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Editorial Comment

Angela J Fawcett

It is a very great pleasure to introduce the second issue of the Asia Pacific Journal of Developmental Differences. I am once again proud of the depth and breadth of material we are able to contribute, including experimental studies, reviews of the area, case studies and meta-analyses. It is particularly important to acknowledge the diversity of research in dyslexia and other learning differences, in terms of both theory and practice. A journal such as APJDD which targets areas across the Asia Pacific where access to local materials may be limited, has a responsibility to introduce experts from across the world, and to provide an opportunity for young researchers to make their mark, as well as providing a forum for local expertise in these areas. I am proud that we are able to fulfill our mission once again to present a series of peer reviewed articles that form a contribution to the literature. We have been able to maintain our standards and meet our publication deadlines in a manner appropriate for a well-rated international journal

In this issue I am particularly proud to present an authoritative review from Professor Joe Torgesen and colleagues from the USA on the importance and value of early intervention. This is an area of research very dear to my heart, through many years experience working with children in the early school years. The evidence from Torgesen on the impact of intervention at an early age has been seminal in the move towards universal early screening and support which I have been advocating since the publication of our early screening test, the DEST, in 1996. It is clear that even a short-term intervention at this age can have lasting effects, on the principle 'a stitch in time saves nine'. In recognition of the importance of this topic, we plan to draw together a series of articles over the next few issues of APJDD in conjunction with further evidence in to an Asia Pacific Handbook of Early Intervention, to be published in 2015. We would like to encourage researchers with material pertinent to this issue to submit their work for review.

Our 2nd article in the current issue is drawn from Priscillia Shen and her colleagues at the Dyslexia Association of Singapore, who have undertaken a rigorous analysis of deficits in children learning Chinese. Their article identifies a distinctive profile of deficits in visual-orthographic, morphological awareness and visual-motor integration in students with dyslexia, in comparison with non-dyslexic controls. In an example of good practice the team use their theoretical insights to create an intervention targeted towards these deficits, and evaluate the programme with a second small group of dyslexic children. Moreover, the children involved in this study are learning Chinese in addition to their main language of English, and many are not able to practice their skills at home. There is clear evidence for success in improving skills overall, although the children continue to struggle suggesting that many will need further more intensive support. It is excellent to note that parents and children alike enjoyed the programme, and there is clear evidence for improvement from the outcomes achieved. This is an important article because the research in this area is more constrained than research into English speaking children, and the results are a resounding endorsement of the approach adopted.

Much of the research into children with dyslexia has focused on decoding, but of course the goal of decoding is to be able to read and understand the material the child is accessing. Sadegi from the Islamic Azad University and colleagues form the University of Canterbury, address the important issue of comprehension, directing their research towards an experimental analysis of reading comprehension in the Persian language.. The results of this study indicate that there are two groups of children who struggle with comprehension. Firstly there are those with problems in decoding, who show evidence of phonological difficulties. Secondly, there seems to be a further group of children who are accurate decoders but who show evidence of problems with morphology. For both of these groups performance remains slow and laboured, which in itself impacts on comprehension through deficits in working memory. This article is clearly an important contribution to the field.

In the current context, the role of computers in improving literacy is particularly important. Our own research indicates that for many children with difficulties, computer based support has many advantages in terms of the child's self esteem. Even the most supportive teacher may become irritated after many attempts to read have failed, but the computer remains unmoved and uncritical. In this article, Dr Thomas Sim from the Dyslexia Association of Singapore, presents a meta-analysis of effect sizes for computer-based intervention studies, with the main criteria that the intervention includes phonology in a pre-post design with full data available for comparison. The four studies identified provide evidence for a medium effect size which suggests that computer based intervention can be a useful tool in supporting children with difficulties. This is an important area for further research, and implications for practice are considered here.

One of the major theoretical contributions of recent years has been the recognition that naming speed may be a factor in deficits arising in dyslexia, with those children who experience both phonology and speed deficits the most difficult to remediate. This is based on the research of Professor Maryanne Wolf and her colleague Professor Pat Bowers. Naming speed is an interesting test, because it involves eye movements, keeping your place on the page, and retrieving names from your lexicon, while maintaining your speed of articulation. It has been called a compendium test with the ability to identify a range of different problems, particularly when there are difficulties in object naming. However, it is clear that this knowledge has not yet been widely disseminated across the Asia Pacific region. Therefore a review of the area provides a useful adjunct to our understanding of deficits in dyslexia, in this article by Dr Kadi Lukanenok from Taillin University.

