? Or are they separate processes that have little in common? While these questions have been adequately addressed and evidence has become reasonably well established for European languages, little empirical research has been conducted for the Semitic languages, namely the Arabic language.

In the current thesis, I present three studies that have generally aimed to identify some cortical and behavioral indices of typical and atypical development of reading and spelling in children from different orthographies, namely Arabic and German. While the first two studies addressed the typical and atypical development of reading and spelling in Arabic-speaking children at the behavioral level, the third study was devoted to identifying cortical indices of German-speaking dyslexic children.

In study I, a cross-sectional study, I developed and validated literacy measures to trace the developmental course of the relationship between reading and spelling in the first three years of learning Arabic with a consideration to evaluate potential gender differences. Analysis of data showed significant developments in literacy skills across age and a significant male advantage in literacy measures pronounced only in first graders. Further analysis of first grade data indicates a potential role of visualization and spatial abilities in the interplay between fluent reading and spelling in the early stages of literacy acquisition, but not in later grades. This might imply a reliance on the visual processing rather than the phonological processing

while learning Arabic in the first grade. High correlations were found between fluent reading and spelling and, interestingly, spelling accuracy develops earlier than fluent reading, suggesting that spelling drives both the alphabetic and orthographic phases in learning Arabic.

In study II, an epidemiological study, a representative sample of 1106 Arabic-speaking third graders were screened for their reading and spelling abilities and their general level of functioning. Based on a "two year behind grade level" as a cut-off score, the prevalence of dyslexic children was estimated to be 8.1%. Based on the 16 percentile, the overall prevalence of the three impaired groups - good readers-poor spellers, poor spellers-good readers, poor readers-poor spellers - was 1.1%, .9% and 12.6%, respectively. The estimated incidence rate (8%-15%) of children suffering reading or/and spelling disorders is, surprisingly, high for Arabic and calls for specific attention to this problem in Arabic-speaking countries. The few previous findings have only addressed limited aspects of reading disability, and did not test spelling problems. Apparently, Semitic writing systems differ markedly from other alphabetic writing systems and, therefore, spelling disabilities may also be different.

In study III, an MEG study, we tested to see if temporal integration is reflected as oscillatory activity in different frequency bands. Therefore, we mapped focal slow waves in the delta (1.5-4Hz) frequency band, using magnetoencephalographic (MEG) source imaging in a sample of 19 dyslexic children with poor categorical perception and 14 controls while listening passively to syllables /ba/ and /da/. Dyslexic children with poor categorical perception differ significantly in the density of magnetic slow waves produced by the two hemispheres. To illustrate, dyslexic children with poor categorical perception showed elevated production of focally-generated slow waves (1-4Hz) predominately in the left hemisphere as compared to controls. The results suggest altered segmentation processes of speech sounds in a subset of children with dyslexia.

Based on the findings of the current thesis, we draw the conclusion that the orthographic characteristics of a language have an impact on the typical and atypical development of reading and spelling both at the behavioral and the cortical level.

Zusammenfassung

Die Lese- und Schreibfähigkeit gehört zu den am höchsten entwickelten Funktionen des menschlichen Gehirns und kann nur durch einen systematisch gestalteten Lernprozess erlangt werden. Obwohl Lesen und Schreiben komplexe Prozesse sind lernt die Mehrheit der Kinder diese problemlos. Dabei ist es allerdings ein noch nicht entschlüsseltes Rätsel, warum manche Kinder, obwohl sie in allen anderen Bereichen normal talentiert sind, in dem Erwerb von Lesen und Schreiben beeinträchtigt sind und somit eine entwicklungsbezogene Dyslexie entwickeln. Dabei wird disktuiert, ob Lesen und Schreiben zwei Seiten derselben Münze sind und damit der Erwerb von Lese- und Schreibfähigkeit gekoppelt ist, oder ob es sich um separierbare Prozesse handelt, wodurch isoliert Defizite nur im Bereich des Schreibens oder nur im Bereich des Lesens auftreten könnten. Während hinsichtlich europäischer Sprachen diese Fragen intensiv beforscht worden ist, wurde bislang kaum empirische Forschung zu semitischen Sprachen, wie etwa der arabischen Sprache, durchgeführt.

In der folgenden Arbeit werde ich drei Studien erläutern, welche darauf zielen, kortikale und behaviorale Hinweise auf typische und atypische Entwicklung der Lese- und Schreibkompetenz bei Kindern verschiedener Orthographien zu erlangen. Während die ersten beiden Studien sich mit der Lese- und Schreibkompetenz arabischer Kinder auf behavioraler Ebene befassen, widmet sich die dritte Studie den kortikalen Merkmalen deutschsprachiger Kinder mit Dyslexie.

In Studie I, einer Querschnittsstudie, entwickelte und validierte ich Instrumente zur Messung der Lese- und Schreibfähigkeit, um den Entwicklungsverlauf der Beziehung zwischen Lesen und Schreiben in den ersten drei Jahren des Erlernens der arabischen Sprache, unter Berücksichtigung potentieller Geschlechtsunterschiede, zu verfolgen. Die Datenanalyse beschreibt die Entwicklung der Lese- und Schreibkompetenz wobei eine signifikante Überlegenheit der männlichen Kinder bei der Messung der Lese- und Schreibfähigkeit bei

Erstklässlern beobachtet wurde. Die weitere Analyse der Erstklässer-Daten zeigt, dass die Fähigkeit zur Visualisierung sowie zur räumlichen Vorstellungskraft möglicherweise eine Rolle bei der Wechselwirkung zwischen flüssigem Lesen und Schreiben in den frühen Stadien ihres Erwerbs darstellt, jedoch nicht bei älteren Schülern. Dies legt die Implikation nahe, dass sich Erstklässler zum Erlernen des Arabischen in erster Linie auf visuelle Prozesse anstatt auf phonologische Verarbeitung stützen. Es wurden hohe Korrelationen zwischen der Fähigkeit zum flüssigem Lesen und der Schreibfähigkeit festgestellt; interessanterweise wird dabei korrekte Rechtschreibung früher als flüssiges Lesen erlernt, was darauf hinweist, dass die Schreibfähigkeit sowohl die alphabetische wie auch die orthographische Phase des Arabisch-Lernens bestimmt.

In Studie II, einer epidemiologischen Studie, wurde eine repräsentative Stichprobe von 1106 arabisch sprechenden Drittklässlern hinsichtlich ihrer Lese- und Schreibfähigkeiten und des generellen Grades ihres Funktionsniveaus untersucht. Basierend auf der „Leistung zwei Jahre hinter Jahrgangsniveau“ als cut-off Score, wurde für dyslektische Kinder eine Prävalenz von 8,1% berechnet. Beruhend auf dem 16. Perzentil ergaben sich folgende Prävalenzen: Gute Lesefähigkeit – schlechte Rechtschreibfähigkeit 1.1%; schlechte Lesefähigkeit – gute Rechtschreibfähigkeit 0.9%; schlechte Lesefähigkeit – schlechte Rechtschreibfähigkeit 12,6%. Die geschätzte Inzidenz (8%-15%) arabischsprachiger Kindern, die an einer Lese – und/oder Rechtschreibschwäche leiden, ist überraschend hoch, und verlangt nach besonderer Aufmerksamkeit hinsichtlich dieser Problematik in den arabischsprachigen Ländern. Die wenigen bisher vorhandenen Erkenntnisse waren auf einige Aspekte der Leseschwäche beschränkt, Rechtschreibschwächen wurden noch kaum untersucht.

Das semitische Schriftsystem unterscheidet sich offensichtlich auch hinsichtlich des Erlernens deutlich von der alphabetischen Schrift weshalb Rechtschreibschwächen ebenso unterschiedlich sein können.

In Studie III, einer MEG- Studie, untersuchten wir, die temporale Integration und Segmentation von Lauten anhand oszillatorische Hirnaktivität. Bei einer Versuchsgruppe von 19 dyslektischen Kindern mit schlechter kategorischer Wahrnehmung und einer Kontrollgruppe von 14 Personen wurde die Quellen magnetischer Hirnaktivität bestimmt, während diese passiv die Silben /ba/ und /da/ hörten. Dyslektische Kinder mit schlechter kategorischer Wahrnehmung unterschieden sich signifikant in der Dichte der Generatoren langsamer Wellen im Vergleich der beiden Hemisphären. Erklären lässt sich dies dadurch, dass dyslektische Kinder mit schlechter kategorischer Wahrnehmung im Vergleich zur Kontrollgruppe eine erhöhte Rate fokaler langsamer Wellen (1-4Hz), überwiegend in der linken Hemisphäre, zeigten. Die Ergebnisse deuten auf einen veränderten Segmentierungsprozess der Sprachlaute bei einer Untergruppe von Kindern mit Dyslexie hin.

Basierend auf den Ergebnissen dieser Arbeit, ziehen wir den Schluss, dass die orthographischen Eigenschaften einer Sprache einen Einfluss auf die typische und atypische Entwicklung von Lesen und Schreiben haben, sowohl auf der behavioralen wie auch auf der kortikalen Ebene.

A Record of Achievements

Submitted Articles and Research Contributions

Study1: The Development of Reading and Spelling Abilities in the First Three Years of Learning Arabic (Reading and Writing: *An Interdisciplinary Journal* published online 2-7-2010).

In this study, I contributed to the conceptualization of the study. I designed the literacy measures based on the Standardized Tests in the German language, and validated them. I, mainly, collected the data. I analyzed the data and conducted the statistical analyses. I wrote the first draft and the revised the manuscript.

Study2: An Epidemiological Survey of Specific Reading and Spelling Disorders in Arabic Speaking Third Graders (Submitted Manuscript)

In this study, I contributed to the conceptualization of the study. With the help of teamwork, I participated in data collection. I analyzed the data and conducted the statistical analyses. I wrote the first draft and the revised the manuscript.

Study 3: Abnormal Oscillatory Brain Responses in Dyslexic Children with Poor Categorical Perception (Manuscript is to be submitted)

In this study, I contributed to the conceptualization of the study. I contributed to the analysis of the MEG data and conducted the statistical analyses. I wrote the first draft and contributed to the writing of the revised the manuscript.

Presentations at Congresses& Seminars

Talks

1. Mohamed, W., Elbert, T., Landerl, K. (2010, March). Typical and atypical; development of reading and spelling in Semitic languages: Evidence from Arabic-speaking children, invited talk at Forschungskolloquim, Lehrstuhl Prof. Dr. Thomas Lachmann, Psychology, Faculty of Social Sciences, University of Kaiserslautern.
2. Mohamed, W. & Elbert, T. (2009, November). Epidemiological findings of reading and spelling deficits in Arabic children. Oral presentation at the annual international convention of the American Speech-Language-Hearing Association (ASHA), New Orleans, LA, USA.

Poster Sessions

1. Mohamed, W. & Elbert, T. (2010, February). A Dissociation of Reading and Spelling deficits in Early Childhood: Epidemiological Findings of Arabic speaking children. Poster session presented at the Annual International Conference, Baltimore, USA.
2. Mohamed, W., Paul, I., Wienbruch, C., Elbert, E. (2008). Atypical lateralization in auditory regions of dyslexic children: Is there a reduced right hemispheric contribution to temporal integration and segmentation? Poster session presented at XI International Association of Congress of Psychology (IASCl) 20-25 July2008, Berlin.
3. Mohamed, W., Paul, I., Wienbruch, C., Elbert, E. (2008). Atypical lateralization in auditory regions of dyslexic children: Is there a reduced right hemispheric contribution to temporal integration and segmentation? Poster session presented at XXIX International Congress of Psychology (ICP) 20-25 July2008, Berlin.

Abbreviations

AM	amplitude modulation
ANCOVA	analysis of covariance
ANOVA	analysis of variance
CL	central left
CP	Categoricalperception
CPM	Coloured progressive matrices
CR	central right
CV	consosnant- vowel
EEG	Electroencephalography
F	Female
FL	frontal left
FMRI	functional magnetic resonance imaging
FR	frontal right
GPC	grapheme- phoneme –correspondence
HZ	Hertz
IQ	intelligence quotient
LH	left hemisphere
L-R	left-right asymmetry
M	Male
MEG	Magnetoencephalography
ms	Milliseconds
PA	phonological awarenesss
PET	positron emission tomography
PGC	phoneme grapheme correspondence
PL	occipo-parietal left
PR	occipo-parietal right
RH	right hemisphere
RH	right hemisphere
SD	standard deviation
SLI	specific language impairment
SPM	Standard progressive matrices
TL	temporal left
TR	temporal right
VOI	visual orthographic image
TOJ	temporal order judgment

1 Theoretical Background for Reading and Spelling

1.1 Types of Orthographies in Alphabetic Writing Systems

Spoken language is believed to precede written language in the evolution of both cultures and individuals. From this observation emerges the simplest theory of the nature of writing systems[1]. Such a theory holds that a script serves as a cipher or notation for the sounds of spoken language (Henderson, 1982, p7). While the linguistic units - phonological strings, morphemes and words, represent spoken language, spelling is the encoding of these linguistic forms into written forms and reflects the general principles of a writing system and its specific orthography (Perfetti, 1997). The writing units are provided by the writing system and its inventory of graphic devices. The linkage between the linguistic units and the graphic units (Fig. 1) form the essence of the relationship between reading and spelling in any alphabetic language.

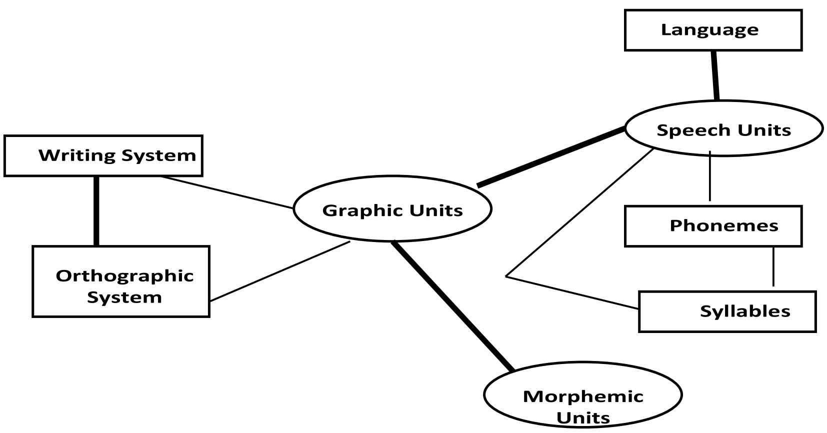

Figure 1 The General relationship among writing systems, orthographies and languages (adopted from Perfetti, 1997)

[1] According to Perfetti (1997), the writing system dictates the level at which general linguistic constraints re imposes on writing and is determined by the smallest linguistic unit encoded in the writing unit. On the other hand, the orthography within writing systems shows a minor but significant variation between linguistic and graphic units. For example, Chinese (logographic), Japanese (syllabic) and Italian (alphabetic) belong to different writing systems, while English, Italian and German (all alphabetic) have different orthographies.

Alphabetic writing systems are based on symbols (letters/alphabets/graphemes) that represent the smallest and most important segments (phonemes) of a spoken language (Lyytinen, Erskine, Aro, & Richardson, 2009). Within the family of alphabetic writing systems, orthographies vary in the degree to which they encode the surface phonology of the language relative to the morphology (Perfetti, 1997) or in the type of relationship between the graphemes, which represent phonemes (Lyytinen et al., 2009). To illustrate[2], Italian is a consistent (shallow/transparent) orthography in which the spelling of words mirrors their pronunciation in a straightforward fashion. The direct mapping from orthography to phonology and from phonology to orthography makes it a bi-directionally consistent system for both reading (forward consistency) and spelling (backward consistency) (Lyytinen et al, 2009; Perfetti, 1997). This symmetrical transparency contrasts with other orthographies that show a unidirectional/asymmetrical consistency between reading and spelling (Perfetti, 1997). German, for instance, is characterized by a forward consistency and a backward inconsistency (Wimmer & Mayringer, 2003). Contrary to symmetric and asymmetric consistent orthographies, English tends toward the deep/inconsistent end of the continuum (Fig.2), and boasts many complexities in the mapping between its grapheme and phoneme since spelling is often unfaithful to surface phonology. For example, in the reading direction, one grapheme may represent numerous phonemes and in the spelling, a single phoneme represents many graphemes. Therefore, English qualifies as a bi-directionally inconsistent orthography (Lyytinen et al., 2009; Perfetti, 1997).

Interestingly, the Arabic writing system functions both as a shallow and a deep orthography. To illustrate, the Arabic script is primarily consonantal with short vowels represented as superscription. All diacritics are regularly mapped onto the phonemes they represent (Saiegh-Haddad, 2007). There is a predictable sound-symbol correspondence between the letters and their sounds if the Arabic text is presented by adding *diacritics* or more specifically a pointing/vowelization system. Texts are typically written in vowelized so-called *shallow orthography* for beginning readers, and in unvowelized *deep orthography* for more advanced readers.

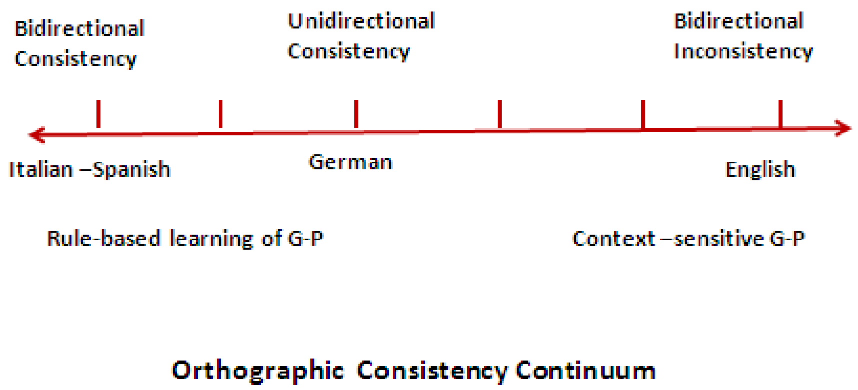

Figure 2: The orthographic consistency continuum of alphabetic languages

1.2 Development of Reading-Spelling in Alphabetic Writing Systems

Adequate reading and writing skills are crucial for successful matriculation through school. From the pedagogical point of view, it is significant to know more about the development of reading and spelling, particularly in the elementary stage (Leppänen, Niemi, Aunola & Nurmi, 2006). Researchers have attempted to determine if reading and spelling are two sides of the same coin in the acquisition of literacy. Or are they separate processes which have little in common?

Both make up visible language: reading converts written forms to speech forms, while spelling means producing words that will be read (Frith, 1980; Perfetti, 1997). Reading and spelling competencies share several similarities, justifying the assumption of close developmental connections (Leppänen et al., 2006). For instance, a single orthographic lexicon is used for reading and spelling processes. Further, in both reading and spelling, children utilize two different channels. The first is the phonological channel, in which children learn how to represent sounds of words in letters and how to translate the phonemic codes to graphemic codes. The second involves direct lexical access without phonological intervention based on visual orthographic skills (for a summary, see Leppänen et al. 2006; Lerkkanen, Puttonen, Aunola & Nurmi, 2004). In addition, a massive body of evidence from experimental and correlation studies suggests that both reading and spelling contribute to and facilitate each other. Empirical evidence shows that the correlations between word reading and spelling in English, for example, are rather high, ranging from .77 to .86. Such high correlations again indicate that very similar processes are measured in these tasks even if different materials for reading and spelling were used. This is true among younger (first to six graders) as well as college students (for a review, see Ehri, 1997).

According to Ehri (1997), students retain word-specific information[3] in memory when they learn to read words, and this information is available to support spelling performance. Throughout their primary years, the adopted reading strategy is likely to strongly affect spelling competence. During the first and second years of reading instruction, with various extensions into the third year, children lay down mental images or templates of words, morphemes, and syllables in memory that will persist for life. These templates are most often called Visual Orthographic Image (VOI). Insufficient storage of VOIs leads to spelling failure (Ehri & Wilce, 1982). Accordingly, a transfer from reading to spelling was evident. This leads some authors to believe that in literacy acquisition, reading is commonly thought to precede spelling (Leppänen et al., 2006). This is probably due to the fact that there is, mostly; one way to pronounce one phoneme, but there is sometimes more than one phonological representation for a phoneme (Abu-Rabia & Taha, 2004). Evidence is provided by German, an asymmetric consistent orthography, whereby pure recognition of orthographic representations required in

[3] According to Ehri (1997), word-specific knowledge consists of information about the spellings of individual words. This information is derived from reading and spelling experiences and is held in memory. It is constructed primarily out of students' knowledge of the general alphabetic system. For example, telephone might be spelled as telephone, or tellafoan, or tellfown . To the extent that learners see telephone and process its GP relations, they remember this spelling and not the alternatives.

reading is easier than full retrieval of the correct letter sequence from orthographic memory required to ensure correct spelling (Moll& Landerl, 2009). On the other hand, effects of spelling on reading have also been documented, particularly in beginning learners. Correlations ranged from .68 to .82 between spellings invented at the beginning of school or midyear and year-end reading scores. Moreover, some training studies have shown that teaching phonetic segmentation and phonetic spelling are beneficial to learning to read (for a review, see Ehri, 1997).

Looking closer into the theories that address the developmental processes in learning the alphabetic principle, they suggest that when learning to read and write, children move from relying on visual and contextual cues to the use of GPC. In later stages of the development of literacy, the recognition of visual and contextual cues and the use of GPC become interlinked and are applied flexibly and with great automaticity (Ehri, 1997; Frith, 1985). To illustrate, in literacy development, after a stage of pre-reading and pre-writing, children enter a stage called a logographic (Frith, 1985), discrimination-net learning (Marsh& Desberg, 1983) or pre-alphabetic level (In, Ehri, 1997). During this visually-based stage, children start with learning to associate words with pictures or situations and recognize words based on salient graphic features. According to Frith (1985), a logographic skill is adopted first for reading, then for spelling. This explains how children read familiar labels and words successfully, while producing scribbles that superficially resemble cursive writing but lack any letter details (Ehri, 1997). The alphabetic stage starts when children rely more on grapheme-phoneme correspondence (GPC) rules, a letter-sound by letter-sound analysis, whereby decoding skills are developed. According to Frith (1985), this skill is believed to be used first for spelling, then for reading. She explains this by the belief that the alphabet is tailor-made for writing rather than for reading. At last, children start to tackle the orthographic stage when they automatically recognize spelling units, especially the morphemic parts of words, while reading. It is important to note here that some researchers, contrary to Frith, argue that these stages do not emerge from steps. According to her six-step model (Fig.3), Frith (1985, 1986) extends those phases to include both input (word recognition/reading) and output components (writing/spelling) of literacy skills. She has argued that reading and writing skills would sometimes show dissociations in development. Accordingly, she has argued that each phase is divided into two steps with either reading or writing as the pacemaker of the strategy that identifies the phase. This division allows a differentiation in terms of level of skill (1 for basic and 2 for advanced) in a particular strategy. In the first phase of literacy acquisition, reading is the pacemaker of the logographic strategy to be adopted later for spelling. Since the alphabet is more fitted to spelling rather than reading, the alphabetic stage is very likely to start only via spelling. The third phase shows again reading as the pacemaker of orthographic strategies, which is transferred later to the spelling output system (Frith, 1985, 1986).

Step	**Reading**	**Writing**
1_a	**Logographic$_1$**	**(symbolic)**
1_b	**Logographic$_2$**	**Logographic$_2$**
2_a	**Logographic$_3$**	**Alphabetic$_1$**
2_b	**Alphabetic$_2$**	**Alphabetic$_2$**
3_a	**Orthographic$_1$**	**Alphabetic$_3$**
3_b	**Orthographic$_2$**	**Orthographic$_2$**

Figure 3 Six Step Model of literacy acquisition (adopted from Frith, 1985)

Importantly, this model has mainly been based on English, and other orthographies are not taken into considerations. Later, the acquisition of literacy skills is believed to be affected by different and unique linguistic characteristics of different writing systems (Abu-Rabia, 1997; 2001; 2002). For instance, Wimmer & Goswami (1994) have pointed out that while it is possible to argue that the sequence of stages, proposed by Frith (1985), may be characteristic of learning to read English, which has a relatively opaque orthography, this sequence may not apply to learning to read a highly transparent orthography such as German. The authors explained that in German, the mapping from graphemes to phonemes is largely consistent, so an adaptive strategy for young German readers would thus be to use grapheme-phoneme translation from the beginning of reading, omitting an initial stage of logographic access (Wimmer& Goswami, 1994). Further evidence has been given from Arabic, which is characterized by something unique in terms of the relationship between consonants and vowel diacritics, the presence of position-specific variants of letters and the transition to a phase where one is able to read without them. In the early stages, children need to rely on a letter-to-sound conversion of print rather than whole-word recognition, while in later stages, these vowels are omitted, and the reader has to depend on the text to recognize words in terms of their semantic features. In an attempt to uncover reading and spelling processes in Arabic, profiles of reading and spelling errors have been analyzed in a sample of 6-11 year-old, normally developing children (Azzam, 1993). Results showed that in Arabic, reading is expected to be the pacemaker for the logographic phase, while spelling is the pacemaker for both the alphabetic and orthographic phases.

Taken together, reading and spelling are two sides of one coin: literacy acquisition in the sense that they are associated and enhance each other. This logical symmetry, however, does not demonstrate that the underlying psycholinguistic processes are mirror images. Indeed, the consensus view has been that reading and spelling are rather different (Perfetti, 1997), and they are expected to completely dissociate across developmental stages of their acquisition. While evidence has been derived from European languages, in general, and from English, in particular, a handful of studies is devoted to other different orthographies, esp. Semitic languages.

1.3 What is Dyslexia? - A Critical View

No orthography appears immune to literacy disorders. Whereas the majority of children master their literacy skills effortlessly, children who do less well, consequently, show impairments in phoneme to letter conversions (Boets, Ghesquière, Wieringen & Wouters 2007; Hoien, Lundberg, Stanovich, & Bjaalid, 1995) and go on to develop dyslexia/Specific Reading Disability (SRD) symptoms.

According to Stanovich (1991), the concept of dyslexia or reading disability has been controversial in the reading community. As early as 1976, the concept was understood and applied in two quite different senses (Benton, 1976). Some authors have used the term to refer to children who fail in reading *due to* cultural, intellectual, emotional as well as organic disadvantages. Later, this view has led to the observations that dyslexia may be associated with psychosocial problems, abnormalities in cognitive processing, and clinically relevant conditions (for a summary see, Heim, 2002). On the other hand, the term was initially formulated by the World Federation of Neurology (In: Snowling, 2000; Stanovich, 1991), and has later been widely used in its original restricted sense to denote "unexpected difficulty" in learning to read experienced by children and adults *not due to* extraneous factors such as sensory acuity deficits, intellectual and socioeconomic disadvantages, and like factors (Benton, 1976; Jiménez, Rodriguez,& Ramírez, 2009; Shaywaitz & Shaywaitz, 2001; Snowling, 2000; Vellutino, Fletcher, Snowling, & Scanlon, 2004). In this sense, the "exclusionary criteria"- namely, the requirement that a person has "adequate" intelligence to qualify for the dyslexia label has been adopted in DSM-VI, (American Psychiatric Association, 1994) for a specific reading disorder (315:00) and in ICD-10, (World Health Organization, 2000) for a combined specific reading and spelling disorder, an impairment of literacy (F81.0). Further, the exclusionary criteria were carried over into the definition of the learning disabilities in general (for a summary, see Stanovich, 1991).

Importantly, whether the term is professionally or legally defined, there has been an emphasis on the existence of significant discrepancies (Stanovich, 1991). A discrepancy definition emerged as a product of the exclusionary philosophy and is claimed if a specific deficit (in spelling or in reading) occurs in the absence of poor general cognitive ability. Operationally speaking, in DSM-IV and ICD-10, to meet diagnostic criteria, a person must show poor performance on a psychometric test of language or literacy and have a mismatch of (1 to 2 SD, or even more than 2 SD) with a test of a verbal or a non-verbal IQ test (Bishop& Snowling, 2004; Lyytinen et al., 2009). Increasingly, the IQ criteria, in general, and the discrepancy criteria, in particular, were controversial and rather not fully satisfactory for theorists and clinicians due to many reasons. First, the IQ discrepancy was primarily used to identify “media dyslexic”, a very bright or a gifted child who is deeply troubled in reading and spelling (Shaywitz, 1998; Stanovich, 1991). Second, there was a belief that IQ scores were valid measures of intellectual potential, and consequently for reading attainment. On applying these criteria, both verbal and nonverbal IQ tests have been used. Bishop and Snowling (2004) pointed out that literacy scores are more strongly correlated with verbal IQ than nonverbal IQ. Stanovich (1991) added that the so-called *Mathew effect*[4] leads to a decline of verbal IQ as a result of poor reading and spelling. Hence, the potent effects running in both directions from reading to IQ and vice versa. Another critique was based on the results of studies that showed no qualitative differences between dyslexic and garden-variety poor readers in reading-related cognitive sub-skills, supporting the view that it is not worth the effort differentiating dyslexic and other poor readers, based on the IQ discrepancy criterion, in theory and in educational treatment (Stanovich, 1991).

The question remains, whether or not the discrepancy criterion is to be abandoned, and if so, what would be the alternatives? Bishop and Snowling (2004) referred to studies wherein

[4] The Mathew effect denotes that the rich get richer and the poor get poorer. Consequently, according to Stanovich (1991), reading difficulties themselves may lead to depressed performance on verbally loaded measures. Therefore, a decline in verbal IQ scores is likely to be caused by poor reading and spelling.

researchers select children whose reading or language abilities fall some way below age level (below the 16th, 25th or 30th percentile) and have nonverbal IQ within broadly normal limits. For the diagnosis of dyslexia, this selection is very likely to be satisfactory compared to the discrepancy criteria. However, it will encompass a heterogeneous group of children, including some who would not normally attract clinical concern, others who have nonspecific reading difficulties, and those who would fulfill ICD-10 diagnostic criteria for dyslexia (Bishop & Snowling, 2004).

1.4 Prevalence of Dyslexia Manifests Itself Differently

Significantly, any figure given for the prevalence of dyslexia must depend on how the term is defined (Miles, 2004). While most defined dyslexia are based on normal development of IQ associated with a reading level of 16th percentile or one SD below the mean (e.g. Lam, et al., 2008; Lindergren, De Renzi, & Richman, 1985; Rama, 2000), in other studies (e.g. Gomez, 2004), dyslexic children were referred to by teachers or parents using subjective reports. Therefore, the prevalence of SRD in European languages was reported to vary from 5 to 17% of school aged children, with as many as 40 percent of the entire population of the United States, for instance, reading below grade level (Shaywitz &Shaywitz, 2001).

Further, Miles (2004) has pointed out that dyslexia manifests itself differently in different languages and countries. To give an example, cross-national comparisons showed an estimated incidence to be around 10% in Italy, United States (Lindergren et al., 1985) and in Finland (Lyytinen, Aro& Holopainen, 2004). While prevalence of dyslexia varies between 3% and 10% in India, (Rama, 2000), it was estimated to be 9.7-12% in Chinese school children (Lam, et al., 2008). The only epidemiological study conducted in Malaysia observed 7% of children suffering dyslexia (Gomez, 2004). Reading disabilities have been noted to be rare in Japan and to be considerably less frequent in southern Europe than in northern Europe or North America, presumably it is related to differences among languages in the regularity of GPC (Lindergren et al., 1985). Most importantly, here, to consider as a source for the variations of prevalence rates either within or between languages is the literacy component to be measured. Research on English typically emphasizes the accuracy of reading and/or spelling, but it is increasingly common, particularly in research on more consistent orthographies, to employ fluency of reading or a combination of reading fluency and accuracy scores as criteria (Lyytinen et al., 2009). Added to that is the observation of some neurologic or cognitive deficits, which are documented to be a strong predictor of literacy skills. Accordingly this affects the incidence rates of dyslexia not just in different languages and nations, but even within one language and the same country (Miles, 2004).

To conclude, the above-mentioned detailed view of prevalence rates shows considerable variations of the prevalence of dyslexia both within and between languages. Resources for the variations are: the definition of dyslexia, the cut-off score to be applied, the literacy component to be measured and the orthographic features of a language.

1.5 Why do some children have difficulty learning to read and spell?

The question of why some children fail to develop their reading and spelling abilities typically has been the focus of a great deal of research over the past four decades and much has been learned about the probable and improbable causes of such failures (Vellutino et al., 2004). The dyslexia scene is currently occupied by no less than four major theories, each supported by a whole body of empirical evidence. The theories can be grouped within two antagonistic frameworks (Ramus, 2003). The first is domain specific view, which posits that dyslexia arise from deficits in systems that are specifically linguistic, namely, in phonological processing. The second school of thought claims that core deficits are nonlinguistic sensory mechanisms, which could be either in visual processing or in auditory processing (Snowling, 1998).

1.5.1 The Phonological Processing Deficit

Over the last few decades, it has been strongly believed that literacy impairments of alphabetic languages are phonologic in nature (Adams, 1990; Goswami & Byrant, 1991; Mody, 2003; Stanvoich, 1991; Temple, 2002; Wagner & Trogesesn, 1987; Mains et al., 1997). Phonological processing refers to the use of phonological information (i.e., the sounds of one's language) in processing written and oral language (Wagner & Torgesen, 1987). The functional unit of phonology is the phoneme and to read a word, a child has to develop the awareness that spoken words can be pulled apart into phonemes and that the letters in a written word represent those sounds (Shaywitz & Shaywitz, 2001). Bentin (1992) and Stanovich (1992) operationally defined Phonological Awareness abilities (PA) by tasks that require phonological sensitivity, either in the early stages of language development, marked by attention to rhymes and syllables, or during more sophisticated levels of language development, marked by phonemic awareness (In: Hoien et al.1995).

As early as 1979, Ehri distinguished four possible relations between phonological abilities and reading. A particular phonological ability can be a prerequisite, a facilitator, a consequence or a correlate of reading. To illustrate, not only a particular phonological ability is required for and/or enhances the literacy acquisition, but could also be a by-product rather than a cause of literacy acquisition. Further, a phonological ability is related to the acquisition of literacy skill only via their shared relation with some third variable, such as IQ (In: Wagner & Torgesen, 1987). Evidence for the possible relations is provided by empirical, co-relational and intervention studies in the last two decades. First, children with dyslexia differ from normal readers in measures of Phonological Awareness (PA) such as segmenting sounds, rhyming, syllable counting, phoneme deletion, sound blending and vocalizing pseudo words (Fox & Routh, 1976; Rack, Hulme, Snowling,& Wright, 1994; Shaywitz, 1998; Snowling, 2000; Temple , 2002). Finally, a large amount of evidence has been accumulated to show that the more knowledge children have about the constituent sounds of words, the better they tend to be at reading. This has been found in the form of both concurrent and predictive correlations between phonological and/or phonemic awareness and reading achievement (for reviews, see Goswami & Byrant, 1991; Mody, 2003). This finding persists into adulthood with evidence that adults with phonological deficits demonstrate symptoms of dyslexia (e.g., Manis, McBride-Chang, Seidenberg, & Keating, 1997). Second, the most compelling evidence for a causal relationship between phonological skills and deficiencies, as manifest causes of inadequate achievement in beginning readers, is given by training studies (e.g., Mains et al, 1997), which have documented that direct instruction of phonological together with phonemic awareness enhances reading and spelling abilities in dyslexics and in middle, low achieving readers as well (for reviews see Goswami & Byrant, 1991; Vellutino et al., 2004).

Evidence for the possible relations between phonological processing abilities and literacy acquisition has also been given at the neurological level. Neuroimaging studies, specifically functional studies using positron emission tomography (PET), have shown significantly reduced blood flow in the left temporo-parietal regions of dyslexics compared to controls while performing a phonological task (e.g., Rumsey et al., 1997). In addition, studies of dyslexic readers engaged in phonological processing during the nonword rhyme task indicate a significant disruption in the neural systems for reading in dyslexic subjects, namely, the posterior superior temporal gyrus (Wernicke's area) and the angular gyrus (e.g., Shaywitz et al., 1998). More evidence comes from investigating event-related potentials (ERPs) in dyslexic adults and controls during an auditory lexical decision task (e.g. Fosker & Thierry, 2004). A P300 modulation was revealed for deviants in control adults, indicating that the phonological change had been detected. This effect was absent in dyslexic adults. This result suggests that dyslexic adults still fail to detect phonological cues in the same way that normal adult readers do. Finally, brain-imaging studies have explored the neural mechanisms of recovery in dyslexic adults (e.g., Eden et al., 2004). In this study, phonologically targeted training resulted in performance improvements in trained compared to non-trained dyslexics, and these gains were associated with two distinct neural mechanism: 1) increased activity in those left-hemisphere regions engaged by normal readers, 2) compensatory activity in the right perisylvian cortex.

Additionally, weak phonological coding is presumed to underlie other difficulties in storing and/or retrieving printed words as unitized and distinctive orthographic representations as well as to difficulties in processing information in working memory that may contribute to difficulties in learning to read and spell. More specifically, difficulties in storage and retrieval could impair the beginning reader’s ability to establish connective bonds between the spoken and graphic counterparts of printed words, which, in turn, could impair the reader’s ability to store quality representations of word spellings, and, thereby, impede his or her ability to acquire fluency in word identification (for a review see Vellutino et al., 2004).

Taken together, there is substantial evidence that both dyslexic children and adults are phonologically impaired compared to typically developing controls and that training these abilities very likely enhances their literacy skills. Yet, the underlying mechanisms of this deficit are still disputed and unclear. One candidate source is suggested to be a more basic deficit of auditory perception – a deficit in auditory temporal processing

1.5.2 Auditory Temporal Deficit

Another theory of reading disability that has attracted widespread attention in recent years – is one that implicates deficiencies in low level auditory processing as the basic cause of the phonological deficits typically observed in dyslexics (Vulletino et al., 2004). At the cognitive level, deficits in analyzing the phonological structure of spoken language have been attributed to possibly inadequate representations of phonemes resulting from basic perceptual deficits (Mains et al., 1997; Tallal, 1980, 1984; Tallal & Piercy, 1973).

The reference here is to Tallal and her associates who have dedicated their 20 years of research to understanding the etiology of early language impairment and the relationship between SLI and dyslexia. They demonstrated that, unlike normal children, dysphasic children are incapable of processing non-speech stimuli presented at rapid rates, i.e., the inter-stimulus interval (ISI) is short, but can adequately process the same stimuli at slower rates (at least 250 ms.) of presentation (Tallal & Piercy, 1973). Accordingly, using both stop consonants and steady state vowels along with brief tones (phoneme discrimination), they found that children with SLI performed as well as normal children in discriminating steady-state synthesized vowels of the same duration (250 ms.), but were inferior to normal children in making temporal order judgments with the stop consonants that have a total duration of 250 msec but with a transitional component of only 43 ms. (Tallal & Piercy, 1974). These results have also been obtained for a sample of dyslexic children (Tallal, 1980). They indicated that due to their deficiencies in processing the rapid formant transition (fast frequency changes) of stop-consonants, children with dyslexia performed poorer than typically developing children in categorizing speech sounds or distinguishing consonant-vowel (CV) syllables. For instance, on a categorical perception[5] task, the time range that distinguishes the syllables /ba/ and /da/ only lasts about 40 ms. (Fig.4).

[5] Categorical Perception denotes that discrimination of different sounds sharing the same phonological category is poor while discrimination of sounds belonging to different phonological categories is quite good, even though the physical differences between the two types of sound pairs are identical (Heim, 2002).

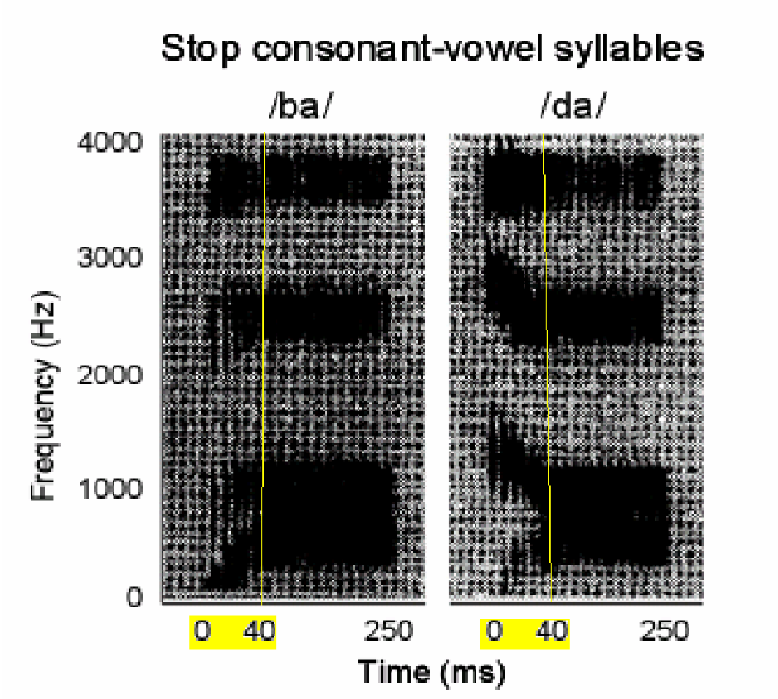

Figure 4 Sound of spectrograms of the stop consonant vowel syllables/ba/ and/da/ (adopted from Tallal et al., 1993)

Taken together, Tallal inferred that dyslexic readers suffer from a basic, non-linguistic deficit in temporal resolution of rapidly changing auditory stimuli that impairs speech perception. Accordingly, this disorder underlies the typically observed phonological deficits (Vulletino et al., 2004). To test this hypothesis, Reed (1989) attempted to replicate Tallal's studies to explore if dyslexic children are characterized by temporal processing and, accordingly, phonological deficiencies. Dyslexic and normal readers were compared in their categorical perception of stop consonants. Results showed that dyslexic were impaired and less consistent in perceiving the boundaries between /ba/ and /da/. Consistent with Tallal, Reed concluded that perceptual difficulty in rapidly changing cues may contribute to inadequately defined sound and representations which, accordingly, interfere with phonology processing.

Support for these findings was obtained by neuroimaging studies during auditory processing tasks. Temple et al. (2000) employed FMRI to examine if adults with dyslexia show deviances in their brain responses to non-speech stimuli analogues of CVC syllables with either rapid or slow acoustic transitions. Results showed that while normal readers exhibited significantly enhanced activation in the left prefrontal cortex in response to rapid stimuli compared to slow stimuli, dyslexics showed no differences in activation as a response to both stimuli. The authors indicated a potential role of left prefrontal regions as mediating auditory processing. Schulte-Körne and colleagues (e.g. 1998) have observed significant differences between dyslexics and controls in the categorical perception of synthetic speech stimuli. Using a passive oddball paradigm, Mismatch negativity (MMN)[6] was determined for both tone and speech stimuli. A significant group difference in MMN suggests that speech perception as measured on an early, pre-attentive level plays a major role in dyslexia not only in children but also in adults.

Based on the assumption that auditory perceptual deficit might be the underlying deficit in dyslexia, Merzenich et al. (1996) and Tallal et al. (1996) developed a computerized intervention program (Fast For Word), composed of seven adaptive exercises and designed to improve auditory and language processing by using nonlinguistic and acoustically-modified linguistic speech (rapid frequency transitions in speech are slowed and amplified). The previous intervention studies showed that language impaired children had improved markedly in their abilities to recognize brief and fast sequences of nonspeech and speech stimuli (Merzeinch et al., 1996) and in speech discrimination and language comprehension (Tallal et al., 1996). Moreover, Temple et al. (2003) has used FMRI on 20 children with dyslexia (8–12 years old) during phonological processing before and after a remediation program (Fast For Word). Physiologically, children with dyslexia showed increased activity, closer to that seen in normal children, in the left temporo-parietal cortex and left inferior frontal gyrus. Increased activity was also observed in right-hemisphere frontal and temporal regions and in the

[6] Mismatch Negativity is an evoked cortical potential that reflects the outcome of an automatic comparison between acoustic stimuli when a deviant is presented randomly at a certain rate among repetitive standard stimuli. The negativity results from the difference between ERP evoked at about 100-250 ms after deviant-stimulus onset and the evoked by the standard stimulus (Lachmann, Berti, Kujala,& Schröger, 2005).

anterior cingulate gyrus. Interestingly, the magnitude of increased activation in left temporo-parietal cortex correlated with improvements in oral language ability (Temple et al., 2003).

Later, Tallal's hypothesis that speech perception is the underlying deficit behind phonological deficiencies in dyslexia has been further questioned. Three debates surround the study of dyslexics' auditory processing. First, what proportion of dyslexics is affected? Second, can the deficit be characterized in terms of 'rapid auditory processing'? And third, does the deficit in auditory processing explain the phonological deficit? (Ramus, 2003). In this scenario, Amitay, Ben-Yehudah, Banai and Ahissar (2002) investigated 30 reading-disabled adults and found that only 6 had difficulties in tasks with high demand on temporal processing while all of them had difficulties with other auditory and visual tasks with no special demand on temporal processing. Consistently, Ramus et al., (2003) observed that while all 16 adult dyslexics had problems with phonology, only 10 of 16 adult dyslexics had deficits with auditory processing. The authors consider this to be a high incidence compared to other studies that typically find 1/3 of dyslexics affected on auditory processing. In a recent study, Lachmann, Berti, Kujala & Schröger (2005), investigated auditory processing in 8-11 year-old children with developmental dyslexia by means of event-related brain potentials (ERP). Cortical sound reception was evaluated by recording N250 responses and by analyzing the mismatch negativity (MMN) to syllables and tones. Based on their scores in frequent word and nonword reading, dyslexics were classified in two subgroups. Generally, results showed that both cortical and sound reception and sound discrimination were impaired in dyslexic children. Dsylexics-1 being impaired in nonword reading (or both nonword and frequent word reading) and Dyslexics-2 as impaired in frequent word reading, but not in nonword reading. Diminished MMN were pronounced only in Dyslexics-2 compared to normal readers. Interestingly, no differences were found between the two subgroups of dyslexics as indicated by the responses to standard stimuli. The authors have concluded that different diagnostic subgroups of dyslexics have different patterns of auditory processing deficits. Further, Mains and colleagues (1997), administered phonological awareness and phoneme identification tasks to dyslexic children and both chronological age (CA) and reading-level (RL) comparison groups. Dyslexic children showed less sharply defined categorical perception of a *bath–path* continuum varying voice onset time when compared to the CA but not the RL group. The dyslexic children were divided into two subgroups based on phoneme awareness. The results suggest that some dyslexic children have a perceptual deficit that may interfere with the processing of phonological information and that speech perception difficulties may be *partially related* to reading experience (Mains et al., 1997). To test if the auditory deficit can be characterized in terms of 'rapid auditory processing'?, Mody et al. (1997) have hypothesized that speech deficits in dyslexia could be either due to *a speech-specific* failure in phonological representation or to the *auditory temporal processing*, proposed by Tallal and her colleagues. To verify, two groups of second-grade children (20 "good readers," 20 "poor readers"), matched for age and intelligence, were selected to differ significantly on a /ba/-/da/ temporal order judgment (TOJ) task, said to be diagnostic of a temporal processing deficit. Results showed that poor readers' difficulties with /ba/-/da/ reflected perceptual confusion between phonetically similar, though phonologically contrastive, syllables rather than difficulty in perceiving rapid spectral changes. Authors provided documentation that the difficulties of poor readers on TOJ tasks using speech stimuli were due to speech discrimination deficits rather than temporal order judgment deficits. Moreover, Waber et al. (2001) and Breier et al. (2002) concluded that the speech perception difficulties are related to and possibly contribute to phonological processing difficulties, which, in turn, affect reading skills (In: Vellutino et al., 2004). Further, there does not seem to be a causal relationship between deficient auditory temporal processing and phonological skills, even in children who do show auditory perceptual deficits. It therefore might be concluded that deficient audition *can* lead to poor phonology, but poor phonology is not a consequence of deficient audition (Paul, 2005).