It is important to recognise the many manifestations of dyslexia in different subtypes of dyslexia, while not denying the importance of the overarching phonological deficit. In the next article by Jost from the Czech Republic, the progress of a young child in developing literacy is followed, with a case study of the predictive value of eye movements, amongst other tests for learning differences. Over a five year period, a group of around 100 children were tested on eye movements, IQ, reading, motor skills, attention and self-esteem. The case study from this child provides some support for the use of eye movements as a possible prognostic indicator for dyslexia and other learning differences.

Finally, the last article in this issue by Hani Zohra Muhamad from the Dyslexia Association of Singapore, addresses the issues of co-morbidity and dyslexia. It is very clear that the child described here is hard to reach or teach because of the attention deficit hyperactivity problems concurrent with his dyslexia. In a sensitive analysis, flexibility is shown in addressing the issues arising from handling this complex child. We now know that co-morbidity between dyslexia, specific language impairment (SLI), dyspraxia and ADHD are the rule and not the exception. It is therefore particularly germane that we should identify approaches that allow this complexity to be addressed. This is a clear success story that is worthy of reporting in this journal, as an example of good practice for those struggling with similar cases.

In conclusion, the APJDD welcomes the submission of further articles in the field of developmental differences. The journal continues to be available freely and we hope to provide a dedicated website shortly, as well as the facility to preview articles which have been accepted for publication.

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Dyslexia: A Brief for Educators and Parents

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Purpose:

Dyslexia is a term that has been applied since the early part of the 20th Century to many students with reading difficulties. The term comes from medicine, but its broadest application is within education. Many educators, however, remain confused about the term in spite of the fact that major advances in our understanding of dyslexia have been made through scientific research over the past 40 years. The purpose of this paper is to briefly describe what is currently known about dyslexia, focusing particularly on methods of early identification, prevention, and remedial instruction.

What is Dyslexia?

The most widely accepted current definition of dyslexia is the following:

> *Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.*

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This definition is the one used by the National Institutes of Child Health and Human Development which has sponsored the majority of recent research on dyslexia, and it was also adopted by the Board of the International Dyslexia Association in 2002. The individual elements of this definition will be discussed in turn.

Dyslexia is a specific learning disability that is neurological in origin.

Dyslexia is a term used to refer to a specific type of learning disability. It is important to acknowledge that students may struggle in learning to read for many reasons, including lack of motivation and interest, weak preparation from the pre-school home environment, weak English language skills, or low general intellectual ability (Snow, Burns, & Griffin, 1998).

In fact, the family and socio-cultural conditions associated with poverty actually contribute to a broader and more pervasive array of reading difficulties in school-aged children than do the neuro-biological conditions associated with dyslexia. Students with dyslexia represent a *subgroup* of all the students in school who experience difficulties learning to read.

The primary evidence that students with dyslexia have a problem that is inherent, and not the sole result of poor teaching or lack of experience, comes from twin studies showing that dyslexia is substantially heritable (Olson & Gayan, 2001), and from brain imagery studies showing differences in the way the brains of dyslexic students function (Shaywitz, 2003).

It is characterized by difficulties with accurate and / or fluent word recognition and by poor spelling and decoding abilities.

Although students with dyslexia can show a variety of subtle or not-so-subtle language problems prior to entry in school (Catts & Kahmi, 2005), their problems become very noticeable once they begin learning to read. They have extreme difficulties acquiring accurate and fluent phonemic decoding skills (phonics), and this interferes with their ability to read text accurately or to read independently.

Dyslexic students struggle to acquire both knowledge of letter-sound correspondences and skill in using this knowledge to "decode" unfamiliar words in text. In first grade, their difficulties with accurate word identification quickly begin to interfere with the development of text reading fluency. Difficulties decoding unfamiliar words in text interfere with the development of fluency because, to become a fluent reader in the primary grades, students must learn to recognize large numbers of words automatically, or at a single glance.

Students learn to recognize individual words "by sight" only after they accurately read them several times (Ehri, 2002). Thus, the initial difficulties that students with dyslexia have in becoming accurate and independent readers interfere with the development of their "sight word vocabularies," and they quickly fall behind their peers in the development of reading fluency.