In conclusion, findings of studies testing Tallal's theory have led to a similar conclusion, thus questioning its viability. Vellutino et al. (2004) pointed out that the most significant problem is that sensory deficits at the auditory level do not explain the word recognition difficulties in a parsimonious manner. However, since the 1980s, temporal sensitivity in the visual domain has been investigated primarily in terms of the magnocellular deficit hypothesis for dyslexia (Heim, 2002)

1.5.3 The Visual Deficit

Phonological acoustic analysis is not the only difficulty that reading presents. Subtle visual details of letter shape and order must be identified as well. Theories implicating deficiencies in the visual system have been the most influential theories of dyslexia, from before the turn of the century (Morgan, 1896; Hinshelwood, 1917) through to the 1970s and 1980s, when linguistic deficit explanations of the disorder began to compete with visual deficit explanations (Vellutino et al., 2004). At that time children were thought to be suffering from *word blindness*. Ever since Orton (1925) wrote about the specific difficulty which dyslexics have with printed symbols and, in particular, reversible letters and words (b/d, P/q, was/saw), there has been interest in the idea that dyslexia results from a visual perceptual problem (Snowling, 2000). Reversal errors are common in beginning readers and normally become fairly rare with reading experience. In dyslexics these problems, which involve orientation and order of letters, may persist into adulthood (for summary see Rusiak, Lachmann, Jaskowski, & Leeuwen, 2007). In studies conducted comparing poor and normal readers across a broad age range (most often grades 2 through 8), few significant differences between these groups were found on measures of visual processing ability when the influence of verbal coding was controlled (for summary see Vellutino, 2004). Further, reading disability has also been associated with abnormalities in perception of visual motion (Eden et al., 1996). To illustrate, impairment in visual tasks that require rapid processing of visual information has been found consistently in dyslexics, implying that functional anomalies in the magnocellular cells, which are important in detecting fast, low-contrast information, is likely to be deficient in dyslexia (e.g., Lovegrove, Gazia, & Nicholson, 1990)

The magnocellular hypothesis is among the most dominant, but also one of the most controversial theories in recent years. The visual system is comprised of two parallel systems, the magnocellular system and the parvocellular system, both residing in the layers of the lateral geniculate nucleus of the visual cortex. The magnocellular system – often called the transient system – originates in the retina and projects the primary visual cortex (V1). It consists of large neurons that have high conduction velocity and demonstrate a high degree of sensitivity to movement and rapid changes in the visual field. In contrast, the parvocellullar system consists of small neurons that are sensitive to color and fine spatial details. In reading, the parvocellular system is believed to be operative during eye fixations and the magnocellular (transient) system is believed to be operative during saccadic movements of the eyes. The magnocellular system is (presumably) responsible for suppressing the activity of the parvocellular system when the eyes are in motion; thereby inhibiting the visual trace that normally persists for a short duration (approximately 250 ms.) after a visual stimulus has been terminated (Stein, 2001; Stein & Walsh, 1997).

While reading, the visual magnocellular system is responsible for timing visual events. Thus, sensitivity to visual motion seems to help determine how well orthographic skill can develop in both good and bad readers. In dyslexics, the development of the visual magnocellular system is impaired: development of the magnocellular layers of the dyslexic lateral geniculate nucleus (LGN) is abnormal; their contrast sensitivity to transient stimuli of low spatial frequencies is lessened, their motion sensitivity is reduced (e.g., Lovegrove et al., 1986); many dyslexics show unsteady binocular fixation; hence poor visual localization, particularly on the left side (left neglect). Dyslexics' binocular instability and visual perceptual instability, therefore, can cause the letters they are trying to read to appear to move around and cross over each other (for review see Stein, 2001). Moreover, a deficit in the inhibitory function of the transient system creates masking effects along with visual acuity problems when dyslexics are reading connected text (Vellutino et al., 2004). Support has been provided by anatomical and electrophysiological studies demonstrating structural and functional anomalies in the magnocellular pathways of a small number of those studied with dyslexia (e.g., Livingstone, Rosen, Drislane, & Galaburda, 1991).

More evidence has been given by the multiplicity of irregular spellings which implies that in English precise visual as well as auditory sequencing is important for reading (Stein & Talcott, 1999). In Semitic languages, which are characterized by the vowelization/pointing system (see study 2.1 for details), predictive correlations were observed between both visual and verbal ability and reading. This suggests the requirement of visuo-spatial processing due to the complexity of the pointing system (Myler& Brenznitz, 1998). According to Abu-Rabia & Taha, 2004), young learners of Arabic, in their initial stages of acquisition, suffer from the lack of ability to manipulate GPC rules, so a possible reliance on visual word recognition strategies to manipulate a change in letter shapes in accordance with its position in a word is suggested.

Nevertheless, the visual contribution to learning to read, hence to dyslexia, is constantly underestimated. One reason is that simple reduction in visual acuity does not impede reading greatly in already proficient readers. Thus more subtle impairments of visual processing than simply a loss of visual acuity are responsible for reading problems. In addition, Stein et al., (1995) found that while visual processes contributed unique variance in predicting reading skills in poor readers, the amount of variance was quite small compared to the variance contributed by measures of phonological skills. Clinical cases showed the absence of evidence that dyslexics typically experience the types of visual perceptual anomalies that are said to be a consequence of transient system deficits (Vellutino et al., 2004). Therefore, it would appear that transient system deficits have not been shown to be causally related to reading difficulties. The final source of evidence is derived from regression studies evaluating the components of reading ability, which have shown that visual abilities are relatively poor predictors of word identification, spelling, pseudoword decoding, and reading comprehension. This was true at all age and grade levels, 2 through 7, evaluated in these studies (e.g., Vellutino et al., 1991).

To resolve these contradictory results, some researchers hold the opinion that developmental dyslexia is not a single clinical entity. For example, by observing the qualitative errors of reading and spelling performances, Boder, (e.g., Boder, 1973) classified dyslexia into homogenous subgroups: *dysphonetic, dyseidetic*, or *mixed*. To clarify, on one hand, *Dysphonetic* dyslexia have difficulty learning sound-symbol relationships, thus show phoneme-grapheme errors. Therefore, they rely on global decoding strategies and read words as visual gestalts. On the other hand, children with *dyseidetic* dyslexia generally use phonetic strategies, GPC rules, but show difficulty in perceiving whole word recognition. Their performance in reading and spelling is characterized by visuospatial letter reversals. Not many acquired dyslexics fall neatly into either of these two categories, however most display a combination of both phonological and visual problems, perhaps with one kind of error predominating. To explain this, Castles and Coltheart (1993) have proposed two routes for reading, one for reading familiar words, and the other for new words. For skilled readers, the visual patterns of whole words have been laid down in their 'sight vocabulary'. Thus, these words could be retrieved by their meanings (semantics) using a direct visual route from word to meaning without needing to translate the letters into sounds or syllables. Paradoxically this is precisely the strategy that very young children use when they first begin to learn to read before they have learnt the alphabet principle. However, Lytinnen et al. (2009) have commented that a purely visual strategy cannot help with reading unfamiliar words, and most words are unfamiliar to a beginning reader. Thus, a reliance on an auditory/ phonological route has to be activated and need to be learnt proficiently. Yet, whether dyslexic children may lack one or both of the two skills is still disputable.

1.5.4 The Double Deficit

In his article, Lovett (1987) has referred to the two criteria of achievement against which any development of reading skill should be measured: accuracy and automaticity. As a result, he has distinguished between reading-accuracy-disabled children and reading-rate-disabled children. This affects the view that dyslexia is caused primarily by limitations in phonological coding, which has not been accepted by all scholars. In particular, Wolf, Bowers, and their colleagues (2002) think that there are disadvantages in using a single, phonological lens to study dyslexia where the importance of other factors in explaining the heterogeneity of dyslexia, esp. in English-based dyslexia research can be overlooked or minimized Accordingly, they developed an alternative conceptualization of dyslexia, known as the "double deficit". The central question of this hypothesis is whether the processes underlying naming speed represent a second core deficit in children with developmental dyslexia. The history of this research began with a hypothesis by Geschwind (1965), who contended that a young child's color-naming ability would be a good predictor of later reading achievement (In Wolf et al., 2002). Evidence was provided by Denkla and Rude (1976) who designed the best known measure of serial or continuous naming speed known as the *rapid automatized naming* (RAN) test. In this test, a visual array of 50 stimuli, consisting of five symbols in a given category (e.g., letters, numbers, colors, or objects) are presented 10 times in random order and required to be rapidly named (see Fig.5).

O a S d P A o S p

Figure 5. Example of one line of rapid automatized naming test for letters

On the basis of research in the neurosciences, there is extensive evidence that many severely impaired readers have naming-speed deficits caused by disruption of a precise timing mechanism that normally influences temporal integration of the phonological and visual counterparts of printed word. This impairs the rapid recognition and retrieval of visually presented linguistic stimuli, namely the orthographic patterns. As a result, the authors incorporated both phonology and naming-speed processes as two sources of dyslexia. In addition, dyslexics are, therefore, classified into three subtypes: one caused by deficiencies in phonological; a second caused by slow naming speed that specifically disrupts orthographic processing and reading fluency; and a third caused by a combination of both types of deficit known as the "double deficit". Based on a cut-off score of one standard deviation below the mean standard scores, prevalence for the three subtypes were: 19%, 15% and 60% for single phonological deficit, naming-speed deficit, and double deficit, respectively (Bowers & Wolf, 1993; Wolf & Bowers, 1999; Wolf et al., 2002).

In their reviews, Wolf, Bomors & Biddle (2000) and Wolf et al. (2002) have offered three types of evidence to support the double deficit theory. First, in a serious of cross-sectional, longitudinal, and cross-linguistic studies, the authors found that naming speed tasks, especially letter and digit naming tasks have consistently been found to predict aspects of reading performance in able and disabled reading groups. These results were applied across languages tested to date, including German (e.g., Wimmer, Mayringer, & Landerl, 2000), Dutch (e.g., van den Bos, 1998), Finnish (e.g., Korhonen, 1995) and Spanish (Novoa & Wolf, 1984). Second, a number of studies have shown that children grouped into either single deficit or double deficit subgroups tend to perform below normals on reading scores. Similarly, the double deficit groups typically perform below the single deficit groups on such measures (for review, see Wolf et al., 2000). Furthermore, in an asymmetric orthography as in German, subtypes of good reader-poor spellers and poor readers-good spellers differentiate themselves on measures of RAN and phonological abilities. To illustrate, while children with isolated reading deficits were impaired in RAN measures, children with isolated spelling deficits were deficient in phonological measures (Wimmer & Mayringer, 2003; Moll & Landerl, 2009). Third, phonological awareness and rapid naming appear to be differentially related to reading subskills. While the former has been shown to be highly correlated with the accuracy of word identification in word identification and letter-sound decoding, the latter has been shown to be more strongly correlated with speed of word identification and speed of letter-sound decoding (e.g., Wolf et al., 2000).

Although such findings are suggestive, the double deficit hypothesis can also be challenged on theoretical, interpretive, and methodological grounds. To brief, Vulletino et al., (2004) have summarized the criticism based on: the lack of specification regarding the precise timing mechanism that presumably underlies the formation of orthographic codes; the inadequacy of temporal integration of letter identities deficit and serial processing of a word's component letters as being a cause for unskilled word recognition and malformation of orthographic codes across age; the lack of typical control for autocorrelation effects created by the variance that rapid naming and phonological skills share with reading performance.

In their chapter, Lytinnen et al. (2009) have pointed out that the time used for the naming task is supported to be an index of the ease and automaticity with which phonological representations can be retrieved from memory. They added that whether phonological skills and naming fluency are both based on some third factor connected to the phonological domain is currently unclear, but for practical purposes naming fluency makes a clear contribution to the prediction of reading failure in automatization, which has been reported to naturally affect reading comprehension as an ultimate goal of reading. Here, it is worth noting Wolf at al. (2002) have commented, regarding their hypothesis,

"At no point do we suggest that the two deficits and their combinations encompass all possible sources of breakdown in reading failure. Rather, this view is explicitly directed towards a more comprehensive understanding of the heterogeneity of impaired readers by directing attention to a second source of breakdown" (p.45).

1.6 Synopsis and Overview of Studies

The review of literature showed that not only is literacy acquisition determined by the competency of the beginning learner, but is also determined by the qualities and features of the language and its orthography to be mastered. Indeed, the majority of research has targeted the beginning learner of English other than different languages. As previously mentioned, English has an opaque (or deep) orthography in which the relationships between letters and sounds are inconsistent and many exceptions are permitted. As such, English presents a significantly greater challenge to the beginning reader than other more regular alphabetic systems that contain consistent mappings between letters and sounds and are described as transparent (or shallow) orthographies (Lytinnen et al., 2009). Evidence can be seen in the variations of the ease of reading acquisition, known as fluent reading, according to differences in orthographic depth, showing that transparent orthographies are faster to learn compared to English (Symour et al., 2003).

For many decades, only the accuracy component in literacy acquisition has been the focus of research in the context of reading, while fluency has been neglected. It needs to be borne in mind that in more consistent orthographies, the focus is moving toward the accommodation of reading fluency as a more primary feature of both skilled and disabled reading. Accordingly, the developmental progress of transparent orthographies, in European and Semitic languages, differ from those reported for English (Azzam, 1993; Wimmer & Goswami, 1994). This is why, predictors of literacy skills have been reported to vary according to orthographic depth. While phonological skills have been documented to be a good predictor of literacy skills across languages, at least in an English context, their predictive role may last a shorter time as it is not accuracy that requires further honing after 1 to 2 years of instruction, but fluency (Lytinnen et al., 2009). Alternatively, RAN measures, including speed factors, have proven to strongly predict the performance of reading fluency in consistent orthographies compared to phonological skills, which predicted spelling (Landerl

&Wimmer, 2008). Moreover, in Semitic languages, early stages of literacy acquisition have been thought to be more affected by visual processing than phonological processing due to the complexity of the vowelization system (Myler& Brenznitz, 1998). A more stark comparison is afforded between learning to read in alphabetic languages and learning to read in non-alphabetic languages, such as Chinese, which contains a large number of visual symbols or characters that represent units of meaning (morphemes) rather than phonemes as in an alphabet. The task of learning to read is therefore a considerable feat for Chinese children, who must learn literally hundreds of visually complex characters that contain phonetic and radical components. Investigations of typical and atypical development in Chinese have concluded that dyslexia in Chinese is associated with multiple deficits, rather than with a core phonological deficit (In Vellutino, 2004).

Finally, epidemiological studies have also reported variations in the prevalence of dyslexia. Such variations could not only be attributed to the definition of dyslexia *per se*, but, very likely, to differences among languages in the regularity of GPC (Lindergren et al., 1985). Consequently, while diagnosis of English dyslexia has been based on accuracy measures, in transparent writing systems, criteria tend to center on speed and fluency rather than error-rate.

Taken together, the evidence underlines the fact that dyslexia is not an all or none condition. Instead, it a complex condition that depends on the dynamic interaction between certain innate susceptibilities as well as the home and school environments on one hand, and the cultures in which children learn to read and spell on the other. It is not an all or none condition (Vellutino et al., 2004). While evidence has been well documented for European languages, Semitic languages have been scarcely investigated, calling for more studies to be conducted in order to uncover both the typical and atypical development of literacy skills.

Therefore, <u>in study 1</u>, we mainly aimed at validating literacy measures for accessing Arabic in the first three years of its learning. In this study, I investigated the typical development of reading and spelling in the first, through to the third grade, in a sample of 111

Arabic speaking children. The study was motivated by two main questions**:** 1) what is the developmental relationship between reading and spelling in Arabic (first through third grade); 2) are there gender differences in literacy acquisition of Arabic-speaking children? Interestingly, the answer for the second question has led to a *post hoc* hypothesis, which is that visualization has a potential role in the early stages of learning Arabic. In study 2, I applied the validated literacy measures to a representative sample of Arabic-speaking third graders in order to screen them for dyslexia. This study mainly aimed to estimate prevalence rates of associations and dissociations between reading and spelling in Arabic. Therefore, I applied the same cut-off scores used in shallow orthographies, namely German, which is likely to share the same orthographic depth of vowelized Arabic. Gender ratios and schooling have also been taken into consideration. While presenting behavioral indices of dyslexia in Semitic languages in the first two studies, in study 3 we looked at cortical indices of dyslexia in German, a language which is comparable to Arabic in terms of orthography depth. In this study, I looked into the abnormal slow waves of a subtype of dyslexic children whose categorical perception is severely impaired. For many decades, this deficit has been believed to be a low-level deficit resulting in dyslexia in a group of children. However, its mechanism is still disputed. Using a new method, which has been developed by Christian Wienbruch in 2007, we compared the oscillatory responses of children with poor categorical perception to their normal counterparts.

2 Study Parts

2.1 The Development of Reading and Spelling Abilities in the First Three Years of Learning Arabic[7]

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Abstract

In a cross-sectional study, we investigated the development of fluent reading and spelling in the first three years of learning Arabic. The goals of our study were to: 1) validate suitable measures for fluent reading and spelling in the first three years of learning Arabic; 2) trace the developmental course of the relationship between fluent reading and spelling in the first three years of learning Arabic; and 3) evaluate potential gender differences in literacy skills and intelligence in the setting. The performance of 111 native Arabic students of the first three grades was assessed for one-minute reading, spelling and Raven's Coloured Progressive Matrices (CPM). Results showed significant developments in all measures across age. Reading fluency correlated highly with spelling measures. This association was more pronounced in the first but not in later graders. Boys performed better than girls as indicated by each of the measures used. Further analyses of first grade data indicate a potential role for the interaction of reading, gender, and CPM on the spelling scores. Based on our findings, we suggest that, in the Arabic orthography, both alphabetic and orthographic skills are adopted first for spelling. However, developing orthographic strategies in spelling does not guarantee

[7] This study has been published on line 2-7-2010 in Reading and Writing: *An interdisciplinary journal*. Part of this a has been presented as in poster ASHA (2009) and LDA(2010), see Appendix

the same transition to fluent reading processes as children in the first three years of learning Arabic are not yet exposed to unvowelized scripts forcing the reader to rely on orthographic strategies in order to read fluently. Moreover, our results indicate a potential role of visualization and spatial abilities in the relationship between fluent reading and spelling in the early stages of literacy acquisition, but not in later grades.

2.1.1 Introduction

The start of formal education is a crucial period for the acquisition of literacy. From the pedagogical point of view, it is significant to know more about the development of reading and spelling during this phase (Leppänen, Niemi, Aunola & Nurmi, 2006). Only recently, word reading fluency has moved from being a neglected aspect of reading to being a popular topic in the field of reading research (Landerl & Wimmer, 2008). Additionally, the magnitude, consistency, and stability of gender differences across time have recently been questioned. While the relationship between reading and spelling abilities as well as the existence of differences between boys and girls in various cognitive and educational abilities among school students in the United States and Europe has become reasonably well established, little empirical research has been reported for Arabic backgrounds. Therefore, we wanted to explore the developmental course of fluent reading and spelling during the first three years of learning Arabic. More precisely, we tried to examine the relationship between fluent reading and spelling. According to Taouk and Coltheart (2004), literacy acquisition is highly likely to be dependent upon the nature of the writing system which the child seeks to master. Hence, the special nature of Arabic orthography should be considered carefully in any discussion of a comprehensive theory of how children learn to read and spell.

Arabic orthography

Arabic is a Semitic language containing 29 consonants and 8 vowels. The Arabic writing system is primarily consonantal with short vowels represented as superscripted. This makes the Arabic writing a syllabic one (Hanna & Greis, 1972). All diacritics are regularly mapped onto the phonemes they represent (Saeigh-Haddad, 2007). There is a predictable sound-symbol correspondence between the letters and their sounds if the Arabic text is presented by adding diacritics or more specifically a pointing/vowelization system. Texts are typically written in vowelized so-called shallow/transparent orthography for beginning readers, and in unvowelized deep orthography for more advanced readers. In many cases, an Arabic word consists of only root consonants and short vowels. The additions of short vowels or more complex affixes (phono-morphological information) help to provide both semantic and phonological information to the root. Moreover, vowelizing the end of a word indicates its grammatical function. Paradoxically, the diacritical system in Arabic itself, although useful in decreasing phonological ambiguity, might constitute a source of difficulty for the beginning reader while mastering Arabic word decoding skills necessary for the phonological (non-lexical) route. When text is not vowelized, like in modern written and printed literary scripts, the reader has to depend on context and/or morphology and syntax and early exposure to print (e.g., Abu-Rabia, 2000). The majority of Arabic letters differ in form depending on their position in a word or in a smaller graphemic unit (connected with a preceding letter, connected with a following letter, connected with both letters; and not connected) (for a summary, Abu-Rabia, 1997; 1998; 2001; 2002; Elbeheri & Everatt, 2007; Taouk & Coltheart, 2004). Some scholars have considered Arabic as a case of diglossia, a term according to which the spoken and the written language are substantially different in terms of vocabulary, phonology, syntax, and grammar, which means that these children read a language with which they are unfamiliar (Abu-Rabia, 2000; Saeigh-Haddad, 2003; 2004; 2007). However, the term Arabic diglossia is not universally accepted (see, e.g., El-Hassan, 1979).

Learning to read and spell

Early models of literacy acquisition proposed that children would acquire the different subcomponents of reading and spelling in a sequence of stages. According to these models, young children first go through a stage called a logographic (Frith, 1985), discrimination-net learning (Marsh & Desberg, 1983) or pre-alphabetic (Ehri, 1985). During this visually-based stage, children begin to associate words with pictures or situations and recognize words based on salient graphic features. According to Frith (1985), a logographic skill is adopted first for reading, and only later for spelling. This explains how children read successfully familiar labels and words, while at the same time producing scribbles that superficially resemble cursive writing but lack any letter details (Ehri, 1997). The next alphabetic stage starts when children rely more on grapheme-phoneme correspondence (GPC) rules, a letter-sound by letter-sound analysis, whereby decoding skills are developed. According to Frith (1985), this skill is believed to be used first for spelling, then for reading as here the sequential writing down of each letter makes it obvious to the child that these letters have a systematic relationship to the sounds of the spoken word. At last, children start to tackle the orthographic stage when they automatically recognize spelling units, especially the morphemic parts of words, while reading. Thus, in Frith´s model spelling acts as a kind of pacemaker for the alphabetic stage and reading is the pacemaker for the orthographic stage.