These difficulties typically result from a deficit in the phonological component of language that is often unexpected in *relation to other cognitive abilities and the provision of effective classroom instruction.*

The discovery that students with dyslexia experience difficulties processing the phonological features of language (Liberman, Shankweiler, & Liberman, 1989) was important in establishing the foundations of the current scientific understanding of dyslexia. The phonological processing problems of students with dyslexia are usually not severe enough to interfere with the acquisition of speech, but they sometimes produce delays in language development, and they significantly interfere with the development of phonemic awareness and phonics skills for reading.

Spoken words are composed of strings of phonemes, with a phoneme being the smallest unit of sound in a word that makes a difference to its meaning. Thus, the word *cat* has three phonemes, /c/-/a/-/t/. If the first phoneme is changed to /b/, it makes the word *bat*, or if the second phoneme is changed to /i/, it makes the word *bit*.

When students first begin to learn to read, they must become aware of these individual bits of sound within syllables so they can learn how our writing system represents words in print. The letters in printed words correspond roughly to the phonemes in spoken words. Once a child understands this fact, and begins to learn some of the more common letter/sound correspondences, he/she becomes able to "sound out" simple unfamiliar words in print. Skill in using phonemic analysis to identify words that have not been seen before in print (and beginning readers encounter these words in their reading almost every day) is one of the foundational skills required in learning to read text independently (Share & Stanovich, 1995). Because of their phonological processing difficulties, students with dyslexia experience difficulties acquiring phonemic awareness, which is followed by the difficulties learning letter sounds and phonemic decoding skills that have already been described.

Phonological processing skills are only moderately correlated with general intelligence, so it is possible to have average, or above average general intellectual ability and still experience the kind of reading difficulties observed in students with dyslexia. A student can also have below average general intellectual skills and have the same kind of phonological processing disabilities.

Dyslexia is *not caused* by low general intellectual ability, but rather by special difficulties processing the phonological features of language, that can co-exist with above average, average, or below average general intellectual ability. This is one reason why previously used "discrepancy formulas" for the identification of students with learning disabilities were unfair to many students.

Children who had both low general intellectual ability and phonological processing difficulties were routinely denied learning disability services, even though their reading problem was not caused by low general ability, but rather by the type of phonological processing problems identified as the core cause of dyslexia (Fletcher, Denton, & Francis, 2005).

It is important to note here that science has shown it is incorrect to think of dyslexia as an "all or none" phenomena. That is, the phonological processing abilities required for acquisition of early reading skills are normally distributed in the population, just like musical talent, athletic ability, or most other human abilities. It is possible to have extremely weak phonological processing skills, or to be only mildly impaired in this area. It is also possible to have above average skills in the phonological domain. If students have extreme phonological processing weaknesses, it is very, very difficult for them to acquire early reading skills, while students with mild difficulties in this area often require only a moderate amount of extra instruction to become good readers (Wagner & Torgesen, 1987).

Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge.

One of the most serious consequences of early difficulties becoming an accurate, confident, fluent, and independent reader is that it affects the amount of reading that students do. For example, a study done a few years ago indicated that students reading at the 50th percentile (average) in 5th grade read about 600,000 words in and out of school during the school year. In contrast, students reading at the 10th percentile read about 50,000 words during the same period of time (Anderson, Wilson, & Fielding, 1988). Large differences in reading practice emerge as early as the beginning of first grade (Allington, 1984).

In addition to directly affecting the development of reading fluency, these practice differences have a significant impact on the development of other cognitive skills and knowledge, such as vocabulary, reading comprehension strategies, and conceptual knowledge (Cunningham & Stanovich, 1998). This latter type of knowledge and skill, in turn, is important for comprehension of texts in upper elementary, middle, and high school (Rand, 2002).

Of course, other "secondary consequences" to the child's self-esteem and interest in school can be just as important as the effect on intellectual skills in determining ultimate school success.

How can students with dyslexia be identified in school?

Children likely to have difficulties learning to read can be identified as early as preschool or kindergarten, but it is frequently not possible to differentiate in preschool or kindergarten between students who have dyslexia, and students who are at risk for reading problems for other reasons. For example, the clearest indicators of dyslexia in kindergarten are difficulties acquiring phonemic awareness, learning letter/sound correspondences, and learning to decode print using phonemic decoding strategies (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001).

Unfortunately, many poor children, or those with limited exposure to Standard English in their homes, also manifest these same types of difficulties in kindergarten.

An accurate diagnosis of dyslexia in preschool or kindergarten is more likely when these problems occur in students who:

1. have strong abilities in other areas of language such as vocabulary;

2. come from homes that provide a language and print rich pre-school environment; and,

3. have a first or second-degree relative who experienced severe early reading difficulties. However, inherent phonological processing difficulties can also occur in poor children who come to school with limited vocabularies and knowledge of print. Although the phonological weaknesses of these students are most likely the result of lack of certain kinds of language experience in the home, they may also be the result of biologically based, inherent phonological processing weaknesses.

One group of researchers (Vellutino et al., 1996) has argued that because early reading difficulties can result from both inherent weaknesses in phonological processing ability and from poor instruction or lack of prior print/language experience, response to high-quality, intensive reading instruction may be the best way to identify students with inherent cognitive limitations. Theoretically at least, students who lag behind in the development of early reading skills because of a lack of appropriate experience in the pre-school environment should respond rapidly to high-quality, intensive interventions.

In contrast, students with severe and inherent phonological processing weaknesses should respond more slowly if at all. Although response to this type of intervention would not identify as dyslexic a student whose inherent phonological difficulties were mild (because these students should respond well to explicit and intensive instruction), it will certainly identify students with the *most serious* reading difficulties, whether they be caused by inherent phonological weaknesses or by other factors.

If students are still struggling to master early reading skills by the end of kindergarten, even though they have had exposure to relatively intensive interventions, then they should be provided with additional intensive intervention in first grade (or longer) until they are able to master all reading skills appropriate to their grade level. This, of course, is true for all children, regardless of the exact cause of their reading difficulties.

To summarize, we currently understand how to identify students at risk for reading failure with a relatively high degree of accuracy as early as preschool or kindergarten. Reliable tests of phonemic awareness, letter/sound knowledge, or phonemic decoding will show these students to be substantially behind their peers, unless they have already received powerful instructional interventions.

At present, however, we have neither the equipment nor the scientific knowledge to use brain imaging as a way of diagnosing dyslexia in young children, particularly if the goal is to differentiate them from other students who are struggling in learning to read for different reasons.

In first grade, reliable tests of phonemic awareness, phonemic decoding, and text reading accuracy and fluency will also identify these students accurately. In later grades, dyslexic students who have not received powerful interventions may still remain relatively impaired in phonemic awareness, and will always perform poorly on tests of phonemic decoding, text reading fluency, and spelling. In late elementary, middle, and high school, the reading comprehension performance of these students is likely to be below average (in spite of intellectual abilities that are frequently average or above average), but their reading comprehension performance is usually not quite as low as their word-level reading scores. Particularly in cases where these students have average or above average general intellectual skills, they can often compensate for their poor ability to read the words on a page by "filling in the gaps" through reasoning and use of their background knowledge.

We currently have no scientific evidence that effective prevention of reading difficulties in students with dyslexia depends on accurate differential diagnosis of the disorder in kindergarten or first grade. What is critical is that difficulties learning to read are identified as early as possible, and that intensive and well-targeted interventions be provided to students who are lagging behind, no matter what the cause. This approach to early assessment and intervention is exemplified in the "response to intervention" (RTI) approach which is currently being proposed as a replacement for discrepancy models as a method of identifying students with learning disabilities (Burns, Jimerson, & VanDerHayden, 2007; Fletcher, Lyon, Fuchs, & Barnes, 2006).

The RTI approach is both a method that can be used to diagnose learning disabilities (dyslexia included), and a way of organizing early instruction in reading. When used as a diagnostic approach, it assigns the diagnosis of disabilities like dyslexia to students who show continued inability to acquire grade appropriate reading skills in spite of high quality initial instruction and appropriately intensive intervention support.

The major weakness of the RTI approach (which is also true of discrepancy approaches) to diagnosis is that the number of students who will be diagnosed as having "dyslexia", or "learning disabilities", depends directly on the quality and intensity of instruction students receive. If schools provide only weak initial instruction and minimal interventions, then a large number of students will end up in third grade (or any grade) as poor readers who could be diagnosed as having "dyslexia" because of their failure to respond to weak instruction.

However, if schools provide consistently strong initial instruction along with sufficient amounts of high-quality, well-targeted, and intensive interventions, then relatively few students will end up being diagnosed as having dyslexia because of continued poor reading skills.

The model for instruction prescribed by the RTI approach involves three elements:

1. Classroom teachers that provide high quality initial instruction along with small group instruction that is differentiated according to student needs. Classroom teachers are encouraged to differentiate instruction in multiple ways (time, group size, focus of instruction, lesson structure) in order to more effectively meet the needs of all students in their classroom.