It is important to note here that some researchers, contrary to Frith, argue that these stages do not emerge out of steps. Instead, they suggest that performance in reading and spelling influence each other over the distinct stages of literacy development, and the direction of this influence changes over time (for review, Ehri, 1997; Snowling, 2000). Moreover, different writing systems show different and unique linguistic characteristics that affect the acquisition of literacy skills in different languages (Abu-Rabia, 1997; 2001; 2002). For instance, Wimmer and Goswami (1994) have pointed out that while it is possible to argue that the sequence of stages, proposed by Frith (1985), may be characteristic of learning to read English, which has a relatively opaque orthography, this sequence may not apply to learning to read a highly transparent orthography such as German. The authors explained that in German, the mapping from graphemes to phonemes is largely consistent, so that an adaptive strategy for young German readers would be to use grapheme-phoneme translation from the beginning of reading, omitting an initial stage of logographic access (Wimmer & Goswami, 1994). Further evidence has been given from Arabic which is characterized by a unique orthography in terms of the relationship between consonants and vowel diacritics, the presence of position-specific variants of letters and the transition to a phase where one is able to read without them. In the early stages, children rely on a letter-to-sound conversion of print rather than whole-word recognition. The former process can only be fulfilled when the Arabic script is presented in a vowelized way, (Taouk & Coltheart, 2004) which facilitates early decoding, (Share & Levin, 1999), reading accuracy and reading comprehension among beginning and more advanced Arabic learners (for a summary see, Abu-Rabia, 1997; 2001; 2002; Elbeheri & Everatt, 2007; Taouk & Coltheart, 2004). This in turn accelerates an earlier transition from the phonological-recoding (alphabetic) phase to the orthographic phase. Importantly, in Azzam's (1993) study, profiles of reading and spelling errors of 6-11 years old normally developing children showed that in Arabic reading, the visual-based logographic skills are adopted first for reading, while alphabetic and orthographic skills are adopted first for spelling. Additionally, to acquire basic literacy in Arabic, Azzam suggests that the use of an alphabetic strategy may be enough for competent reading, while competent spelling requires at least the usage of orthographic strategies if not the grammatical/semantic phase. As a result, it is predicted that the interdependence between reading and spelling diminishes in later stages of literacy acquisition in Arabic (Azzam, 1993).

According to many theorists, the two components of literacy, reading, and spelling, are closely linked. Overall, experimental and correlation studies suggest that both reading and spelling contribute to and facilitate each other. Empirical evidence shows those correlations between word reading and spelling in English, for example, are rather high, ranging from .77 to .86. Such high correlations, again, indicate that very similar processes are measured in these tasks even if different materials for reading and spelling were used. This is true among younger (first to six graders) as well as college students (for a review, see Ehri, 1997). These findings, found in the English context, suggest that not only a single orthographic lexicon is, probably, used for reading and spelling processes (for a summary, see Leppänen, et al., 2006; Lerkkanen, Puttonen, Aunola & Nurmi, 2004), but also that both reading and spelling require in parts the same phonological and visual skills.

Although the association between reading and spelling development is strong, reading is commonly thought to precede spelling in the literacy acquisition of alphabetic orthographies (Leppänen et al., 2006). This is probably due to the fact that spellers need lexical knowledge to ensure orthographically correct spelling, while readers may rely on partial orthographic knowledge of those words in the text while reading (Abu-Rabia & Taha, 2004). Evidence has been provided for German, an asymmetric consistent orthography, in which the recognition of orthographic representations required in reading is easier than full retrieval of the correct letter sequence from orthographic memory required to ensure correct spelling (Moll & Landerl, 2009).

Moreover, throughout their primary years, the adopted reading strategy is likely to strongly affect spelling competence. During the first and second years of reading instruction, with various extensions into the third year, children lay down mental images or templates of words, morphemes, and syllables in memory that will persist for life. These templates are most often called Visual Orthographic Image (VOI). Insufficient storage of VOIs leads to spelling failure (Ehri & Wlice 1982).

Processes of reading and spelling in Arabic have been derived by data collected from samples with an age range of 8-30 years (Abu-Rabia, 1995; 1997). Some studies were based on data derived from bilingual children: Arabic-Hebrew (Abu-Rabia, 2001) and Australian-

Lebanese (Taouk & Coltheart, 2004). To our knowledge, except for the analysis of reading and spelling errors in 6-11 years old Arab children in Azzam's study (1993), there are no other attempts to study the relationship between reading and spelling abilities at the very early stages of learning Arabic in a monolingual sample. In addition, only reading fluency in Arabic orthography has so far only been investigated for pseudowords (Saeigh-Haddad, 2005).

Gender differences.

With respect to gender differences in cognitive abilities, two opposing positions have been taken. One viewpoint has been asserted by Feingold (1988), Hunt and Hughes, (2004) and Richardson (1997), who suggest different patterns of gender differences in abilities as a result of socialization and cultural influences which shape a gender-typed behavior. An opposite view has been presented by Kimura (1999), who postulates that gender differences in cognitive abilities are significantly biologically determined, largely by hormonal influences and genetic factors (for a summary, see Khalefa & Lynn, 2008). If true, we would expect identical gender-differences in different cultures.

In addition, Lynn (1994; 1999) has proposed a developmental theory for gender differences in intelligence, in general, which he later applied to the results of Raven Progressive Matrices. He postulates that both boys and girls mature at the same rate up to the age of 7 years. At the age of 8 or 9, the growth of girls accelerates and remains advanced until 14–15 years. At 15–16 years the physical growth and the intelligence of girls slows relative to boys.

While a rich literature on gender differences in reading exists, very little is known about the development of spelling abilities. However, assumptions about spelling might be drawn from reading research. Accordingly, girls usually outperform boys in verbal and oral as well as reading tests (Allred, 1990; Horne, 2007), a view that is supported by epidemiological investigations of gender differences in the United States, Germany, New Zealand, and the

UK (reviewed by Chiarello et al., 2009). Additionally, reading disabilities are certainly more frequent in boys than in girls (Rutter et al., 2004). On the other hand, a number of reports point to less simple relationships. Using a simple spelling test, Millar and Barber (1981) found that males made significantly more errors than females, but there were no significant gender differences in another judgment task that emphasized the knowledge of phonological rules related to spelling. Many studies of more normal reading children have not found strong gender differences. Hyde and Linn (1988) conducted a large-scale meta-analysis of studies that examined gender differences in general verbal abilities. They suggest that the overall magnitude of gender differences in these samples is quite small, especially when excluding dyslexic subjects from the analyses. Further, computerized assessments of literacy skills did not detect the established gender effect, while girls performed better in paper and pencil versions of the same tests (Horne, 2007).

In the current analysis, we describe the developmental course of fluent reading and spelling abilities in the first years of learning Arabic. Three goals were set for the present study: 1) develop and validate tests of fluent reading and spelling for the first three years in primary school;) investigate the relationship between reading and spelling in the first three years of learning Arabic; and 3) examine potential gender differences in literacy skills and fluid intelligence, including reasoning and visualization skills as measured by Raven´s Coloured Progressive Matrices in the first three years of learning Arabic.

2.1.2 Method

Participants

Altogether 111 Arab children in grades 1 through 3, who were enrolled in a private school in Egypt, were randomly recruited[8] for the current study. There were 34 children from the first grade (56% male, mean age = 5.89 ± .43 *SD* years), 30 children from the second grade (60%

[8] Children were randomly selected based on alphabetically-ordered lists of classes.

male, mean age = 6.98 ± .58 *SD* years) and 47 children from the third grade (60% male, mean age = 7.93 ± .40 *SD* years). Assessments took place 3 months after the beginning of the school year. Three children were excluded from the study as they had hearing abnormalities, severe visual difficulties, neurological disorders, or had not attended kindergarten. Parental consent forms were sent home and the voluntary consent of children was also required.

Tools

The following literacy measures were developed for the current study: a one-minute reading test (words and pseudowords) and a spelling test.

One Minute Reading Test

A one minute reading test has been proven as an efficient way to assess and evaluate the reading performance, especially in orthographically transparent languages (Willburger & Landerl, 2009). The Arabic script serves as a transparent orthography when presented in a vowelized form. Therefore, we used a one minute reading test which was designed to provide an assessment of accuracy as well as the fluency of the reader. The test provides a score for correct words to be read aloud in only one minute and was modelled after the *Ein-Minuten Leseflüssigkeitstest* designed by Willburger and Landerl (2009). Two sheets were presented to the child including either words or pseudowords. Each sheet contained 136 items to be read aloud, which were presented in eight columns in terms of word frequency, length, or difficulty level. Practice items were given to the participants before reading the test items. Both sheets were presented in vowelized Arabic form. A test-retest method (second assessment was one month later) for 109 children showed reliability coefficients of .95 and .73 for word lists and pseudoword lists, respectively, $p < 0.01$. The test could be proven to be valid as it distinguishes children with different reading abilities: good, average and poor readers as rated by teachers. Test performance was highly consistent with teacher´s categorization of good, average, and poor readers, in a random sub-sample of 83 students.

ANOVA showed a significant GROUP effect, for the word reading test F (2, 81) = 5.80, $p < 0.01$), and pseudowort reading test [F (2, 81) = 5.43, $p < 0.01$], respectively. Post hoc comparisons (Scheffé-Test) showed that poor readers, as estimated by teachers' ratings, received the lowest scores on word and pseudoword. lists, respectively, (mean = 2.6 and 1.2) as compared to average readers (mean = 9.6 and 4.5) who in turn received significantly lower scores as compared to good readers (mean = 23.2 and 12.6; all p-values < 0.01). Moreover, scores of the teachers given to the children based on their performance on scholastic achievement in Arabic was positively correlated with the scores of the children on our reading test, (r = .35 and r=.34; $p < 0.01$ for word reading and pseudoword reading respectively).

Spelling Test

The test was designed based on the *Salzburger Lese- und Rechtschreib-Test* (SLRT) by Landerl, Wimmer, & Moser (1997). The final version of our test consisted of 36 sentences with 36 target words. Only target words have to be written. Sentences were read aloud with a consideration to the external vowelization *(alaamaat iaraab)*. The score of the correct number of correctly transcribed graphemes (max. = 204) was determined following May´s (2002) *Hamburger Schreib-Probe* (HSP). Criteria for Arabic spelling in the first three years had been thoroughly studied as provided by the teacher's guide for teaching Arabic in those years. Accordingly, target words for the test were selected based on the specific skills that students should master in each grade. A test-retest method (the second assessment was one month later) for 43 children showed a reliability coefficient of .92, $p < 0.01$ for grapheme accuracy. Again, the test proved to be valid. It showed the ability to distinguish between good, average, and poor spellers, based on teachers' observations and ratings of a random sub-sample of 84 students. An ANOVA showed a significant GROUP effect [F (2, 82) = 12.28, $p < 0.01$]. Post hoc comparisons (Scheffé-Test) confirmed that poor readers as estimated by teachers' ratings received the lowest scores (mean = 68.4) as compared to average spellers (mean = 92), who in turn received a significantly lower score than good spellers (mean = 149.91); $p < 0.01$). Moreover, scores of the teachers given to the children based on their performance on scholastic achievement in Arabic was positively correlated with the scores of the children on our spelling test, (r =.47; $p < 0.01$ for word reading and pseudoword reading respectively).

CPM- Raven's Colored Progressive Matrices

The Colored Progressive Matrices (CPM) were constructed in the 1940s as a suitable test for children aged 5 to 11 years, and were thus designed as an easier version of the Standard Progressive Matrices. The CPM comprises 36 items divided into three sets of 12 (set A, Ab, and B). Within each set, items (which are brightly colored to attract and maintain children's attention, except the very last few items in set B which are presented as black-on-white) are ordered in terms of increasing difficulty. In each test item, a candidate is asked to identify the missing segment required to complete a larger pattern. The CPM has commonly been employed as an estimate of the non-verbal component of Spearman’s g-factor in research, but more recently as the purest measure of fluid intelligence. Since no normative scores for CPM were available for us in Arabic backgrounds, we used raw scores for statistical analyses (Raven, 2000; Raven, Bullheller, Court, Häcker, & Raven, 2006).

Procedure

The tests were administered during three sessions. In the first session, the spelling test was group-administered in the natural school conditions, which had been highly controlled to prevent cheating. Children were instructed to listen to the teacher who uttered a sentence and then dictated the target word in correctly vowelized spoken Arabic. Then children had to write down the target word. Once the dictation was completed, the sheets were collected. Subsequently, the one minute reading test was individually administered in a quiet place, namely the library. Children were encouraged to read aloud as fast as they could by giving them a practice for both words and pseudowords. They were reminded to pay attention to diacritics as they would help them to read the vowelized script correctly. Exactly one minute as measured by a stop watch was given for each sheet and numbers of correctly read words and pseudowords per minute were scored separately. The last session in which CPM was individually administered was on a separate day. Children were told to play a little puzzle with the examiner. All sessions were administered in the early morning so as to guarantee attention and stable performance on the tests. The duration of sessions ranged from 50 to 75 minutes.

The statistical analysis was carried out using SPSS16 and STATISTICA6 for Windows. ANOVAs, t-tests (for normally distributed variables) and Wilcoxon-Rank tests for independent samples (for not normally distributed variables) were performed to determine differences between age groups and effects of gender. Correlation coefficients were calculated between psychometric measures and age.

2.1.3 Results

Table 1 presents reading fluency, spelling and CPM means and SDs for grades 1 through 3. Moreover, the box plots for word and nonword reading, spelling and CPM presented in Figure 6 illustrate an expected increase of all psychometric scores with the age/grade level of school. Overall, there were statistically significant differences in all literacy measures (word reading, pseudoword reading and spelling) across the three grades. Third graders outperformed second graders, whose means were significantly higher than first graders, $p < 0.01$. Means of CPM scores were 13.5, 17.5 and 19 for 6, 7 and 8 years old, respectively. Comparing these age scores to the British norms (Raven, 2000), our sample showed normal development with no signs of mental retardation. A repeated measure ANOVA was conducted to determine the lexicality effect. Word Type (word, pseudoword) served as a within factor for the whole cohort. Results showed a significant effect for LEXICALITY, [F (1, 110) = 118.52, $p <$ 0.01)].

Table 1. Descriptive statistics for all measures

Grade	Reading Fluency			Spelling	CPM
	Word	pseudoword	Word+pseudoword		
1(N=34)	4.9(4.62)	2.97(3.44)	7.85(7.75)	84.41(49.52)	14.09(4.30)
2(N=30)	15.9(9.93)	7.73(6.06)	23.63(15.54)	144.67(37.59)	17.90(4.99)
3(N=47)	35.7(18.97)	17.98(12.00)	53.67(30.14)	178.02(31.09)	19.08(5.03)

Values enclosed in parentheses represent SDs. Column and row means and SDs are also provided.

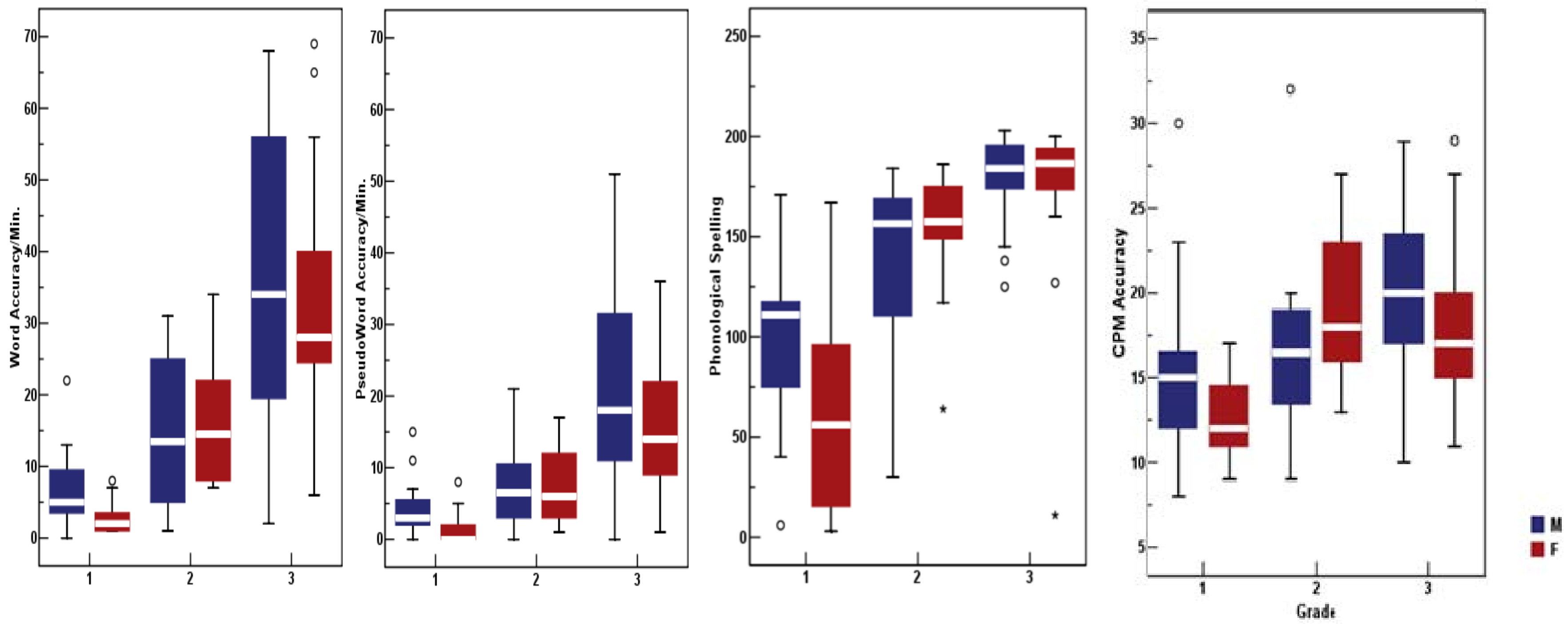

Figure 6 Box plots of the first three years for **(A)** word and pseudowords accuracy/min, for the reading test, **(B)** for the grapheme spelling accuracy and for the CPM with a consideration of gender differences.”M “refers to male, while “F” stands for female

(A) **(B)**

Correlations between the psychometric measures and age are presented in Table 1. The substantial positive correlations between reading and spelling in Arabic ranged from .88 to .92, $p < 0.01$. There were also significant positive correlations, ranging from .48 to 52, $p < 0.01$, between CPM and all literacy skills. Furthermore, there was a strong correlation between word and nonword reading in the whole cohort (r=.92, $p < 0.01$). A combined score of the number of correctly read words per minute and correctly read pseudowords per minute (Reading) was subjected to further statistical analysis.

Table 2. Spearman Rank Correlational analyses for the whole cohort

	Age	CPM	Word Reading	Pseudoword Reading
CPM	.52			
Word Reading	.79	.52		
Pseudoword Reading	.65	.48	.92	
Spelling	.77	.48	.91	.88

Note: r- values equal to or greater than .43 are significant at the .01 level.

The scatter plot in Figure 7 illustrates the relation between spelling and reading fluency scores (correct word/min. + correct pseudoword/min.). Obviously, there are no fluent readers with a poor spelling score, whereas fluent reading may considerably vary for those with good spelling scores. Fluent reading skills may further increase with age, when spelling has reached a saturation, which implies that adequate spelling develops earlier than good fluent reading.

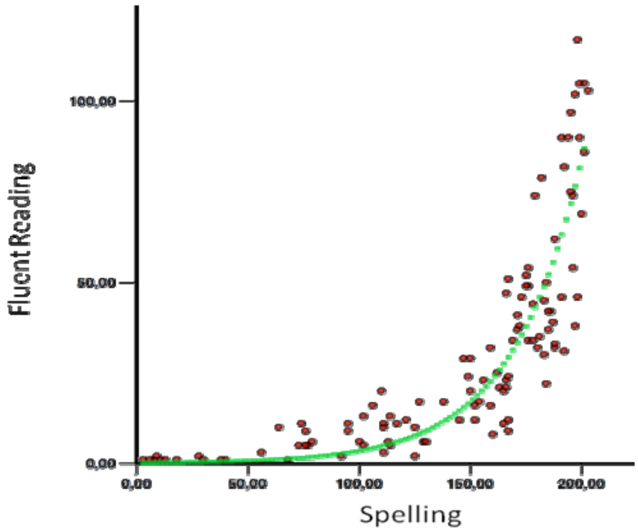

Figure 7 The scatter-plot illustrates the relationship between spelling and reading abilities. The lines indicate a significant exponential trend for the whole cohort. R square =.84

To investigate potential gender differences in the psychometric tests, a two-way ANOVA was used to determine the effect of AGE and GENDER on the CPM scores. Results showed a significant main effect of AGE and an AGE*GENDER interaction [F (2, 98) = 11.24, p < 0.01]; [F (2, 98) = 3.07, p < 0.05]; respectively. No significant effect was found for GENDER [F (1, 103) = .38 p < 0.05]. Post hoc Bonferroni tests showed that first graders scored significantly lower than both second and third graders; p < 0.01. No significant differences were observed between second graders and third graders. A male advantage was observed only in the first graders, p < 0.05. Furthermore, P values were computed for either t-tests or Wilcoxon Rank tests for independent samples to assess gender differences in the literacy skills. Again, only boys in first grade outperformed girls, (p < 0.05).

The observation of a potential gender difference among first graders may indicate the importance of visualization skills as measured by the CPM in forming the observed association between fluent reading and spelling. Therefore, we further investigated first graders by computing an ANCOVA to test if gender differences in the spelling measure would persist after controlling IQ and reading level. Using a 3*1 covariate model, GENDER served as a fixed factor, while READING and CPM were chosen as covariates. The results showed a significant effect only for the interaction of READING*CPM*GENDER on spelling, [F (2, 27) = 9.71, p < 0.01], but no significant effects were found for READING, [F (1, 33) = .46]; GENDER, [F (1, 33) = .18, p =0.68] or for GENDER*CPM, [F (1, 33) = 1.87, p =0.18]. A trend has been indicated for the effect of CPM [F (1, 33) = 3.91, p = 0.06].

2.1.4 Discussion

Overall, the findings of the current study indicated that normally developing children in grade 1 through 3 are characterized by: (a) an increase of the ability to rapidly name words and pseudowords, to correspond each phoneme to its grapheme and to develop their visual and spatial abilities; (b) an association between fluent reading and spelling in earlier grades which diverges later as spelling develops earlier than fluent reading; (c) an observed male advantage of literacy skills as well as visualization abilities, as measured by CPM, only in first graders, and (d) a reliance on visual strategies which likely mediate the interplay between fluent reading and spelling in its early stages of literacy acquisition, namely the first grade, but not in later stages.

Development of the Relationship between Reading and Spelling

Normally developing Arab children showed a smooth increase in their fluent reading performance as a function of age/grade level. A foundational processing factor, namely fluency in word identification has been suggested as an indicator of overall reading competence (Cohen-Mimran, 2009) and as a critical prerequisite for adequate reading comprehension (Perfetti & Hart, 2001) as well. Taking into consideration that Arabic scripts were presented in a vowelized way in our literacy measures, patterns of results similar to languages with invariant GPC are, therefore, expected. Our results are similar to a group of longitudinal studies, which aimed to trace the development of reading fluency and/or spelling in transparent orthographies such as German, Dutch, or Finnish. A high stability of reading fluency across ages was observed in Finnish children as well as in German children. Importantly, word recognition speed was a relevant and highly stable indicator of reading skills and the only indicator that discriminated reading skill levels in consistent orthographies (for a summary, see Landerl & Wimmer, 2008).

Further, we compared the fluency rate of first graders in Arabic with the previous results of Seymour, Aro and Erskine (2003) in which they compared the reading fluency rate of first graders in European orthographies. As they have operationally defined fluency rate as a speed of <2.25 s/item on the word list reading task, Arabic speaking children showed a relatively low fluency rate. This might be due to the fact that despite its simple syllabic transparent orthography, Arabic is a multi-syllabic word based language (Saiegh-Haddad, 2004). This, in turn, adds some complexity to its literacy acquisition and may lead to a relative reduction in fluency compared to simple shallow orthographies (Seymour et al., 2003).

Interestingly, there is a high correlation between word and pseudoword reading fluency in the whole cohort. This is consistent with the results of Thomson, Creuthner, & Creuthner (2006), who report a high correlation between words and pseudowords for children in the first four years of learning English. In our study, this correlation could be explained by the fact that lists of words and pseudowords were graded in terms of familiarity and complexity. Therefore, it is possible that some of the pseudowords, constructed by replacing one letter of a familiar word, were accessed through the direct lexical route and recognized directly as words. The reliance on the direct lexical route was again observed by the lexicality effect (reading more words than pseudowords) in the whole cohort.