2. Reliable screening and progress monitoring tests to identify students falling behind in reading growth. Any system that provides reliable assessment of emerging reading skills several times a year would identify all students with dyslexia in the system as well as other students who are struggling in reading for different reasons.

3. Interventions for struggling readers that are sufficiently powerful to accelerate their reading development toward grade level standards. Sometimes these interventions are provided by classroom teachers, sometimes by reading specialists (including special educators), and sometimes by paraprofessional tutors. Data from ongoing progress monitoring of student growth is used to guide adjustments to interventions so that all students receive instruction that effectively accelerates their reading growth. In many schools, the classroom teacher, by herself, will not be able to provide sufficiently intensive interventions to meet the needs of all her students, so a school level system for allocating intervention resources will be required (Torgesen, 2006).

The most important point of this section is that we can, using tests currently available, accurately identify students who are likely to struggle with reading starting in preschool or kindergarten.

What these tests cannot do this early is to differentiate students with dyslexia from other students who will struggle in learning to read for reasons other than dyslexia. The goal of every school should be to provide interventions for all struggling readers that are sufficiently powerful to bring their reading skills up to grade level standards. If this is accomplished for all struggling readers, then it will automatically be accomplished for all students with dyslexia.

What type of instruction is most effective for students with dyslexia?

Prevention of reading difficulties in students with dyslexia requires both effective classroom instruction during the regular "reading block" and powerful intervention support for children with the most severe phonological processing difficulties (Foorman & Torgesen, 2001). From their classroom teacher, children with dyslexia need engaging, systematic, and explicit instruction in all the critical components of literacy development (i.e. phonemic awareness and phonics, fluency, comprehension, vocabulary, spelling, and writing), and they will also need extra support during the time when small group instruction is differentiated based on student needs.

If classroom teachers are not skilled in providing this type of instruction, many schools will simply have too many students requiring extra interventions, and school resources will be overwhelmed. Another way of saying this is that regular classroom teachers should be able to meet the instructional needs of many students with dyslexia who are only *mildly impaired* in phonological processing. If their instruction is not strong enough to meet the needs of mildly impaired students, those with more severe processing difficulties may not be able to receive the much more intensive instruction they require (Foorman, Breier, & Fletcher, 2003).

At this point, it is useful to remember that children with dyslexia are only *one subgroup* of all the students in a school that that may be at risk for reading failure. Many students with dyslexia come to school with well developed vocabularies, strong reasoning and thinking skills, and excellent language comprehension abilities. The most efficient approach for these students will usually be to provide intervention support focused on their areas of primary difficulty which would typically be phonemic awareness, phonemic decoding, and text reading accuracy and fluency. Of course, like all other students, children with dyslexia need instruction in vocabulary and reading comprehension strategies, but the instruction they receive from their regular classroom teachers in these areas will typically be sufficient.
In many schools, there will be another large group of students "at risk" for reading difficulties. These children come largely from families of lower socio-economic or minority status, or they are English Language Learners, and they enter school significantly delayed in a much broader range of pre-reading skills (Whitehurst & Lonigan, 1998; Hart & Risley, 1995). These children have weaknesses in both the broad oral language knowledge that supports reading comprehension and in the phonological and print-related knowledge required in learning to read words.

Classroom instruction that explicitly teaches how letters and sounds relate with ample opportunities to practice these relations by reading text are important for such children (Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998), as well as outreach to parents to build language and literacy experiences in the home (Foorman, Anthony, Seals, & Mouzaki, 2002). Although it is theoretically possible for a child to enter school weak in vocabulary and conceptual knowledge, but strong in the phonological skills and knowledge required in learning to read words, these children are, in fact, quite rare. This pattern of abilities is not commonly observed because the same pre-school environmental conditions that are associated with limited vocabulary growth also have a negative impact on the growth of print-related knowledge and skills like phonemic awareness and letter knowledge.

Children with general oral language

weaknesses plus phonological weaknesses will require interventions in a broader range of knowledge and skill than those who come to school impaired only in phonological ability. However, because both groups have weaknesses in the phonological and print-related domain, *both kinds of children* will require special support in the growth of early word reading skills if they are to get off to a strong start in learning to read. As was mentioned earlier in the section on identification of students with dyslexia, the screening, progress monitoring, and diagnostic tests used with young children should be able to help target interventions on areas of greatest need in all students requiring special reading interventions. The same, is true, of course, for older students with dyslexia who continue to have reading difficulties.