Consistent with literature on European languages, our results show high correlations between reading and spelling measures in normally developing Arab children, suggesting a single orthographic lexicon used for reading and spelling processes (for a summary, see Leppänen et al., 2006; Lerkkanen et al., 2004). Stahl, Pagnucco, and Suttles (1996) showed that success in reading is associated with spelling success during the first grade: Good readers always tended to be good spellers, a conclusion that is strongly supported by our results, presented in Figure 2. Our results also showed a divergence between reading and spelling skills depicted by the earlier development of spelling skills compared to good fluent reading, supporting Frith's argument (1985) that spelling is the pacemaker of the alphabetic phase, and reading comes later.

In Arabic, the dissociation between reading and spelling can be expected to be most pronounced during the transition from the logographic to the alphabetic phase (Abu-Rabia & Taha, 2004). Azzam (1993) postulated that the acquisition of both basic literacy and competent reading, defined by reading accuracy, requires the use of an alphabetic strategy. Spelling, on the other hand, requires at least the usage of orthographic strategies if not the grammatical/semantic phase as well. As a result, it is plausible here that the interdependence between reading and spelling diminishes in later stages of literacy acquisition in Arabic (Azzam, 1993). Further, our results showed that adequate spelling develops earlier than fluent reading. Hence, we suggest here that while alphabetic strategies could be sufficient for accurate reading, orthographic strategies are a prerequisite for fluent reading. Such strategies develop earlier in the Arabic orthography as it is presented in a vowelized way for children in the first three grades of its learning. Accordingly, we assume that fluent reading develops later when diacritics are omitted and children have to rely on orthographic strategies. Similar to this view were the findings of Cohen-Mimran (2009) which showed that in order to read unpointed Hebrew texts fluently, children had to integrate their phonological, orthographic, semantic, syntactic, and morphological processes. Another possible explanation for the early development of spelling compared to fluent reading could be attributed to the phonological distance between the spoken and the literary/standard representations of Arabic language, referred to as *Arabic diaglossia* (see Saiegh- Haddad, 2003; 2004; 2005). Accordingly, this might have an impact on literacy acquisition, namely reading, as some letters represent standard phonemes that are not familiar to kindergarten and first-grade children in their spoken form[9]. Moreover, awareness for standard phonemes was also found to be indirectly related to pseudoword reading fluency in Arabic (Saiegh-Haddad, 2003). However, by the end of the first grade, the isolation of diglossic phonemes does not seem to be as strongly related to pseudoword fluent reading, suggesting a potential role for other cognitive factors such as the speed of converting graphemes to phonemes and memory (Saiegh-Haddad, 2005).

Gender Differences

CPM

Our data revealed the expected age/grade effect for CPM scores. CPM has been regarded as one of the typical tests of GF or fluid intelligence (Jensen, 1998; Mackintosh, 1998). Our results for Arabic children are consistent with previous studies on European and American children. Cotton et al. (2005) observed an age effect for Australian children aged from 6-11 years with the greatest mean differences between 6 and 9 years of age. In Arabic backgrounds, Khaleffa and Lynn (2008) administered CPM on a representative sample of 986 Yemeni children whose ages ranged from 6-11 years. In relation to British norms, their results showed an advantage of younger children 6-7 years on visualization items, but not of older children on abstract reasoning items. These results were previously reported for Syria and the United Arab Emirates (Khalefa & Lynn, 2008).

Taking a closer look at gender differences, our results showed an advantage for boys over girls on CPM scores, which was, however, only pronounced in the first grade and not in later grades. It has been proposed that the progressive matrices are not a pure measure of reasoning ability, as has been frequently asserted, but also a measure of visual-spatial capabilities, namely, in CPM and later items of Standard Progressive Matrices (SPM) (Lynn, Backhoff, & Contreras-Niño, 2004). Importantly, studies that examined visual-spatial abilities

[9] An example of this is the phonological representation of standard / ð / as /d/ in spoken Arabic.

have always favored males and have had the largest and most consistent gender differences of any psychometric abilities (Jensen, 1998). The meta-analysis of gender differences in spatial abilities reported by Lynn et al. (2004) showed that boys tend to perform slightly better on average than girls on visualization.

In line with Lynn's developmental theory for gender differences in intelligence (1994; 1999), we observed a male advantage in first graders, which is no longer evident in grades 2 and 3. The results we obtained from our study would be consistent with the assumption of an age-dependent gender difference in CPM, resulting from a male advantage in visualization and visual-spatial abilities due to biological factors in first graders. Alternatively, it might be argued that boys' skills are promoted more in their pre-school environment. However, we included only children that had visited kindergarten before they entered school and only children who were sent to a private school by their parents. This suggests that both boys and girls had a rather favorable and comparable environment in this case, which fostered their development.

Literacy Measures

In this study we investigated the pattern of gender-differences in literacy skills across grades 1 through 3. What is striking is the male advantage observed in the first grade, which was not evident in the higher grades. Our results are partially consistent with the study of Millar and Barber (1981) in which they found that males made significantly more errors than females while performing a simple spelling task, but there were no significant gender differences in another judgment task that emphasized the knowledge of phonological rules related to spelling. Contrary to the dominant view that girls outperform boys in verbal abilities, many studies of typically developing children have not found strong gender differences in reading. Further, Hyde and Linn (1988) conducted a large-scale meta-analysis of studies that examined gender differences in general verbal abilities. They suggest that the overall magnitude of gender differences in these samples is quite small, especially when excluding dyslexic subjects from the analyses. Computerized assessments of literacy skills did not detect the established gender effect, while girls performed better in paper and pencil versions of the same tests (Horne, 2007). Still, the presently observed superiority of male compared to female first graders in literacy skills is somewhat puzzling. It is likely that other abilities that specifically and directly affect literacy acquisition in the Arabic orthography. Notably visualization processing might have contributed to this finding.

Relationship between Reading and Spelling and the Potential Role of Visualization

Our results showed that the male advantage of first graders in literacy skills might be related to the visuo-spatial abilities as measured by CPM. Similar to Hebrew, which is characterized by the pointing system, predictive correlations were observed between both visual and verbal ability and reading. Again, this suggests the requirement of visuo-spatial processing due to the complexity of the pointing system (Myler & Breznitz, 1998). According to Abu-Rabia and Taha (2004), young learners of Arabic suffer from the lack of ability to manipulate GPC rules in their initial stages of acquisition. Consequently, Arabic orthography clearly demands visual word recognition strategies to manipulate change in letter shapes in accordance with its position in a word. This might also explain why the male advantage in literacy skills diminishes in second and third graders, suggesting a decline of the relevance of visual processing in advanced learners and a stronger reliance on GPCs conversion and phonological decoding.

Taken together, our data support a developmental change in the relation between reading and spelling. In first graders, the interdependence between reading and spelling abilities is at least partly mediated by visualization abilities and it therefore enhances the visual-orthographic route (Abu-Rabia & Taha, 2004). Children’s spelling and reading skills diverge soon after the onset of formal instruction (Bosman & Van Orden, 1997). This is due to the fact that spelling in Arabic requires higher order strategies than accurate word recognition (Azzam, 1993). However, fluent reading requires the development of orthographic strategies.

It is important to note some limitations of our current study. First, it is a cross sectional study, which calls for future longitudinal studies that should further investigate the developmental changes of Arabic-speaking children in literacy skills across different age and grade levels. Moreover, our results on gender differences will need to be replicated in more representative samples with larger numbers of participants.

2.2 An Epidemiological Survey of Specific reading and Spelling Disorders in Arabic Speaking Third Graders[10]

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Abstract

A relation between reading and spelling disabilities has been reported for European orthographies but has not been tested for Arabic. The scarce previous findings addressed limited aspects of reading disability only, and did not test spelling problems. We screened a representative sample of 1106 Arabic speaking third graders (52% boys, mean age 8.2 ± .57SD years old) for their reading and spelling abilities and their general level of functioning. Based on *two year behind grade level* as a cut off score, 90 children (8.1%), all with an IQ of 85 or above and without any evidence of neurological, sensory, or motor impairment were classified as severely impaired readers/severely impaired spellers.

To calculate the prevalence of the dissociation between reading and spelling, children with reading and/or spelling disorders in third graders, we applied the same criteria used in previous studies (Moll& Landerl, 2009; Wimmer& Mayringer, 2003). The overall prevalence of the three impaired groups: good readers-poor spellers, poor spellers-good readers, poor readers-poor spellers, were 1.1%, .9% and 12.6%, respectively. The estimated incidence rate (8%-15%) of children with specific reading or/and spelling disorders is high for Arabic and calls for specific attention to this problem in Arabic speaking countries. Semitic writing

[10] This data has been presented at ASHA (2009) and LDA (2010), see Appendix.

systems differ markedly from languages with other orthographies and, therefore, spelling disabilities may be different.

2.2.1 Introduction

Dyslexia/SRD has been characterized by an unexpected difficulty in reading experienced by children and adults despite adequate opportunities, intellectual ability, and motivation considered necessary for accurate and fluent reading (Jiménez, Rodriguez, & Ramírez, 2009; Shaywitz & Shaywitz, 2001). According to ICD-10, (World Health Organization, 2000), spelling difficulties are frequently associated with specific reading disorder and often remain into adolescence even after some progress in reading has been made (F81.0). This is, likely, due to the fact that the two components of literacy, reading and spelling, are closely linked. Empirical evidence shows those correlations between word reading and spelling in English, for example, are rather high, ranging from .77 to .86. Such high correlations, again, indicate that very similar processes are measured in these tasks even if different materials for reading and spelling were used. This is true among younger (first to six graders) as well as college students (for a review, see Ehri, 1997). These findings suggest that a single orthographic lexicon is, probably, used for reading and spelling processes (for a summary, see Leppänen, Niemi, Aunola, & Nurmi, 2006; Lerkkanen, Puttonen, Aunola & Nurmi, 2004). Furthermore, both reading and spelling, require in parts the same phonological and visual skills.

Although the association between reading and spelling development is strong, there exists a considerable number of children with striking dissociations (Fayol, Zorman, &Lété, 2009; Moll & Landerl, 2009; Wimmer & Myringer, 2003). This has been documented by the diagnosis of specific spelling disorder in ICD-10, but only in cases wherein reading skills are intact (F81.1). Evidence for such a dissociation at the symptom level between reading and spelling has also been reported for cases that suffered any of the two neurological disorders, alexia or agraphia, but with no signs of the other (for review Coslett, 2000; Beauvois & Derouesne, 1981).

In literacy acquisition of alphabetic orthographies, reading is commonly thought to precede spelling (Leppänen et al., 2006). This is probably due to the fact that there is, mostly; one way to pronounce one phoneme, but there is sometimes more than one graphemic representation for a phoneme (Abu-Rabia & Taha, 2004). Evidence is provided by German, an asymmetric consistent orthography, whereby pure recognition of orthographic representations required in reading is easier than full retrieval of the correct letter sequence from orthographic memory required to ensure correct spelling (Moll & Landerl, 2009).

Following the theories of literacy development, after a stage of pre-reading and pre-writing, children enter a stage called a logographic (Frith, 1985), discrimination-net learning (Marsh & Desberg, 1983) or pre-alphabetic level (Ehri, 1985). During this visual-based stage, children start with learning to associate words with pictures or situations and recognize words based on salient graphic features. According to Frith (1985), logographic skill is adopted first for reading, then for spelling. This explains how children successfully read familiar labels and words, and at the same time produce scribbles that superficially resemble cursive writing but lack any letter details (Ehri, 1997) The alphabetic stage that starts when children rely more on grapheme-phoneme correspondence (GPC) rules, a letter-sound by letter-sound analysis is believed to be used first for spelling. This is due to Frith's idea that the alphabet is tailor-made for writing rather than for reading. Finally, children start to tackle the orthographic stage when they automatically recognize spelling units, especially, the morphemic parts of words, while reading. It is important to note here that some researchers, contrary to Frith, argue that these stages do not emerge from steps, but that performance in reading and spelling influence each other over the distinct stages of literacy development, and the direction of this influence changes over time (for review, Ehri, 1997; Snowling, 2000). Moreover, Wimmer and Goswami (1994) have pointed out that while it is possible to argue that this sequence of stages may be characteristic of learning to read English, which has a relatively opaque orthography, this sequence may not apply to learning to read a highly transparent orthography such as German. In German, the mapping from graphemes to phonemes is largely consistent, so an adaptive strategy for young German readers would thus be to use grapheme-phoneme translation from the beginning of reading, omitting an initial stage of logographic access (Wimmer& Goswami, 1994).

SRD is reported to be the most common of the learning disabilities and is estimated to affect 80 percent of all individuals identified as learning disabled (Shaywitz & Shaywitz, 2001). In English- speaking countries, the prevalence of SRD is estimated to range from 5 to 17% of school aged children, with as many as 40 percent of the entire population of the United States, for instance, reading below grade level (Shaywaitz &Shaywitz, 2001). In addition, the prevalence of the potential dissociation between reading and spelling disorders has been also reported. Wimmer and Mayringer (2003) examined the dissociation in two samples of German speaking third and fourth graders. They identified 4.3% and 6.4% of children with single fluency deficit (poor readers/good spellers) and 7.9% and 6.8% of children with single spelling deficit (good readers/poor spellers) for third and fourth graders, respectively. In a recent study, Moll and Landerl (2009) replicated these findings in a more representative sample of 2029 German-speaking elementary school children. Results showed equally high prevalence rates for isolated deficits in reading (7%) or spelling (6%). In a sample of 1453 French-speaking fifth graders, Fayol et al. (2009) observed equal prevalence ratios (4%) of isolated reading and spelling deficits.

While the incidence of reading and spelling disorders and the relationship of the two skills among school students in the United States and Europe have become reasonably well established, little empirical research has been reported for Arabic backgrounds. To our knowledge, there was only a single attempt by Farrag, El-Behary, and Kandil (1988) to estimate the prevalence of specific reading disability in Egyptian second and third graders.

Incidents ranged from 1%-8%, depending on the selection criterion applied. 8% of the children were labeled as backward readers, while 3% whose IQ was 90 or more were diagnosed as SRD. Three years later, children with SRD were reassessed and only 1% read three years developmentally delayed behind their expected grade level.

To date, only a handful number of studies have compared the assessment of reading problems using measures of reading fluency rather than traditional measures of reading skills (Meisinger, Bloom & Hynd, 2009). The present study, mainly, aims to investigate the associations and dissociations between fluent reading and spelling in an epidemiological sample of 1106 Arabic speaking third grade children.

Reading and Spelling in Arabic

The Arabic writing system is primarily consonantal with short vowels represented by superscription. All diacritics are regularly mapped onto the phonemes they represent. Only when these diacritics are written, could the vowelized Arabic script be described as a shallow orthography or as *orthographically transparent* (Encyclopedia Britannica, 1974; Elbeheri& Everatt, 2007; Saiegh-Haddad, 2007). Evidence shows that the vowelized script functions as a significant facilitator of reading accuracy and reading comprehension in beginning and more advanced Arabic learners (for a summary, see Abu–Rabia, 1997; 2001; 2002; Abu-Rabia, Share,& Mansour, 2003; Taouk & Coltheart, 2004).

Paradoxically, the diacritical system in Arabic itself, although useful in decreasing phonological ambiguity, might constitute a source of difficulty for the beginning reader while mastering Arabic word-decoding skills necessary for the phonological (non-lexical route). When texts are not vowelized, like in modern written and printed literary texts, the reader has to depend on context and/or morphology and syntax and early exposure to print (e.g. Abu-Rabia, 1998). The majority of Arabic letters differ in form depending on their position in a word or in a smaller graphemic unit (connected with a preceding letter, connected with a following letter, connected with both letters; and not connected) (Abu-Rabia, 1997; 2001; 2002; Elbeheri & Everatt, 2007; Taouk& Coltheart, 2003). Interestingly, some scholars have considered Arabic as a case of *diglossia*, a term whereby the spoken and the written language are substantially different in terms of vocabulary, phonology, syntax, and grammar, meaning that these children read a language with which they have relatively little familiarity (Abu-Rabia, 2000; Saiegh-Haddad, 2003; 2004; 2007). However, the term Arabic diglossia is not universally accepted (see, e.g., El-Hassan, 1979).

Reading in Arabic is unique in terms of the relationship between consonants and vowel diacritics, the presence of position-specific variants of letters and the transition to a phase where one is able to read without them. In the early stages, children rely on a letter-to-sound conversion of print rather than whole-word recognition. The former process can only be fulfilled when Arabic script is presented in a vowelized way (Taouk & Coltheart, 2004). This vowelizing/pointing system facilitates early decoding by reducing phonological ambiguity (Share & Levin, 1999). This in turn accelerates an earlier transition from the phonological-recoding phase to the orthographic phase. On the other hand, the diacritical system in Arabic itself requires learning and thus may constitute a source of difficulty for the beginning reader while mastering Arabic word decoding. More precisely, any minor error resulting from confusions of a group of letters that are strikingly similar in shape, presence of diacritics above and below the letters and finally, the variation of letter shape as a function of letter position in a word can all lead to incorrect decoding. It is likely, therefore, that problems will arise in the phonological-recoding phase (Abu-Rabia & Taha, 2004; Azzam, 1993) especially for poor readers (Abu-Rabia, 1995).

In an attempt to uncover the development of reading and spelling processes in Arabic-speaking children in grades 1 through 6, Azzam (1993) has analyized their profiles of reading and spelling errors. Results showed that, in Arabic, the logographic phase, including visual processing, is first adopted for reading, while alphabetic/phonological and orthographic skills develop first for spelling. Compared to English, dissociation between reading and spelling in Arabic would be expected to be pronounced during the transition from the logographic to the alphabetic phase (Abu-Rabia & Taha, 2004). Results showed that for orthography such as Arabic where the shape of letters varies according to their position in the word, beginning learners suffer from the lack of ability to use GPC rules. According to Azzam(1993), to acquire basic literacy in Arabic, the use of an alphabetic strategy may be enough for competent reading, while competent spelling requires at least the usage of orthographic strategies if not the full grammatical/semantic skills. As a result, it is predicted that the interdependence between reading and spelling diminishes in later stages of literacy acquisition in Arabic (Azzam, 1993).

Aims of the Present Study

In the context of calculating the prevalence rates of specific reading and spelling deficits in a large and representative sample of 1106 Arabic speaking children in Grade 3, we were able to further investigate associations and dissociations between reading and spelling skills. Specifically, we aimed to identify children who develop normally in terms of their general cognitive abilities (measured by a nonverbal IQ test), but are severely impaired in both reading and spelling skills. To label a child as severely impaired in reading and spelling, we applied a cut off score of *2 years behind grade level* in literacy measures. This was possible, as we had investigated the level of reading and spelling in first graders at the same schools in an earlier Study (Mohamed et al., 2010). This 2-year criterion helped in the identification of children whose IQ is within the normal limits, but who show developmental delay assessed not just by their below grade level performance (below 16th percentile), but by the delay in their development. Moreover, it gave us the chance to compare our results with the only study reported for Arabic, which used the same developmental delay criteria for their sample of fifth and sixth graders (Farrag et al., 1988). To calculate the prevalence rates of dissociations between reading and spelling, we applied the same criteria used in previous studies (Moll& Landerl, 2009; Wimmer& Mayringer, 2002). Again, this enabled us to compare our results to previous findings

2.2.2 Method

Participants

During the academic year 2008-2009, a largely (exclusion criteria below) representative sample of 1106 3rd grade elementary school children were screened for their reading and spelling abilities as well as their general level of cognitive functioning. Third graders were chosen, as in the Egyptian educational system, the third grade is of particular relevance for assessing and assisting children with reading deficits. Mean age was 8.2 ± .57SD years. Children were randomly selected from 26 public schools (52% Boys), 6 private schools (55%, Boys), 3 language schools[11] (59%, Boys), and 1 experimental school (46%, Boys). Schools were selected to represent the different districts in Beni-Suef, a city marked by a comparatively high rate of birth in North Upper Egypt Region. A group of first graders served as a control group to get a cut off score of *2 years-behind grade level* in reading and spelling. Therefore, 34 children were recruited from the 1st grade (56%, Boys, mean age = 5.89 ± .43SD years)

Children were assessed 3-months after the beginning of the academic year. Children who did not attend Kindergarten were excluded from the study. Only children with IQ 85 or above and without any evidence for neurological, sensory, or motor impairment were included in this study. Parental consent forms were sent home and the verbal consent of children was inevitable.

[11] Both Language and experimental schools offer a type of schooling whereby children are intensively presented to a second language other than Arabic, their mother tongue. It is mostly, the English language in which most of the classroom subjects are instructed, except for History. While languages schools fees are fully afforded by parents of the children, fees of the experimental schools are mostly sponsored by the government.

We operationalized specific reading or spelling disabilities based on the criteria of Jiménez et al. (2007) as follows: (a) low performance on the literacy measures, (b) poor academic performance in literacy skills using a teacher's rating report, and (c) a normally developing IQ to exclude students with intellectual deficits. However, the discrepancy between literacy achievement and IQ test scores has been challenged since it has proved to be mostly important for the identification of very bright children who have dyslexia (for a summary, see Shaywitz, 1998); therefore, it has not been included in our definition. A cut-off score of *2-yearbehind grade level*, which indicate a developmental delay, was used to label children who are severely impaired in reading and spelling.

Assessment

Two important criteria for selecting the screening measures were their successful validation and their practicality. The literacy measures have been validated in a previous study (Mohamed, Elbert, & Landerl, 2010).

Literacy Measures

One Minute Reading Test

The *One Minute Reading Test* has proven to be an efficient way for the assessment and diagnosis of a reader's performance, especially for orthographically transparent languages (Willburger & Landerl, 2009). The Arabic script serves as a transparent orthography when presented in a vowelized form "which is perfectly suitable for the first stages of learning Arabic. The test provides a score for correct words to be read aloud in only one minute and was modelled after the "Ein-Minuten Leseflüssigkeitstest" designed by Willburger and Landerl, (2009). Two sheets were presented to the child including either words or pseudowords. Both sheets were presented in vowelized Arabic form. This test has proven to be a reliable and valid tool for the assessment of reading fluency in Arabic speaking children (Mohamed et al., 2010).

Spelling Test

The test was designed based on Landerl, Wimmer, and Moser´s (1997) Salzburger Lese- und Rechtschreib Test (SLRT). The final version of our test consisted of 36 sentences with 36 target words to be dictated. Each word was analyzed into its graphic units (graphemes). The score of the correct number of correctly transcribed graphemes (max. = 204) was determined following May´s (2002) Hamburger Schreib-Probe (HSP). This test has proven to be reliable and valid tool for the assessment of spelling in Arabic speaking children (Mohamed et al., 2010).

General Ability

Children's general ability was assessed using "The Non-verbal Pictorial Mental Abilities" test. It measures non-verbal deductive reasoning abilities of Egyptian children, applicable to an age range of 8 through 18 years. The test takes only 10 minutes to administer and can be applied in a group format. It contains 60 pictorial items, in which children have to cross out the odd picture that does not belong to the same category of the other four pictures (Saleh, 1978). Stimuli are drawn from the Egyptian environment and can be used across the Arab backgrounds (Elbeheri, Everatt, Reid, & Mannai, 2006)

Procedure

First, the "Non-verbal Pictorial Mental Abilities" test was administered in a group format following typical school conditions; next the spelling test was given. The testing conditions did not allow dishonest responding. An Arabic teacher read aloud the sentence and children had to write down the target word in correctly vowelized Arabic. Once the dictation was complete, the sheets were collected. Second, the one-minute word and pseudoword reading test was individually administered in a quiet place (the library). Children were encouraged to read aloud as fast as they could by giving them a practice for both words and pseudowords.

Their attention was specifically directed towards the diacritics, which would help them to read the vowelized script correctly. Then one minute measured by a stopwatch was given for each sheet, and numbers of correctly read words and pseudowords were scored. The test session for each child took almost 50 minutes including instructions.

Statistical analysis was carried out using SPSS16 and STATISTICA6 for windows. Pearson correlations were computed to study relations between measures. Descriptive data present the prevalence of children with reading and spelling disorders separately for gender and school type.

2.2.3 Results

The descriptive data for literacy measures presented separately as box plots for boys and girls in each school type (Figure 8). Correlations between the test scores are presented in Table 3. Substantial positive correlations between reading and spelling in Arabic ranged from .63-.98. There were also significant positive correlations between general ability measured by the non verbal IQ test and all literacy skills.

Table 3. Pearson correlation matrix for the whole cohort.

	non verbal IQ	Word Reading	Pseudoword Reading	Reading
Word Reading	.18			
Pseudoword Reading	.18	.87		
Reading	.19	.98	.95	
Spelling	.23	.67	.63	.67

Note: r- values equal to or greater than .18 are significant at the .01 level.

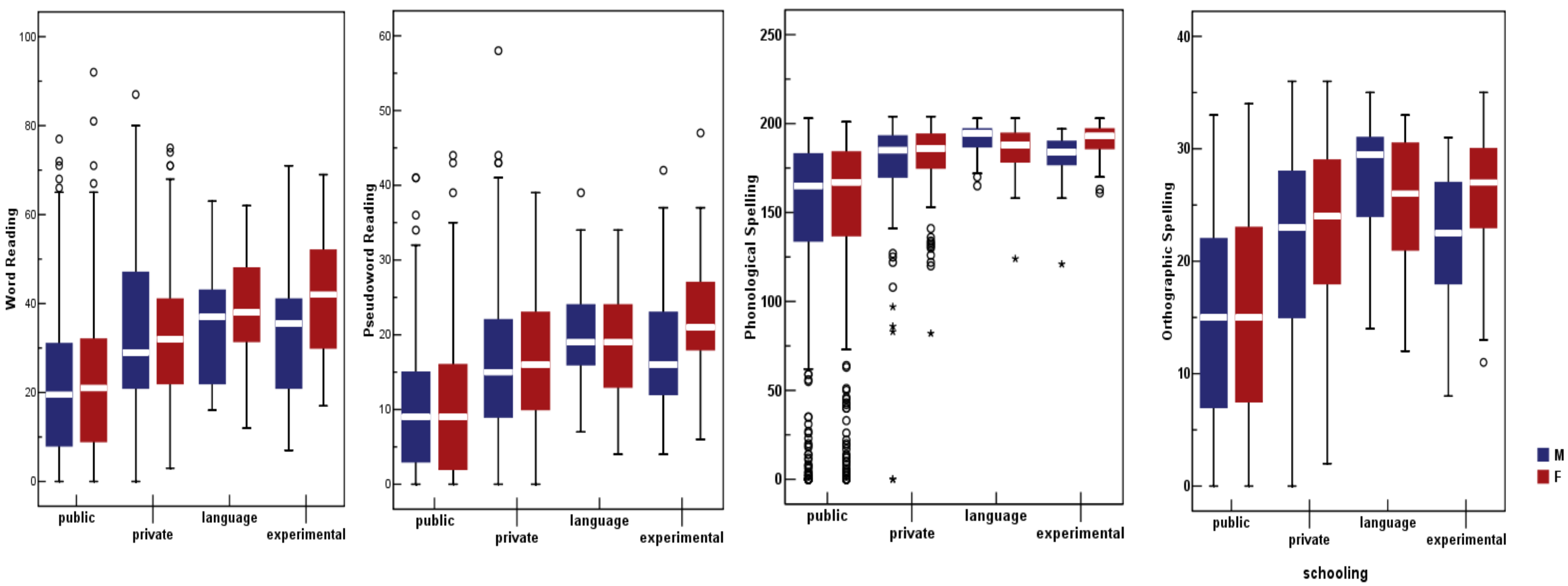

Figure 8. Box plots of psychometric measures in different school types for each gender separately. “M” stands for male, while “F” stands for female

Scatter plots in Figure 9 illustrate the relation between fluent reading (correct number of words per minute + correct words of pseudo words per minute) and spelling measures (phonological and orthographic, respectively).

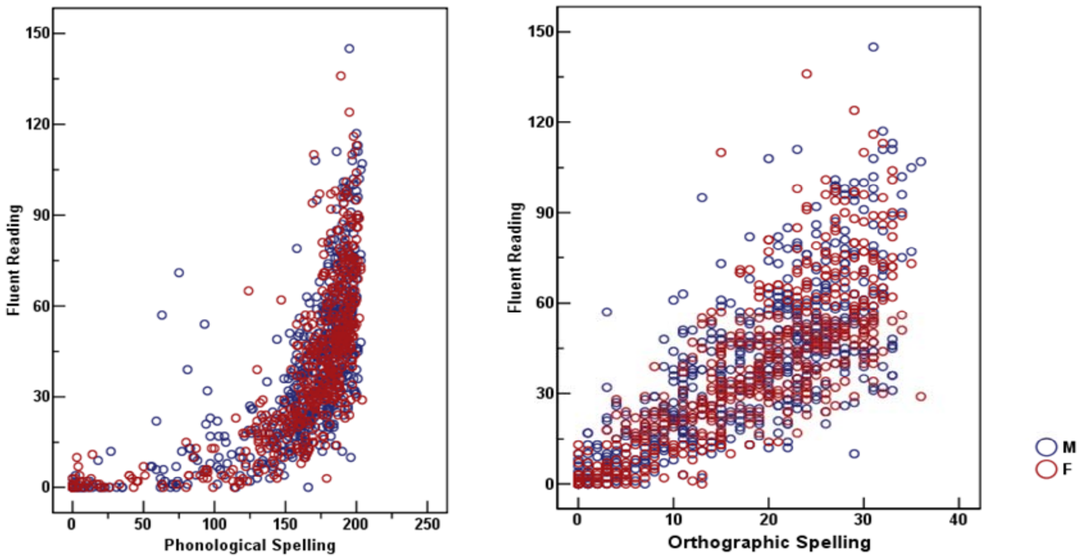

Figure 9 Plotting of fluent reading against spelling (phonological, orthographic)

Applying the literacy tests to a control group of first graders, we got a mean score of 84 and 8 for spelling and reading measures, respectively. The mean scores were used as cut-off scores to label a child as a severely poor reader or severely poor speller. As a result, 90 children (8.1%) were identified as severely poor spellers and severely poor readers. Then, we looked further into those children taking into consideration their gender and the school type (Figure 10). As illustrated, 51 boys were labeled as severely poor readers-severely poor spellers with an incidence of 56.7% that was not significantly different from the incidence of 39 girls (43.3%) (P = 0.21). Interestingly, we did not observe a single case in either experimental or language schools. Thus, severely impaired children in reading and spelling were significantly more prevalent in public schools compared to private schools with an incidence of as 96.7% and 3.3%, respectively ($P < 0.01$).

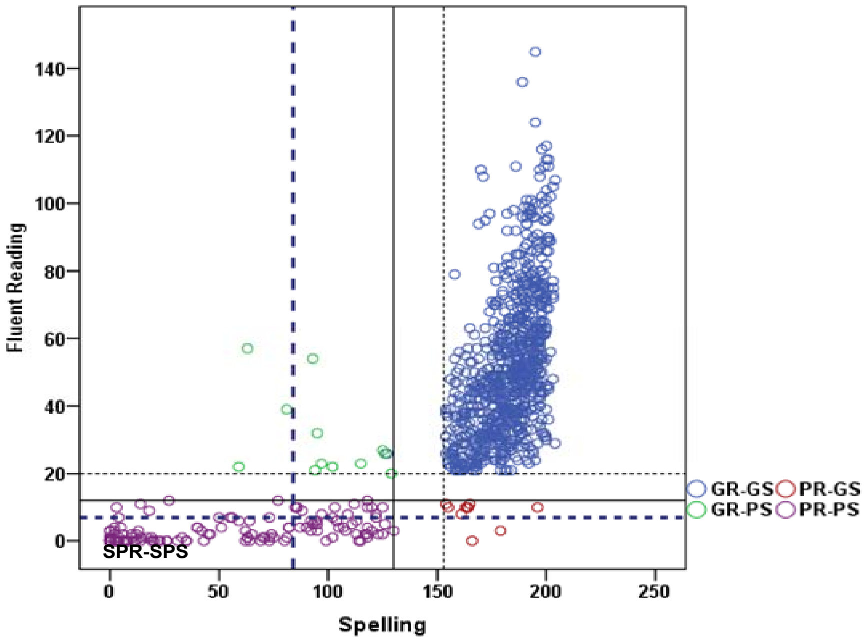

Figure 10 Plotting of fluent reading against spelling. Cut off scores are represented by reference lines

To calculate the prevalence of the dissociation between reading and spelling, children who got scores below the 16th percentile in either fluent reading or spelling measures were grouped as poor spellers or poor readers. Children who scored above the 25th percentile were labeled as good readers or good spellers. Consequently, we calculated the prevalence of these four groups of children: good readers-good spellers, good readers-poor spellers, poor spellers-poor readers, poor readers –poor spellers.

Out of 150 children with poor reading skills, 6.7% showed good spelling skills, while out of 152 children with poor spelling skills, 7.9% had intact reading skills. Overall prevalence of the three impaired groups: good readers-poor spellers, poor spellers-good readers, poor readers-poor spellers, were 1.1%, 0.9% and 12.7%, respectively.

2.2.4 Discussion

Overall, the findings of the current study pointed out the prevalence of reading and spelling disorders in Arabic speaking third graders with a reference to the association and/or dissociation between the two components of the literacy skills. Compared to other orthographies, the present data showed that there is: (a) More association than dissociation between fluent reading and spelling in the vowelized Arabic script, (b) a development of adequate spelling which is very likely to precede fluent reading and at the same time enhances it, (c) an incidence rate of 8-15% of Arabic speaking third graders who suffer from specific reading or / and spelling disorders.

Associations between Reading and Spelling

The presently observed correlations between reading and spelling in Arabic ($r=.67$, $P<0.01$) are not as high as the one reported for English ($r=.77$-$.86$) (Ehri, 1997). On the other hand, they are higher than the one reported for German ($r=.57$, $P<0.01$) by Moll & Landerl (2009) ($z= 4.77$, $P<0.01$)[12]. This might be explained, assuming that vowelized Arabic lies between German and English in terms of orthographic consistency.

Based on the *2 years –behind grade level* as an indication for a developmental delay, 8.1% are identified as severely impaired (dyslexia)/ children with reading and spelling disorders. This incidence rate is within the range of 5-10% reported for European languages. However, when we applied the "below 16th percentile", we got a percentage of 12.6%. Adding dissociations between reading and spelling to that, depending on the" below16th percentile", the incidence range increased from 8.1 to 15% , which markedly exceeds incidence of other orthographies. Cross-national comparisons showed an estimated incidence to be around 10% in Italy, United States (Lindergren, De Renzi, & Richman, 1985) and in Finland (Lyytinen, Aro& Holopainen, 2004). While prevalence of dyslexia varies between 3% and 10% in India, (Rama, 2000), it was estimated to be 9.7-12% in Chinese school children (Lam, et al., 2008). The only epidemiological study conducted in Malaysia observed 7% of children who present with dyslexia (Gomez, 2004). The observed difference holds true, even when taking into account that the definition of the dyslexia varied across these studies.

[12] We calculated the significance between the two correlations using the Fisher r-to-z transformation.

While most defined dyslexia based on normal development of IQ associated with a reading level of 16th percentile or one SD below the mean (e.g. Lam, et al., 2008; Lindergren et al., 1985; Rama, 2000), in other studies (e.g. Gomez, 2004), dyslexic children were referred to by teachers or parents using subjective reports.

Gender ratios as illustrated in the box-plots show comparable scores in all literacy skills for boys and girls in all different school types. Moreover, we identified roughly equal numbers of dyslexic boys and girls. Such balanced gender ratios have also been revealed for English (Shaywitz et al., 1998) and Chinese (Lam, et al., 2008). On the other hand, several epidemiological studies have found dyslexia to be two to four times more common in boys than in girls (eg. Rutter et al., 2004) and it seems that this was probably not due to the tendency on the part of parents and teachers to refer more boys to clinics (for a summary, see Jorm, 1983). However, Shaywitz & Shaywitz (2001) showed that when actual reading scores, and not teachers rates, are used to identify children, there were no significant differences in the prevalence of dyslexia between boys and girls.

School type had a strong impact, whereby children in public schools were underachievers in all literacy skills compared to the other types of school. Moreover, children with reading and spelling disorders in all categories were significantly more prevalent in public and private schools than in language and experimental schools. Two reasons might explain these findings: First, children in public schools mostly descend from families of lower socioeconomic status compared to other types of schools. It has been reported that there is a notably scarcity of retarded readers amongst the highest social classes (Jorm, 1983), in which home literacy environment (e.g., print exposure) is more favorable for the developing reading skills (Finucci, 1985). Another possible interpretation could be associated with the early intensive bilingual education offered for language and experimental schools. Substantial research has been devoted to the effects of learning a second language on the development of first language literacy skills (for a detailed report, see Bournot-Trites & Tallowitz, 2002). One of the conclusions drawn from these studies is that by grades 2 and 3, there is no longer a lag between bilinguals and monolinguals in their L1 literacy skills. This supported the concept of Cummin's hypothesis of developing "functional bilinguality" whereby second language is enriched with no accompanied loss or even with usual enhancement in L1 competencies compared to monolinguals who have been schooled in their L1 only. The key point, here, is that instructing a deep orthography like English to beginning learners whose first language is of a consistent orthography (e.g., vowelized Arabic), might possibly, accelerate the development of their orthographic strategies, especially in spelling which is assumed to develop earlier than good fluent reading in Arabic . Therefore, we may predict that bilingual education enhances literacy skills in L1.

Are there dissociations between deficits in reading and spelling?

Despite the significant associations between reading and spelling development, a considerable number of children present a striking dissociation between the two skilled performances (Moll & Landerl, 2009). Plotting the data in Figure 2 revealed that spelling develops earlier than good fluent reading. This result could be explained by Frith's developmental model (1985, 1986) in which the alphabetic phase, including phonological decoding skills, develops first for spelling. According to Azzam (1993), Arabic speaking children showed that spelling accelerates both the alphabetic and the orthographic phase and only reading comes later. This indicates an asymmetry and divergence between spelling and reading in Arabic. Such an asymmetry has been revealed through the data by the occurrence of some children who show isolated reading deficits, while their spelling skills are intact.

Another possible explanation for the early development of spelling compared to fluent reading could be attributed to the phonological distance between the spoken and the literary/standard representations of Arabic language, referred to as *Arabic diaglossia* (see. Saiegh- Haddad, 2003; 2004; 2005). Accordingly, this might have an impact on literacy acquisition, namely reading, as some letters represent standard phonemes that are not familiar to kindergarten and first-grade children in their spoken form. Moreover, awareness for standard phonemes was also found to be indirectly related to pseudoword reading fluency in Arabic (Saiegh-Haddad, 2003). However, by the end of the first grade, the isolation of diaglossic phonemes does not seem to be as strongly related to pseudoword fluent reading, suggesting a potential role for other cognitive factors as the speed of converting graphemes to phonemes and memory (Saiegh-Haddad, 2005).

If this is the case, then it is still puzzling to observe some children who are good readers and suffer isolated spelling deficits. Looking closer into the data, this group of children shows only adequate level of reading skills (ranging from 25th to 50th percentile). We can hardly find cases who are truly good fluent readers in this category (good readers-poor spellers). This could be justified by the assumption that children with adequate levels of fluent reading rely on either logographic or alphabetic strategies[13], but are not able to develop orthographic strategies yet, which occur first in spelling in the Arabic language. Accordingly, it is plausible that these children fail to spell the form of words correctly, developing isolated spelling deficits.

To sum, dissociations between fluent reading and spelling in vowelized Arabic are, very likely, to emerge for three reasons: (1) the earlier development of spelling compared to reading during the alphabetic and the orthographic phase and (2) the disparity between the spoken and literal form of Arabic, referred to as Arabic diglossia (isolated reading deficit); or (3) the immature development of spelling orthographic strategies (isolated spelling deficits).

[13] Those children were able to read the first two columns in the two word lists (words and pseudowords) which mainly includes words with high frequency, and pseudowords that are similar to high frequent words. To do this task, children have to rely either on logographic strategies or on alphabetic strategies to read familiar words and pseudowords, respectively.

2.3 Abnormal Oscillatory Brain Responses in Dyslexic children with Poor Categorical Perception[14]

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Abstract

The condition of dyslexia has been associated with problems in speech perception, particularly in the processing of speech signals (e.g., phonemes). Speech signals contain information on different time scales. For instance, while rapid spectral changes as formant transitions may occur on time scale (20-40ms), syllabic and prosodic information occur on a time scale of (150-300ms). Therefore, the segmentation of the auditory stream into discrete representations is a prerequisite for speech perception, According to Peoppel (2003); the input speech signal has a neural representation that is bilaterally symmetric at an early representational level; however it is elaborated asymmetrically in the time domain. Consequently, it has suggested that temporal integration in different windows is reflected as oscillatory neuronal activity in different frequency bands. In this study, we are testing if the temporal integration is reflected as oscillatory activity in different frequency bands by mapping focal slow waves in the delta (1.5-4Hz) frequency band. We used magnetoencephalographic (MEG) source imaging in a sample of 19 dyslexic children with poor categorical perception and 14 controls while listening passively to syllables /ba/ and /da/.

[14] Part of this data has been represented at ICP (2008), and IASCL (2008), see Appendix.

Dyslexic children with poor categorical perception differ significantly in the density of magnetic slow waves produced by the two hemispheres. To illustrate, dyslexic children with poor categorical perception showed elevated production of focally generated slow waves (1-4Hz), predominately in the left hemisphere as compared to controls. The results suggest altered segmentation processes of speech sounds in a subset of children with dyslexia.

2.3.1 Introduction

Language abilities, namely, phonological skills are one of the most reliable indicators of success in early reading acquisition. Phonological processing skills make use of the sound structure of language to perform oral and written language manipulation (Wagner & Trogesen, 1987) For years, evidence has been provided by correlational, longitudinal and intervention studies as to the role of high levels of phonological awareness in enhancing reading achievement not only in individuals with dyslexia, but also in middle and lower level readers (for review, see Castles & Coltheart, 2004; Fox & Routh, 1976; Mains, McBride-Chang, Seidenberg, Keating, 1997; Rack, Hulme, Snowling, & Wightman, 1994; Shaywitz, 1998; Snowling, 2000).

According to Chang-Bride’s integrated model (1996), there are associations between phonological processing skills, speech perception and the word reading process. These associations have been supported to be based on indirect relations in the sense that the speech perception's association with word reading is mediated by the associations of speech perception with the phonological processing skills included. Moreover, deficits in analyzing the phonological structure of spoken language have been attributed to possibly inadequate representations of phonemes resulting from basic perceptual deficits (Mains, McBride-Chang, Seidenberg, & Keating, 1997; Tallal, 1980; 1984; Tallal & Piercy, 1973). For instance, in tasks requiring the categorization of speech sounds and the processing of stop consonants, individuals with dyslexia performed more poorly than control subjects (Mains et al., 1997;

Mody, 2003; Sernicales, Sprenger-Charolles, Carré, & Demonet, 2001). Results indicated that due to their deficiencies in processing the rapid formant transition (fast frequency changes) of stop-consonants, which lasts about 40 ms, children with dyslexia performed poorer than typically developing children in categorizing speech sounds or distinguishing consonant-vowel (CV) syllables like /ba/ and /da/.

Taken together, it has been inferred that dyslexic readers suffer from a basic, non-linguistic deficit in temporal resolution of rapidly changing auditory stimuli that impairs speech perception. As a result, this deficit contributes to inadequately defined sound and representations which interfere with phonology processing (Reed, 1989; Tallal, Miller & Fitch, 1993; Vellutino et al., 2004)

Since the late 19th century (Broca, 1861; Wernicke, 1874), speech processing has been investigated with a consideration to the functional hemispheric asymmetry of the auditory cortex (In: Okamoto, Stracke, Draganova & Pantev, 2009). Later evidence for the dominance of the left hemisphere in speech processing has been originally provided by observations of patients with neurological deficits at both the behavioral and the neurological level. Studies employing recent neuroimaging techniques as functional magnetic resonance imaging (FMRI) (Belin, Zatorre, Laifaille, Ahad& Pike, 2000) and MEG (Eulitz, Diesch, Pantev& Hampson, 1995) have supported the view that speech is dominantly processed in the left hemisphere. However, for lower level perceptual functions, cortical lateralization has been more ambiguous (Poeppel, 2003).

Based on investigations of monkeys and humabeings, Merzenich, Schreiner, Jenkins and Wang (1993) have addressed the neural mechanisms involved in the auditory cortex, based on investigations of monkeys and human beings. They proposed that neurons respond strongly to successively presented temporal stimuli only when inputs are “chunked” in time periods (amplitude modulation (AM) cycle lengths) extending from about 50 to 200 ms in cortical A1 or from about 200 to 500ms in a series of secondary auditory cortical fields. The

A1 temporal chunking is perfectly appropriate for the analysis of inputs at the input rates of speech phonemes, while the longer best-AM periods of most “secondary” cortical fields blanket the integration time periods appropriate for receiving signals at syllable rates. Consequently, it was suggested that insufficiently developed or degraded representational maps, assumed to be centered in cortical perisylvian regions, result in noisier processing, which then would require more time for correct recognition of phonemes and consequently words (Merzeinch et al., 1993; Merzenich et al., 1996; Wright, Buonomano, Mahncke, & Merzenich, 1997).

Additionally, a growing body of neuroimaging research has led to the emergence of several models which deal with the question of what exactly is computed in left and right auditory areas (functional segregation) during speech and non-speech processing (Giraud et al., 2000; Hall et al., 2002;Zatorre, 2003; Zatorre & Belin, 2001; Zatorre, Belin & Penhume, 2001). On the basis of psychophysical and neuroimaging data, Zatorre and his colleagues have argued that right hemisphere, namely right temporal superior temporal areas, is specialized for the analysis of the spectral properties of signals (e.g., pitch changes), while left hemisphere areas are better suited for the processing of rapid temporal modulation (Zatorre, 2003; Zatorre & Belin, 2001; Zatorre, Belin & Penhume, 2001) . This finding has been also consistent with Tallal et al. (Tallal et al., 1993) as it asserts the basic notion that there is a leftward bias in the analysis of rapid spectral changes.

On the other hand, functional asymmetries in the auditory domain have been assumed to be related simply to the time frames over which auditory information is processed in each of the hemispheres [15]. It is uncontroversial that the information contained in speech signals occurs on multiple time scales. For instance, according to Poeppel and his colleagues (Poeppel, 2003; Poeppel, Idsardi& Wassenhove, 2008) speech processing requires the segmentation of an acoustic stream to generate matches with stored representations of phonemes whereby this process would rest on signal analyses occurring concurrently on two time scales. To illustrate, rapid spectral changes such as the formant transition associated with place-of- articulation information may occur on time scales on the order of ~20-80 ms for its segmental level. In contrast, syllabicity and prosodic phenomena would require a longer temporal integration of ~150-300ms, i.e., neural mass activations lasting for the corresponding time windows. In adopting this view, the authors have proposed to resolve the controversial issue of the possible relation between temporal processing and speech perception, in general and phonetics and phonology, in particular.

In principle, while a long time window chosen for sound signal analysis yields high frequency resolution but comparably poor temporal resolutions, a short time window results in high temporal but relatively poor frequency resolution. Accordingly, there must be a trade-off between spectral and temporal auditory processing precision, which would manifest within the hemispheres and differ between the hemispheres, leading to relative temporal or spectral processing hemispheric specialization, respectively (Okamoto et al., 2009).