The primary differences between instruction appropriate for all children in the classroom and that required by children with relatively severe dyslexia are related to the manner in which instruction is provided. Specifically, instruction for children with severe dyslexia must be more *explicit and comprehensive*, more *intensive*, and more *supportive* than the instruction provided to the majority of children. Interventions provided to students with dyslexia should also be targeted on the specific types of skill and knowledge that are interfering with their reading growth.

Explicit instruction is direct, systematic, and leaves nothing to chance. Most of the knowledge that is acquired in the process of *typical* reading development is discovered by the child during interactions with print. As children read, they notice useful generalizations about print-sound relationships, and they also learn to recognize many words "by sight" which is the first step toward fluent reading (Share & Stanovich, 1995).

However, because of their weaknesses in the area of phonological processing (specifically their delayed development of phonemic awareness), children with dyslexia require explicit and systematic instruction to help them acquire the knowledge and strategies necessary for decoding print. As Gaskins, Ehri, Cress, O'Hara, and Donnelly (1997) have pointed out, "First graders who are at risk for failure in learning to read do not discover what teachers leave unsaid about the complexities of word learning. As a result, it is important to teach them procedures for learning words" (p. 325).

Not only do children with dyslexia require more explicit instruction (meaning that more things must be directly taught), they also acquire skills and knowledge in the phonological domain more slowly than average students. Both of these teaching/learning challenges make it necessary to provide students with dyslexia much more *intensive instruction* than other students in order to maintain normal growth patterns in reading. The most practical method for increasing instructional intensity for highly at-risk students is to provide small group instruction both during, and in addition to, the instruction the students receive during the reading block. Although there are many different ways to organize this instruction (Greenwood, 1996; Fuchs, Fuchs, Mathes, & Simmons, 1997; Torgesen, Houston, Rissman, & Kosanovich, 2007), there can be no question that children with dyslexia will learn more rapidly under conditions of greater instructional intensity than they will in typical classroom settings.

Effective early interventions, as well as remedial instruction that is powerful enough to accelerate students' rate of reading growth, almost always involve extra small group or 1:1 instruction for periods of time varying from 20 minute a day to 90 minutes a day, four or five days a week (Elbaum, Vaughn, Hughes, & Moody, 1999, Scamacca, et al., 2007, Torgesen, 2005). To provide effective preventive or remedial instruction for students with severe dyslexia, schools need to develop the capacity to provide substantial amounts of skillful and targeted small group instruction to these students for as long as it takes to help them acquire grade level reading skills.

The last characteristic of effective instruction for students with dyslexia that differentiates it from instruction sufficient for most children is that it must be more supportive, both emotionally and cognitively. Because acquiring the basic skills required for accurate and fluent reading is so difficult for children with dyslexia, their need for more positive emotional support in the form of encouragement, feedback, and positive reinforcement is widely understood. However, their potential need for more cognitive support, in the form of carefully "scaffolded" instruction, is less widely appreciated. Instruction for at risk or children with reading disabilities typically involves two types of scaffolding.

One type of scaffolding involves careful sequencing so that skills build very gradually—children are always systematically taught and practiced on the skills required for any task they are asked to do (Swanson, 1999). Another type of scaffolding involves finely tuned interactions between teacher and child that support the child in accomplishing a task that he/she could not do without the teacher's help (Stone, 1989). The dialogue between teacher and student leads the child to discover what kind of processing, or thinking, needs to be done in order to complete the task successfully. The point of this type of instructional interaction is that the child is led to discover the information or strategies that are critical to accomplishing the task, rather than simply being told what to do. As Juel suggested (1996), the ability to offer scaffolded support while children are acquiring reading skills may have increasing importance as the severity of the child's disability increases.

Can reading difficulties in dyslexic students be prevented?

The best answer to this question from current research is that serious reading difficulties can be prevented in most students with dyslexia if the right kind of instruction is provided with sufficient intensity early in development. For example, in one study conducted in Florida several years ago (Torgesen, et al., 1999), the 12 percent of students most at-risk for reading difficulties were identified in kindergarten based on their performance on measures of letter knowledge and phonemic awareness. Students received 1:1 intervention in reading for 20 minutes a day, four days a week, starting in the second semester of kindergarten and extending through the end of second grade. However, by today's standards, these students' regular classroom teachers did not provide systematic and explicit instruction in phonemic awareness and phonics during the regular reading block.

At the conclusion of instruction, children in the strongest instructional condition performed in the average range on measures of phonemic decoding (average score = 48th percentile) and reading accuracy (average score = 45th percentile). However, there was substantial variability in response to the instruction, and 30% of the group scored below the 30th percentile in phonemic decoding at the end of the study. The corresponding figure for reading accuracy was 39 percent.

Since the children in this study were selected to be the 12% most at risk for reading failure, the authors estimated that, if the strongest condition from this study were available to all students who needed it, approximately 4% of all children would remain weak in phonemic decoding ability and 5% would perform below the 30th percentile in sight word reading at the end of second grade.

In a follow-up study conducted by the same research team (Torgesen, Rashotte, Wagner, & Herron, 2001), students who were the 18% most at risk for reading failure at the beginning of first grade (based on performance on letter knowledge and phonemic awareness) were provided with small group (3 students) reading instruction for 50 minutes a day, four days a week, from October through May. This study was conducted only in schools in which the classroom teachers provided systematic and explicit instruction in phonics (also vocabulary, fluency, and comprehension) during the regular reading block, and the interventions were offered in addition to that instruction.

At the end of first grade, students in the strongest instructional condition scored at the 74th percentile on a measure of phonemic decoding (they had scored at the 4th percentile at the beginning of the year) and at the 67th percentile on a measure of reading accuracy. The percent of children obtaining scores below the 30th percentile on these measures was 12% (phonemic decoding) and 10% (reading accuracy). Using calculations similar to those applied to the previous study, the authors estimated that, if interventions and classroom instruction as strong as those provided in this study were available for all students who needed them, only 2% of students would remain seriously impaired in phonemic decoding and reading accuracy at the end of first grade.

Other recent intervention studies tell a roughly similar story. If strong interventions are provided to "at risk" students as early as kindergarten and first grade, the overall percentage of students who continue to struggle with basic reading skills can be reduced to under 5% (Mathes et al., 2005; Scammacca, et al., 2007; Torgesen, 2002). Of course, becoming a proficient reader by the end of third grade involves much more than learning to read words accurately and fluently. The ultimate goal of reading instruction is to enable students to comprehend the meaning of what they read. However, the examples provided in this section are relevant to a discussion of the prevention of serious reading problems in students with dyslexia because the "core difficulty" these students face involves learning to read text accurately and fluently.

These examples demonstrate that, if sufficiently powerful interventions are available, it is possible to maintain the word level reading skills of most students with dyslexia at roughly average levels during the early primary grades.

As another example of what can be accomplished in preventing reading difficulties with powerful instruction provided in the early primary grades, the experience of schools in the Kennewick, Washington, school district is instructive (Fielding, Kerr, & Rosier, 2007). In 1995, the 13 elementary schools in this district were challenged to have 90% of their students reading at grade level (as assessed by a good measure of reading comprehension) within three years. In the year prior to the initiative, the percent of students in 3rd grade reading at grade level was 48% in the district, and within 9 years, 9 of the 13 schools had accomplished the 90% goal. One of the stronger schools (Washington Elementary) accomplished the goal in 5 years, and in 2006, 98% of students at Washington were reading at grade level at the end of third grade. Washington had to make radical changes in the way they organized and delivered reading instruction in K-3 in order to accomplish this goal. They teach reading to all students in an uninterrupted two-hour block, and some students in first and second grade receive an additional 60 to 90 minutes of small group intervention in addition.

They accomplished part of the their goal by aligning instruction and working harder at third grade, but they didn't achieve their ultimate results until they began carefully monitoring reading growth in kindergarten through second grade and providing intensive interventions to students who were lagging behind.

How effective is remedial instruction for older students with dyslexia?

Unfortunately, there are many students with dyslexia currently in our schools who did not receive timely and sufficiently powerful interventions to prevent the emergence of serious reading difficulties. When children with dyslexia have been in school three or four years and have not had sufficiently strong preventive instruction, they will show two obvious difficulties when asked to read text at their grade level.

First, they will not be able to recognize as high a proportion of the words in the text fluently or "by sight" as average readers. There will be many words they stumble on, guess at, or attempt to "sound out." The second problem is that their attempts to identify words they do not immediately recognize will produce many errors. They will not be efficient in using phonemic analyses in combination with context to identify unknown words. It also is the case that a small number of children with the most severe form of dyslexia will show these same weaknesses despite the provision of timely and powerful interventions.