Based on the aforementioned findings, we argue that multi-time resolution processing- in the context of which segmentation occurs subsequently on segmental and syllabic time scales-are reflected as oscillatory neuronal activity in different frequency bands. Hence, we predicted that focal slow waves generated in the 1.5-4 Hz frequency (delta band) would indicate the processes at short temporal integration windows during speech processing. Therefore, the goal of the present study was to investigate if a noisy representation of phonemes, and with it a corresponding categorical perception deficit, may stem from deficits in temporal integration and segmentation in the auditory cortex. The results of this study were expected to reveal perceptual deficits in certain temporal and spectral sound contexts rather than a general deficit in the presentation of rapidly presented sounds in dyslexic children with categorical perception deficits.

Abnormal patterns of slow waves have been consistently reported in reading-impaired children. Enhanced levels of delta and theta have been most consistently found in temporal and frontal areas, with predominance in the left hemisphere of impaired readers (Harmony, Hinojosa, Marosi&Becker, 1990; Penolazzi, Spironelli & Angrilli, 2008) and have been interpreted as a marker of dysfunctional linguistic processing (Penolazzi at al., 2008). Using magnetic source imaging, we calculated the distribution of focal generators of slow waves separately for brain regions while subjects performed a simple phoneme discrimination task. We tested if impairments of the sub-lexical phonological representation level are related to altered laterality patterns of magnetic slow activity in temporal brain regions. It is noteworthy that the use of neuromagnetic rather than neuroelectric activity has the advantage that widespread generators which typically have radial orientation (as activity in opposing walls of a sulcus would cancel out) go largely undetected by the measurement, enhancing relatively the more specific tangentially oriented neural sources (Elbert, 1998; Wienbruch, 2007).

2.3.2 Methods

Generation of sample

All together 68 children were either in the 3rd or 4th grade in elementary schools in and around the city of Konstanz, Germany were recruited for the current study. It is assumed here that in about three or four years of formal tuition even children with poor literacy development had a good chance to develop reasonable non-lexical and lexical procedures for their reading and spelling. The current sample is a sub-sample of Paul, Bott, Heim, Wienbruch, and Elbert (2006). Therefore, we followed the same criteria of Paul et al. (2006) for classifying a child as either dyslexic or control. To sum, a dyslexic child was chosen based on: 1) teachers' informal assessment and parents' self–report of the children's weaknesses in literacy skill; 2) a performance which is significantly below the normative sample (e.g., <50 *T*-values) on a test battery (see below materials) including not only literacy skills (reading and spelling), but also phonological abilities (e.g., Mottier Test) and categorical perception (phoneme identification); and 3) a normal development of nonverbal IQ(with IQ 85 or above).

Further, subjects who showed a history of co-morbid disorders including depression, neurological conditions or ADHD, were excluded.

Participants

Nineteen dyslexic children with poor categorical perception (40% of the whole dyslexic sample) and 11 without any reading, spelling or categorical perception deficits have finally been selected for the current study after giving informed consent. Demographic variables have been controlled for the subgroups (a) age (controls 9.1 ± .60SD, individuals with dyslexia 9.3± .51SD); (b) gender (controls 50%, individuals with dyslexia 58% male); and (c) handedness (controls 100%, individuals with dyslexia 90% right-handed). Table 1 illustrates means and standard deviations of the two groups on the whole test battery.

Crucially, the final selection of these subgroups was based on the children performance on a categorical perception task (CP), which represents "phonemic identification", served as criterion for admission into the dyslexic with categorical perception deficit and the control groups. In this task, a child was asked to identify stimuli of a 10-item /ba/-/ba/, continuum into the phonemic categories. A high perception index indicates reliable and correct categorization of the syllables (Paul et al., 2006). Means of identification percentage of both /ba/ and /da/ syllables in controls as compared to dyslexic children with poor categorical perception across trials are represented (Fig. 11).

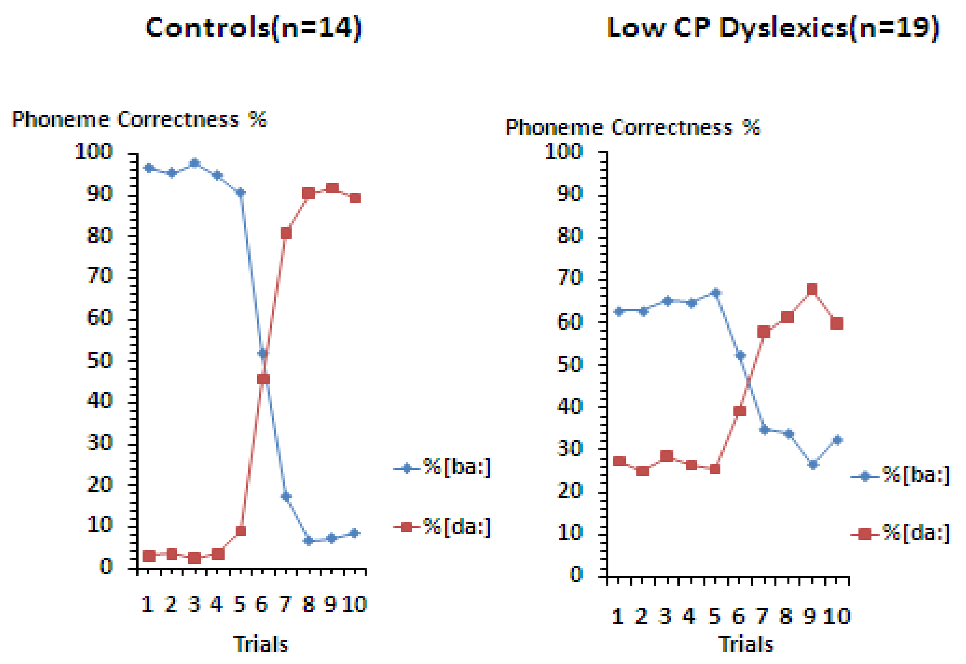

Figure 11. Categorical perception index: Means of identification percentage of both /ba/ and /da/ syllables in controls as compared clinical dyslexia subjects across trials

Materials

A battery of tests served to measure language skills. The test battery tests assessed nonverbal IQ, literacy skills, phonological processing abilities and categorical perception.

Literacy Measures

Spelling skills were measured by the diagnostic test of correct spelling, Diagnostischer Rechschreibtest (DRT) for grades 3 and4 (Grund, Haug& Naumann, 1994; Müller, 1997). In this test, a child has to spell out the dictated word and write it in the gaps of the sentences. To test reading skills, children were given Grissemann's (2000) Zurich Reading Test (Zürcher Lesetest, ZLT), an individual reading aloud test. In this test, children were asked to read aloud lists of words and small passages (Grissemann, 2000). Further, children were also asked to read aloud a list of 50 words which vary in complexity (Paul et al., 2006). For reading tests, scores were based on both time and accuracy. Response times were recorded to determine seconds needed to read a word, list of words or paragraphs. Measures of accuracy represented the percentage or the number of words read or spelled correctly.

Phonological Measures

To assess phonological processing abilities, we adimintsered Welte's (1981) Mottier Test. In this test, children were asked to repeat pseudowords (Welte, 1981). Moreover, children were asked to read aloud a list of 50 pseudowords varying in complexity as a measurement for phonological decoding skills (Paul et al., 2006). A phonetic dictation test (Lauteres Diktat Test) developed by Findeisen & Melenk (1991) was administered to measure children's phonological encoding abilities. In this test, children were asked to spell out words. Only phonetic errors were counted as misspellings and other errors as capitalization errors were not counted (Findeisen, 1991).

Categorical Perception

A categorical perception has been also included in the test battery to measure the children ability of phoneme identification (Paul et al., 2006). In this task, Syllables differ only in the onset frequencies of the second and third formants ranging in linear steps from the /ba/ endpoint (item1) to the /da/ endpoint (item10). Categorical perception performance is quantified by using the following formula, $f = \sqrt{\ } \Sigma\ (a_i\text{-}b_i)^2$, with a representing the number of responses for /ba/ and b the number of responses for /da/. A high index indicates correct identification of phonemes.

General Cognitive ability

To grantee the normal cognitive functioning of the current sample, we assessed the non verbal IQ using the German version of Standard Progressive Matrices Test (SPM) which was developed by Heller et al. (1998).

Means and standard deviations of the two groups on the whole test battery are illustrated by Table 4.

Table 4. Means and standard deviations of behavioral measures

	Controls		*Dyslexics with poor CP*	
	M	*SD*	*M*	*SD*
General Ability				
SPM	65.5	13.03	46.21	6.28
Spelling				
DRT	58.64	5.73	36.81	4.99
Reading				
ZLT accuracy%	96	.02	87	.078
ZLT reading time(w/s)	.66	.19	1.57	.86
Word reading accuracy%	91	.06	73	.14
Word reading time(w/s)	70.71	20.04	188.47	90.96
Phonological Measures				
Pseudoword accuracy	.76	.11	.47	.15
Pseudoword reading time	111.93	23.73	249.53	132.609
Mottier Test	.83	.11	.60	.14
PhoneticDictation	.9315	.05	.74	.13
Categorical Perception				
Phoneme Identification	31.95	2.12	18.18	4.53

Study design

The battery of paper and pencil tests for language ability was administered individually during three 45-minute sessions held on three separate days. In a fourth session, MEG was recorded while children were presented with a passive listening task, whereby auditory stimuli were presented through ear tubes 60 dB/SPL over the individual's hearing level. The two phonemes were the fifth and eighth items of the 10-item continuum of synthetic syllables that ranged form /ba/ to /da/, as presented by a male voice. Both syllables were 250 ms long with a 40 ms formant transition (FT) in the onset frequencies period, which distinguished the two syllables. For both syllables the fundamental frequency of formant F0 was 128 Hz with a linear decline to 109 Hz towards the end of the stimulus. The formant frequencies for the vowel /a/ (which was also the same for both syllables) were 770, 1340 and 2400 Hz for F1, F2 and F3, respectively. Starting frequencies for the formants F2 and F3 were 1365 and 2337 Hz for /ba/, 1567 and 2515 Hz for /da/. Therefore, the only acoustical difference between the syllables was between formants F2 and F3 within the first 40ms. In an auditory oddball task, the syllable /ba/ was used as standard stimulus, while /da/ served as the deviant stimulus. In total, 500 stimuli were presented with a constant ISI of 500 ms. Occurrence rates were 85% and 15% for /ba/ and /da/, respectively. Stimuli were presented pseudo-randomly.

Data Acquisition.

Using a 148-channel whole-head neuromagnetometer (MAGNES™ WH2500, 4D Neuroimaging, San Diego, USA), MEG was measured with the subject in a supine position. A video camera was used to monitor the subject's behaviour and to ensure compliance throughout the experiment. Subjects were instructed not to pay any attention to the syllables they heard. To divert the child's attention from the syllables, a silent video was presented onto a white projection field at the ceiling of the shielded room using a video beamer (JVC™, DLA-G11E) and a mirror system. EOG was recorded by two electrodes attached to the left and right outer canthi and electrodes were placed above and below the subject's right eye. In addition, ECG was monitored via two electrodes - one attached to each forearm. EOG and ECG data were acquired using Synamps amplifiers (NEUROSCAN®). Data were recorded using an online high-pass filter of 0.1 Hz and a sampling rate of 508.63 Hz (bandwidth 100Hz). Spatial density of slow waves generators were then identified following the procedure described by Wienbruch (2007).

Data Analysis

Slow wave generators were identified in a semi-automated procedure. Artifacts were recognized by visual inspection (e.g. eye blinks, muscle activity) and excluded from further analysis. The acquired data were decimated by a factor of 16 (anti-alias filters were applied automatically) and digitally filtered (1.5–4.0) delta. Using defined channel groups (anterior, center, posterior, left, and right), a single equivalent current dipole (ECD) was fitted for each time point in artifact-free segments. The dipole density was estimated for each subject within each voxel of the source volume by calculating the average number of dipoles per time unit in the voxel over artifact free segments and divided by the number of artifact free sampling points, followed by calculating the logarithm. For further analysis this score was z-transformed using the mean and standard deviation of a normative group (Wienbruch, 2007).

2.3.3 Results

Table 5 shows descriptive data for Z scores of Delta density in each region. A repeated measure ANOVA was calculated for the densities of slow wave generators collapsed across brain regions, using the general linear model (STATISTICA6). HEMISPHERIC ASYMMETRY (Frontal Left-Frontal Right, Central Left-Central Right, Temporal Left-Temporal-Right, Occipital Left-Occipital Right) served as within factor, while GROUP (Controls and Dyslexic children with poor categorical perception) served as the between subjects' factor. For each region a hemispheric asymmetry coefficient has been calculated by calculating the difference between z scores of both hemispheres (Left- Right).

Table 5. Descriptive statistics of Delta Z scores in each region.

Group	CLZ	TLZ	PLZ	FRZ	CRZ	TRZ	PRZ	FRZ
Controls								
M	.66	-.21	-.03	-.02	.56	-1.14	-.52	-.05
SD	.86	1.54	.67	.95	1.07	1.60	.82	.91
Dyslexics with poor CP								
M	.80	-.32	-.24	.10	.58	-2.28	-.75	-.30
SD	.64	1.25	.76	.77	.76	1.79	.97	.92

Key: Central left Z score(CLZ), temporal left z score(TLZ), parietal left Z score(PLZ), frontal left Z score(FLZ), Central right Z score(CRZ), temporal right Z score(TRZ), parietal right Z score (PRZ), frontal right Z score(FRZ).

Hemispheric Asymmetry and Delta Activity

Analysis of Hemispheric Asymmetry coefficient z-scores of Delta data showed a significant effect for the REGIONAL HEMISPHERIC ASYMMETRY (F (3, 93) =19.5, p<0.01 and an interaction effect of the REGIONAL HEMISPHERIC ASYMMETRY x GROUP (F (3, 93) =4.98, p<0.01). Newman-Keuls Post hoc- analyses revealed that the differential group asymmetries were mainly produced by the temporal region (Newman-Keuls p=0.01). No significant differences between the groups were found for frontal, central or occipital asymmetry (for all p>0.8) (Fig.12).

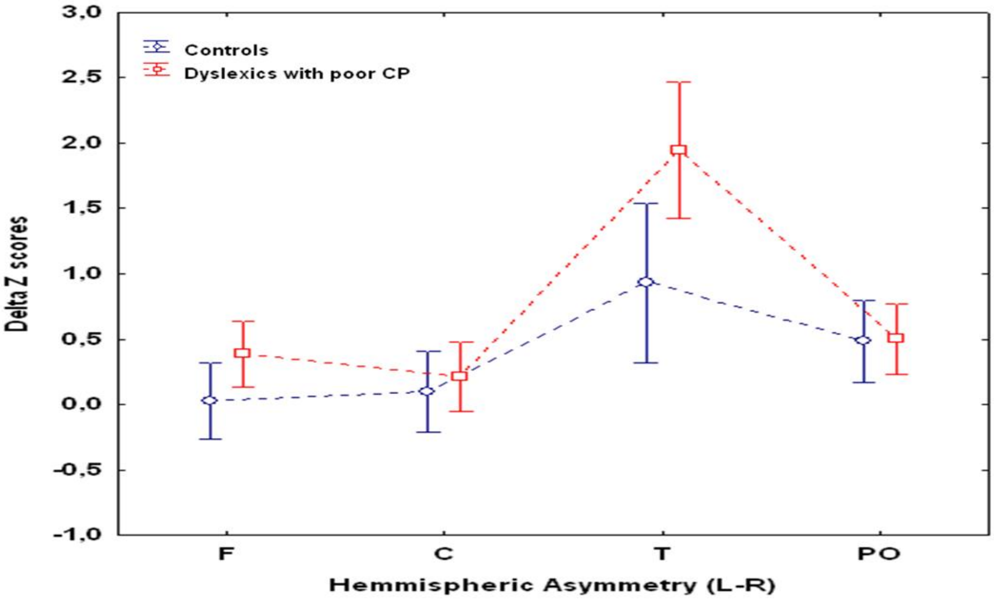

Figure 12 Hemispheric asymmetry in each region.Means of delta z scores (n=33) as a function of the hemispheric asymmetry in each region. Vertical bars indicate confidence intervals at 95%

Voxel-based Analysis for the Delta Band.

Localization of abnormal oscillatory responses at the voxel level indicated enhanced slow wave activity over the left hemispheric speech related per-Sylvian regions for dyslexic children with poor categorical perception as compared to average readers (Fig.13). Differences of z-transformed logarithm voxel-based generator density of slow waves for the left and right hemisphere, medial (top) and lateral (bottom) view. Only voxels with a significance value of $t > 3.42$, $p < 0.05$ are marked in color. Orange voxels indicate more focal slow waves in children with dyslexia than in the controls. Blue voxels indicate less focal slow waves in children with dyslexia than in controls.

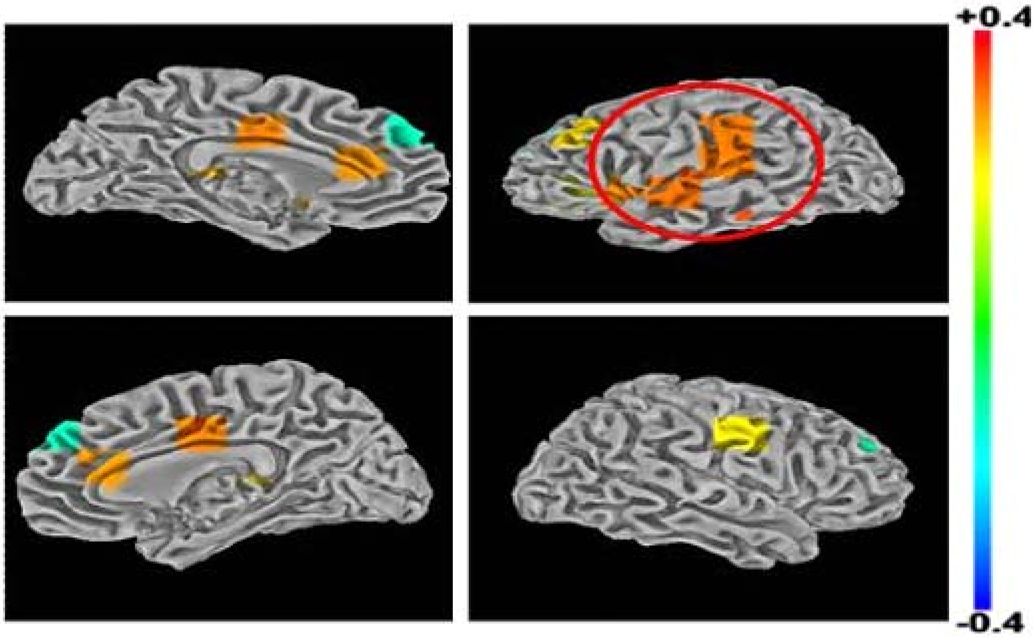

Figure 13 Voxel – based analysis

Differences of z-transformed logarithm voxel-based generator density of slow waves for the left and right hemisphere, medial (top) and lateral (bottom) view. Only voxels with a significance value of $t > 3.42$, $p < 0.05$ are marked in color. Orange voxels indicate more focal slow waves in children with dyslexia than in the controls. Blue voxels indicate less focal slow waves in children with dyslexia than in controls.

2.3.4 Discussion

Using magnetic source imaging, the present exploration of abnormal slow waves in dyslexic children with poor categorical perception confirms and extends previous findings based on EEG-analyses (Penolazzi et al., 2008). The major finding of this study was an elevated delta activation localized in voxels of the left per-Sylvian regions in dyslexics with categorical perception as compared to controls. These results are consistent with a series of previous neuroimaging studies, which have converged to suggest an atypical organization in the temporal cortex of the left-hemisphere for dyslexia, suggesting a reduced engagement of the per-Sylvian regions for phonological processing, altered white-matter connectivity, and functional plasticity associated with effective intervention (Gabrieli, 2009). Moreover, this finding has been in line with the assumptions of Merzenich and his colleagues (1993) that insufficiently developed or degraded representational maps are centered in cortical per-Sylvian areas leads to noisier processing, which then would demand more time to correct the recognition of phonemes, and words, accordingly.

Recently, it has been suggested that the two hemispheres are functionally segregated in terms of processing the temporal and spectral features of an auditory input. As a result, it is strongly plausible to assume, here, that segmentation and integration of sounds also rely on lateralized modules. Previous imaging studies showed that speech processing at the initial stages produced bilateral activation, at least at the level of the auditory core and surrounding superior temporal gyrus as assessed by hemodynamic and electrophysiological methods [In: 26]. Importantly, our current results are consistent with studies that examined segregation and functional hemispheric lateralization in the auditory cortex suggesting that the left hemisphere is optimized for temporal processing, while the right one seems to be tuned for syllabic/prosodic processing (Giraud et al., 2000; Hall et al., 2002; Hickok & Peoppel, 2000; Peoppel, 2003; Peoppel et al., 2008; Zatorre, 2003; Zatorre & Belin, 2001; Zatorre et al., 2002). Zatorre and Belin (2001), for example, not only showed left hemispheric dominance during temporal and right hemispheric dominance during spectral auditory processing, but they also suggested that hemispheric lateralization might partly originates from early basic neural processing levels dealing with the spectral and temporal features of auditory inputs. Recent evidence for this view has been derived by Okamoto et al.'s observations (2009) of different neural responses elicited by change in spectral versus temporal stimulus between the two hemispheres. To illustrate, results showed that N1m responses evoked by the spectral stimulus change were comparably larger in the right hemisphere, whereas the N1m responses evoked by the temporal stimulus change were larger in the left. Significantly, the authors concluded that hemispheric laterality of neural responses does not depend on a specific sound type but rather on spectral and temporal variances, which are differentially encoded into neural activity in the cochlea. Therefore, they strongly suggested that hemispheric lateralization for auditory processing is not only limited to sounds conveying meaning, but also is extended to non-speech signals (e.g., music)

Noteworthy, the current observation of differences in the oscillatory properties between children with poor categorical perception and controls supports the notion of hemispheric specialisation. The fact that the slow waves differentiate both dyslexic children with poor categorical perception and controls suggests differences in the lateralisation of the processing of the temporal and spectral properties of the auditory input, namely CV syllables. If we assume with Poeppel et al. (2008) that the spectral versus temporal right-left asymmetry is a consequence of the size of the temporal integration windows of the neuronal ensembles in these areas, then we would expect to see lateralised differences in the frequency of brain waves, consistent with the present observation. Given that neuronal ensembles in the left temporal cortex are associated with a 20-50 ms shorter integration, the left hemisphere cortical fields preferentially reflect temporal properties of acoustic signals such as "fast frequency changes." The right hemisphere cortex houses neuronal ensembles that occur at longer (150-300 ms) integration windows, and therefore are better suited to analyze spectral changes. The deviant hemispheric lateralisation of delta activity in dyslectic children with categorical perception suggest that the left hemisphere participates in the temporal rather than spectral processing. However, it remains to be tested if this type of hemispheric lateralisation is better suited for other tasks that rely more on the examination of the binaural spectral properties, such as the spatial localisation of sounds.

2.3.5 Conclusions

Overall, the findings of the current study point to several different physiological and functional differences between dyslexic children with poor categorical perception and controls specifically in regards to impairments of the sub-lexical phonological representation level that are related to altered laterality patterns of focal slow brain waves in temporal regions, as measured by MEG. Compared to controls, the present data showed that dyslexic children with poor categorical perception are marked by the following: (a) a deviant hemispheric specialization in the region of the temporal lobe, (b) enhanced delta activity in the left per-Sylvian regions; and c) malfunction of the left hemisphere to process temporal features of the auditory input, namely phonemes.

In conclusion, these observations strongly support the hypothesis that while the left hemisphere of the human auditory cortex of has superior temporal resolution capabilities, the right hemisphere has better syllabic resolution capabilities. Therefore, we suggest that this results in a failure to segregate speech sounds, making it more likely that dyslexic children with poor categorical percption have insufficiently developed or degraded representational maps. This subsequently results in noisier processing which then would require more time for correct recognition of phonemes and consequently words (Merzenich et al., 1993).

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3 General Discussion

3.1 Development of reading and spelling in alphabetic languages

Different writing systems have unique linguistic characteristics, and literacy acquisition is accordingly affected. While developmental theories addressing the English context showed reading as a pacemaker for both logographic and orthographic stages and spelling as a pacemaker for the alphabetic stage, these steps do not apply to other orthographies. Evidence has been provided by the German language, which is of an asymmetrical consistency, in which reading is easier than spelling. In this type of orthography, children do not need to rely on logographic strategies in their earlier stages. Instead, Wimmer and Goswami (1994) have argued that young children develop alphabetic strategies at very early stage as German has consistent GPC rules, esp., with regard to reading.

For orthography like Arabic, which is characterized by both transparent and deep orthographies, depending on its vowelization system, development of literacy acquisition is expected to be a unique process. Bearing in mind that Arabic scripts are presented in a vowelized way for beginning readers, patterns of results similar to languages with invariant GPC are, therefore, expected. In her study, Azzam (1993) pointed out that children adopt both alphabetic and orthographic strategies first for spelling, and then for reading. Additionally, she explained that spelling in Arabic is rather a complex skill, which requires the usage of orthographic strategies, if not the grammatical/semantic phase. Similarly, our cross-sectional study concluded that in the first three years of learning Arabic, children develop logographic strategies for reading, which enable them to recognize familiar words and very simple-structured pseudowords, while they adopt alphabetic and orthographic strategies first for spelling, then for reading. However, our results have indicated that in order to develop an adequate/good rate of fluent reading, children need to develop their orthographic strategies for reading. In Semitic languages, such strategies only develop when children are trained to read unvowelized scripts and integrate their phonological, semantic, orthographic, syntactic and morphological processes (Cohen-Mimran, 2009). As a result, our sample showed earlier development of adequate spelling skills compared to good fluent reading. Another possibility for this could be attributed to the phonological disparity between spoken Arabic and its written form referred to as Arabic diglossia (Saeigh-Haddad, 2003; 2004; 2005), a term which has been not disputed by linguists (for review, El-Hassan, 1979).

To sum up, development of reading and spelling in alphabetic languages manifests itself differently in different orthographies.

3.2 The Role of Visualization in the Literacy Acquisition of Semitic Languages

Due to the dominance of the phonological deficit hypothesis in the English dyslexia context, other deficits, namely, the visual one has been underestimated for many decades. Recently, predictors of literacy skills have been reported to vary according to orthographic depth. While phonological skills have been documented to be a good predictor of literacy skills across languages (e.g., Goswami, 2003), at least in the context of English, and of spelling in German (Landerl & Wimmer, 2008), RAN measures, including speed factors, have proven to strongly predict the performance of reading fluency in consistent orthographies (Landerl &Wimmer, 2008). Failure in reading non-alphabetic languages such as Chinese, which is consistent of visual-based units rather than phonemes that represent meaning (morphemes), is associated with multiple deficits, rather than with a core phonological deficit (In Vellutino, 2004).

Moreover, in Semitic languages, early stages of literacy acquisition have been thought to be more affected by visual processing than phonological processing due to the complexity of the vowelization system (Myler& Brenznitz, 1998). Our sample in study 1 showed that the male advantage of first graders in literacy skills might be related to the visuo-spatial abilities as measured by CPM. Similar to Hebrew, this suggests the requirement of visuo-spatial processing due to the complexity of the pointing system (Myler& Brenznitz, 1998). According to Abu-Rabia & Taha, 2004, young learners of Arabic, in their initial stages of acquisition, suffer from the lack of ability to manipulate GPC rules. Consequently, Arabic orthography clearly demands visual word recognition strategies to manipulate change in letter shapes in accordance with its position in a word. This might also explain why the male advantage in literacy skills, which was in first graders, diminishes in second and third graders, suggesting a decline of visual processing in advanced learners and a stronger reliance on GPC rules including the phonological decoding processing.

Taken together, evidence for a potential role of visualization and visuo-spatial abilities in literacy acquisition has been observed not only in the English context, but also in other orthographies. However, the nature of the role and its long-term effects compared to auditory/phonological abilities across developmental stages, namely in Semitic languages, has not yet been investigated sufficiently.

3.3 Associations and Dissociations between Reading and Spelling

The relationship between reading and spelling is generally considered to be very close, with good readers also being good spellers and poor readers being poor spellers. In the context of English, reading and spelling are highly correlated, irrelevant of the materials presented to children and their ages (for review, see Ehri, 1997). This has justified the assumption of shared underlying processes for both skills. Moreover, it has suggested close developmental connections between reading and spelling. Therefore, it is not surprising to refer to dyslexia in

ICD-10, (World Health organization, 2000) as a combined specific reading and spelling disorder associated with spelling deficits (F81.0). Such a view has been applied to orthographies other than English. In their recent study, Fayol et al. (2009) reported associations between reading and spelling in French-speaking fifth graders as most good readers were good spellers. Consistent with these results, we observed associations in our study 2 between fluent reading and spelling in Arabic speaking third graders. Good spellers are fluent readers, and poor spellers are slow readers. On calculating the prevalence of dyslexia, we recorded a high rate of 8, 1% of poor spellers-slow readers who are two years behind their grade level and 12% who scored below 16% in both skills.

Although the associations between reading and spelling development are strong, a considerable number of children exist with striking dissociations. As early as 1980, Byrant and Bradely showed that young children in their first year at school could read words that they could not write and, more surprisingly, write words they could not read. Furthermore, they showed that while visual strategies, known as look-and-say, are adopted for reading, phonics strategies are adopted for writing (In: Frith, 1982). According to Perfetti (1997), reading and spelling are expected to completely dissociate across developmental stages of their acquisition. Evidence for dissociations between fluent reading and spelling has been reported in German (Wimmer & Mayringer, 2003; Moll & Landerl, 2009), and in French (Fayol, 2009). While evidence for dissociations has been driven by European languages, Semitic languages have never been investigated. Our sample in study 2 has shown a number of children with isolated deficits. In Arabic context, dissociations between fluent reading and spelling are likely to emerge for three possible reasons: earlier development of spelling compared to fluent reading during the alphabetic and orthographic phase, the immature development of spelling orthographic strategies and the disparity between the spoken and literal form of Arabic, referred to as Arabic diglossia.

Taken together, both associations and dissociations between reading and spelling have been observed in different orthographies. This suggests that reading and spelling are likely to be two sides of the same coin: literacy acquisition - in the sense that they are associated and enhance each other; however, the underlying processes are not believed to be mirror images.

3.4 Slow Waves as a Marker for Maturational Lag in Dyslexia

In general, delta activity is related to development and indicates cerebral immaturity. A pattern of increased slower rhythms and few faster waves in the alpha range typically marks infancy and early childhood. This gradually reverses with age (John et al., 1980; Harmony et al., 1990; Penolazzi et al., 2008; Spironelli & Angrilli, 2009). Abnormal slow wave patterns have been consistently reported in reading-impaired children. Enhanced levels of delta and theta have been found in parieto-occipital and temporal areas (John et al., 1980), frontal and temporal areas with a predominance in the left hemisphere (Harmony et al., 1990), and in left anterior cortical sites of impaired readers (Penolazzi et al.2008). These results have been interpreted as atypical functioning in the left posterior regions of the brain (Dupuy, Clarke, Barry, McCarthy & Selikowitz, 2008) reflecting a maturational lag in brain development and as a marker of dysfunctional linguistic processing (Penolazzi et al., 2008). Enhanced slow waves in awake stages during adulthood have been related to brain lesions and are observed in neurological as well as psychiatric patients (Kolassa et al., 2007; Meinzer et al., 2004; Rockstroh, Wienbruch, Ray & Elbert, 2007), namely, dyslexia (Spironelli & Angrilli, 2009).

The major finding of study 3 is elevated delta activation localized in the left perisylvian regions in dyslexics with poor categorical perception as compared to controls. These results are consistent with a series of previous neuro-imaging studies, which have converged to suggest an atypical organization in the temporal cortex of the left-hemisphere for dyslexia, suggesting a reduced engagement of the perisylvian regions for phonological processing, altered white-matter connectivity, and functional plasticity associated with effective intervention (Gabrieli, 2009).

Previous imaging studies showed that speech processing at the initial stages produced bilateral activation; however this does not imply identically executed computations in the left and right auditory cortices. On the contrary, the present difference in oscillatory properties supports the notion of hemispheric specialization. The fact that the slow waves differentiate the groups suggests differences in the lateralization of the processing of the temporal and spectral properties of stimuli. It has been concluded from studies that the left hemisphere is optimized for temporal processing while the right one seems to be tuned for spectral processing. If we assume with Poeppel et al (2003), that the spectral versus temporal right-left asymmetry is a consequence of the size of the temporal integration windows of the neuronal ensembles in these areas, then we would expect to see lateralized differences in the frequency of brain waves, consistent with the present observation. The deviant hemispheric lateralization of delta activity in dyslectic children with poor categorical perception suggest that the left hemisphere participates in the spectral rather than temporal processing with a consequently deficient temporal segregation. While this study addresses the abnormal oscillatory responses in a subtype of dyslexia, other subtypes and the applicability of this to other orthographies are suggested to be further investigated.

3.5 Limitations of the work

There are some limitations for the three studies that ought to be mentioned here. First, for study 1, more longitudinal studies are required to further investigate the development changes of Arabic-speaking children in literacy skills across ages. The investigation of visualization has emerged as *a post-hoc* aim/hypothesis. Therefore a more systematic study with an *ad-hoc* hypothesis of the role of visual, auditory/phonological and RAN skills are suggested to be further investigated. Gender differences, which have been observed in study 1, need to be further investigated in larger samples. That is why the issue was further investigated in study 2 through a representative sample of third graders. For both study 1 and study 2, only speed measures were included: this calls for further studies addressing the relationship between both reading and spelling using accuracy and fluency measures. Moreover, the usage of both similar and different materials for reading and spelling will present a more accurate view of the associations and dissociations between reading and spelling compared to the reliance on different materials. The role of diglossia in the relationship between reading and spelling was also not taken into consideration in study 1 and 2, calling for more investigations. In study 3, we investigated the abnormal oscillatory responses of a subtype of dyslexia with poor categorical perception. It remains to be tested if the observed type of hemispheric lateralization is better suited for other tasks that rely more on the examination of the binaural spectral properties, such as the spatial localization of sounds. Finally, the current work includes two different orthographies; however, it did not offer a direct comparison of reading and spelling skills in them, calling for more cross-linguistic studies.

3.6 Open Questions and Future Directions

Some interesting questions, related to literacy acquisition both at the global level/all languages and at the Semitic languages level, have arisen from the current work. To better investigate those aspects, cross-linguistic studies of languages with different orthographic depth are inevitable. In turn, this helps that to determine processes that are general-domain and others that are specific-domain while learning to read and spell. These questions are as follows:

3.6.1 Global /All languages level

1. How does the orthographic depth of alphabetic languages influence typical and atypical development of reading and spelling?
2. What are the possible effects of diglossia on the relationship between reading and spelling in alphabetic languages?
3. What are the differential cognitive characteristics of children with isolated reading and isolated spelling deficits?
4. What are the possible relationships between dyslexia and bilingualism?

3.6.2 Semitic Languages level

1. What is the role of vowelization in the relationship between reading and spelling?
2. What is the role of visual, auditory/phonological and RAN in learning to read and spell with both vowelized and unvowelized scripts?
3. When reading and spelling associate and dissociate in Semitic languages?
4. What are the cognitive profiles of isolated reading and isolated deficits?

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Appendix

A1: A given example to illustrate how a letter form varies according to its position in a word.

م	موز	لماذا	كريم
= /m/, M	**=Bananas**	**=why**	**=generous**
No connection to letters	Connected to a following letter	Connected to a preceding and a following letter	Connected to a preceding letter

A2: A given example to illustrate how a word meaning varies according to its vowlization , known as *Homographs.*

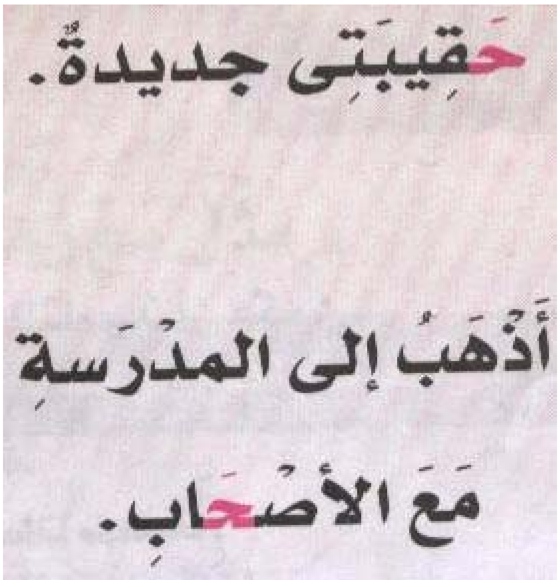
مَلَكَ	مِلْكْ	مَلِكْ
= had	**= belong to**	**= King**

A3: Extracts from (A) newspapers and (B) Text book of the first grade

قمة مبارك وبرلسكوني
تدعم علاقات مصر بإيطاليا

أكد سفير ايطاليا بالقاهرة كلاوديو باتشيفيكو ان القمة القائمة بين الرئيس حسني مبارك وسيلفيو برلسكوني رئيس وزراء ايطاليا في مايو القادم سوف تدعم علاقات التعاون بين البلدين. «التفاصيل ص٨»

(A)



حَقيبَتِي جديدةٌ.

أَذْهَبُ إلى المدْرَسَةِ

مَعَ الأصْحابِ.

(B)

These two examples show the difference between unvowelized scripts presented to advanced learners and vowelized scripts presented to beginning learners of Arabic.

A4. Examples of (A) words, (B) pseudowords, included in the first two columns of the one minute reading test.

كُرّاسَة	أَبْ	فَارْت	فِطّة
تُفّاحَة	أَنَا	مَصْرَتْ	تِمْسَاخْ
حُصَان	كَتَبَ	ذِنِكْ	شَمَكْ
سَمَكَة	فِيْلْ	غَرُوشَة	أَرْثَبْ
جَمَلْ	كلب	ثُوتْ	شَحَرَة
مَدْرَسَة	قلم	نُعْبَان	خُصَانْ
حُوتْ	قِطّة	رَهْزَة	سَزِيرْ
بُرْتُقَالْ	ذَيْلْ	وَزَفَة	شَمَاءْ

(A) (B)

A5. A given example for the spelling test and its scoring.

1- .... أمل كل تلميذ.

This sentence is presented in the sheet to be given for the child to spell out the target word to be dictated in a vowlized way using *alamaat alearaab* which represent both phonological and syntactic knowledge, which is **النجـاح** in this sentence. This word contains 6 letters/graphemes that have to be correctly spelled out. So, a child gets 6 only if he spelled all of them correctly.

ح	ا	ج	ن	ل	ا

Vowelization is sometimes misleading, esp at the end of the word, adds some confusions regarding the grapheme to be written. Some phonemes like ل are sometimes silent while dictated, based on context-however, while should be spelled out in the same word.

A6. Abstract for the poster presented at XI IASCL (2008) & ICP (2008)

Atypical lateralization in auditory regions of dyslexic children: Is there a reduced right hemispheric contribution to temporal integration and segmentation?

Wessam Mohamed, Isabella Paul, Christian Wienbruch, Thomas Elbert

Developmental dyslexia is associated with problems in auditory perception and processing of speech sounds. In particular, it has been suggested that degraded auditory representations may give rise to deficits in temporal processing and – as we suggest here – to deficits in temporal integration. For speech perception, the segmentation of the auditory stream into discrete representations is prerequisite. This will produce neural activity with corresponding frequency content, i.e. with wave lengths in the range of several hundred milliseconds. Consequently, we mapped focal slow waves in both the delta (1.5-4Hz) and theta (4-8 HZ) frequency band, using a magnetoencephalographic (MEG-based) source imaging in a sample of 48 dyslexic and 20 normal readers (aged 8.2 -11.4), while processing phonemes presented in a passive auditory odd-ball paradigm. A group difference in hemispheric asymmetry in the density of magnetic slow waves appeared in the perisylvian regions,

whereby dyslexic children showed less delta activity in the right hemisphere as compared to controls. Our results add to a substantial literature of deviant hemispheric asymmetry in dyslexic children but unprecedentedly suggest impaired right hemispheric contribution to the segmentation process of speech sounds in dyslexia.

A7. Abstract for the talk presented in ASHA international Convention

Epidemiological findings of reading and spelling deficits in Arabic children

WESSAM MOHAMED and THOMAS ELBERT

Clinical Psychology, University of Konstanz, Konstanz, Germany

Abstract (max.75 words)

A relation between reading and spelling disabilities has been reported for European orthographies but has not been tested for Arabic with its different writing system. We verified the usefulness of a test battery that was then applied in a representative sample of 1106 Arabic speaking third graders. The prevalence of specific reading disabilities reached a sizeable 16%. A frequent dissociation (in ¼ of the disabled children) between reading and spelling question a unifying hypothesis for dyslexia.

Summary (max.1000 words)

Specific language disabilities are a common problem in elementary schools and some 5 to 10% of school-age children present with developmental dyslexia in English speaking countries. Reading English maybe harder to learn than reading other European orthographies (Seymour, Aro, & Erskine, 2003) but so far, results indicate that similarities between dyslexic readers using different orthographies are far bigger than their differences (Ziegler et al., 2003). However, about two thirds of the studies on dyslexia come from English-speaking countries and only very few investigations have studied forms of dyslexia in non-European languages. For a not necessarily representative sample of Arabic speaking children Elbeheri and Farrag (1988) estimated that the prevalence of specific reading disability in second and third graders to be only 3%. When children were reassessed three years later, the rate had dropped to only 1%. To our knowledge, it has not been attempted previously to assess the prevalence of both reading and spelling deficits for Arabic in a larger and representative sample. Reading and spelling processes may be linked during development as they both require phonological abilities and rely on the same neural representation of a lexicon. Empirical evidence shows that correlations between reading and spelling are high ranging from .77 to .86 in English-speaking countries.

In study I, we investigated if reading and spelling abilities are linked in the first three years of the elementary school in an Arabic language environment. The ability to detect grapheme-to-phoneme correspondence and to rapidly name words and pseudo words were assesed in a group of 111 children recruited from the first three grades in an Egyptian elementary school (1^{st} =34, 2^{nd} =30,3^{rd} =47). Results showed significant positive coefficients of reading and spelling measures ranging from .63-.75, with a drop of these correlations across the three grades.

In a second study, a representative sample of 1106 Arabic speaking children (52% boys) in the third grade of elementary schools located in lower Egypt were tested for their reading and spelling abilities. The age ranged from 7-9 years with an average of 8.2 ± .57 years. Third graders were chosen, as in the Egyptian educational system, the third grade is of particular relevance for assessing and assisting children with reading deficits. 132 children (11.9%), all with IQ 85 or above and without any evidence for neurological, sensory, or motor impairment were classified as poor readers/poor spellers. In addition, 1.9% of the total sample was classified as good spellers/poor readers, while 1.8 % was classified as poor readers/good spellers. Grapheme-to-phoneme correspondence correlated positively with rapid naming of words (r=.66), and rapid naming of pseudo words (r=.62).

The estimate prevalence rate of 12%-16% is surprisingly high for Arabic and calls for specific attention to this problem in Arabic speaking countries. The scarce previous findings addressed limited aspects of reading disability only, and did not test spelling problems. Semitic writing systems markedly differ from other alphabetic writing systems and therefore spelling disabilities may also be different. In addition, the presently observed dissociation between reading and spelling deficits has not been reported before for the Arabic Language and calls into question that the phonological deficit hypothesis can equally well explain all forms of dyslexia.

A8 Abstract for the talk presented at the 47th annual international conference of LDA, Baltimore.

A Dissociation of Reading and Spelling deficits in Early Childhood: Epidemiological Findings of Arabic speaking children.

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Introduction

The start of formal education is a crucial period for the acquisition of literacy. From the pedagogical point of view, it is significant to know more about the development of reading and spelling during this phase (Leppänen, Niemi, Aunola & Nurmi, 2006). Only recently, word reading fluency has moved from being a neglected aspect of reading to being a popular topic in the field of reading research (Landerl & Wimmer, 2008).

Specific language disabilities are a common problem in elementary schools and some 5 to 10% of school-age children present with developmental dyslexia in English speaking countries. Reading English maybe harder to learn than reading other European orthographies (Seymour, Aro, & Erskine, 2003) but so far, results indicate that similarities between dyslexic readers using different orthographies are far bigger than their differences (Ziegler et al., 2003). However, about two thirds of the studies on dyslexia come from English-speaking countries and only very few investigations have studied forms of dyslexia in non-European languages.

Therefore, we wanted to explore the developmental course of fluent reading and spelling during the first three years of learning Arabic. More precisely, we tried to examine which ability is given priority. How are reading and spelling related? Moreover, to our knowledge, it has not been attempted previously to assess the prevalence of both reading and spelling deficits for Arabic in a larger and representative sample. For Taouk & Coltheart (2004) literacy acquisition is highly likely to be dependent upon the nature of the writing system which the child seeks to master. Hence, the special nature of Arabic orthography should be considered carefully in any discussion of a comprehensive theory of how children learn to read and spell.

Methods

In study I, we validated literacy measures to investigate if fluent reading and spelling abilities are linked in the first three years of the elementary school in an Arabic language environment. The ability to detect grapheme-to-phoneme correspondence and to rapidly name words and pseudo words were assessed in a group of 111 children recruited from the first three grades in an Egyptian elementary school (1st =34, 2nd =30,3rd =47).

In a second study, a representative sample of 1106 Arabic speaking children (52% boys) in the third grade of elementary schools located in Upper Egypt were tested for their non-verbal IQ, fluent reading and their spelling abilities. The age ranged from 7-9 years with an average of 8.2 ± .57 years. Third graders were chosen, as in the Egyptian educational system, the third grade is of particular relevance for assessing and assisting children with reading deficits.

Results& Discussions

Our results showed an expected increase of all psychometric measure scores with the age/grade level of school. Overall, this adds to the validity of the literacy measures developed in this study. Positive correlations between reading and spelling in Arabic ranged from .88 to .92 for the whole cohort. Scattering the developmental data showed that adequate spelling develops earlier than good fluent reading in the early childhood stage of Arabic speaking children. This implies that spelling is the pacemaker for both the alphabetic and orthographic stages in the Arabic Language (Azzam, 1993). To calculate the incidence of children who suffer specific language impairments in both reading and spelling, we depended on the " 2 years –behind grade level as a cut off score. To calculate the prevalence of the dissociation between reading and spelling , children with reading and/or spelling disorders in third graders as well as to investigate the possible dissociation between the two literacy skills, we applied the same criteria used in previous studies (Moll& Landerl, 2009).As a result , we got a prevalence of 8.2% for children who could be labeled as severely impaired dyslexics in both reading and spelling skills. Overall prevalence of the four groups, good readers-good spellers, good readers-poor spellers, poor spellers-good readers, poor readers-poor spellers, was 82.3%, 1.3%, 1.1% and 15%, respectively. The estimate prevalence rate of 8%-17% is surprisingly high for Arabic and calls for specific attention to this problem in Arabic speaking countries. The scarce previous findings addressed limited aspects of reading disability only, and did not test spelling problems. Semitic writing systems markedly differ from other alphabetic writing systems and therefore spelling disabilities may also be different.

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