Several years ago, a large study of special education in the state of Texas reported that students receiving reading interventions did not fall further behind with each year in special education, but neither did they close the reading gap to any meaningful degree (Hanushek, Kain, and Rivkin, 1998). This finding echoed earlier studies (Foorman, Francis, Fletcher, Winikates, & Mehta, 1997; Kavale, 1988; McKinney, 1990; Schumaker, Deshler, & Ellis, 1986; Zigmond, et al., 1995) showing that, at best, students receiving remedial reading instruction in special education make one year's growth for each year of instruction, but rarely do they make the substantial improvements (two or three years growth) that are required in order to help them eventually "close the gap" with their same-age peers.

A recent review of remedial instruction for older students with severe reading disabilities (Torgesen, 2005) indicated that we do know how to accelerate reading growth in older students with dyslexia, but that it is exceedingly difficult to bring them to grade level standards in all areas of reading skill. Further, the instructional conditions in studies that accelerate reading growth in older students are universally more powerful (smaller groups, more instructional time, highly trained teachers) than those typically available to students receiving special education services in our public schools.

One of the most powerful intervention studies to date with older dyslexic students was conducted in Gainesville, Florida, through the Morris Child Development Center (Torgesen et al., 2001). Sixty students with severe reading disability in grades 3-5 who had been receiving special education services for an average of 16 months were provided 8 weeks of very intensive reading instruction. They were taught 1:1 by highly skilled teachers in two, 50-minute sessions, five days a week for 8 weeks, for a total of 67.5 hours of instruction. During this time, in the strongest instructional condition, their scores in phonemic decoding increased from below the 1st percentile to the 39th percentile, their scores in text reading accuracy increased from the 4th to the 25th percentile, and their scores in reading comprehension increased from the 13th to the 27th percentile.

After the study, about 40% of the students were "staffed out" of special education, while the rest remained with no further intervention from the study. At the two year follow-up point, the students scored at the 29th percentile in phonemic decoding, the 27th percentile in text reading accuracy, and the 36th percentile in reading comprehension. The reading comprehension of these students was slightly higher than would have been predicted from the level of their general verbal ability, which was at the 29th percentile.

A finding from this study, which has been observed in other studies as well (Torgesen, 2005), is that the students' percentile rank in reading fluency did not improve nearly as much as the scores for other reading skills. At the beginning of the study, the students' reading fluency fell at the 3rd percentile, while at the two year follow up, it was at the 4th percentile. Although their fluency for lower grade level passages did increase dramatically (from 38 to 101 words per minute), when the students were asked to read passages at their grade level, there were still too many words that they could not recognize "by sight" so, although they could read them much more accurately following intervention, they still had to stop and "sound out" too many words. If students with dyslexia remain essentially "non readers" during the early part of elementary school, they miss out on enormous amounts of reading practice, and it is very difficult to close this practice gap once they become older, because their classmates are reading at such high volumes by that time.

To summarize, it is clear that we currently understand how to provide more powerful interventions to older dyslexic students than they may frequently receive in special education. It is also clear that it is possible for them to acquire useful phonemic decoding skills after third grade, if the instruction they previously received was not sufficient to help them in this area. Another recent review of interventions with older disabled readers has indicated that it can also be very helpful to directly teach these students reading comprehension strategies (Scammacca, 2007). Both lack of early reading practice, and difficulties with word-level reading skills apparently interfere with dyslexic students' ability to acquire the range of strategies that good readers use to increase their comprehension. Although it is challenging to provide appropriately targeted instruction for older students with dyslexia who continue to struggle in reading, it may be even more challenging to provide *sufficient amounts of instruction, in small enough groups* to accelerate their development.

For older students with severe reading disability, assistive technology in the form of devices that decode print may be helpful in allowing them to acquire information from content classes such as social studies and science. It is important to continue to work to improve their functional reading skills, yet it does not make sense to allow a severe bottleneck in reading to preclude maximal acquisition of the knowledge about the world that is required to be an independent participant in society.

Conclusion

Scientific research has contributed substantially to our understanding of dyslexia and other forms of reading difficulty over the past 40 years. We now have a widely agreed upon definition, and we also have assessments that can accurately identify children with dyslexia as early as kindergarten. We also understand many of the instructional conditions that must be in place to prevent the emergence of the early word-level reading difficulties that are characteristic of students with dyslexia.

Further, we have demonstrations from successful schools and districts that illustrate ways to provide these conditions on a large scale. We also have research-based knowledge about the conditions required to accelerate the development of reading skills in older students with dyslexia, although the nature and duration of instruction required to "normalize" the reading ability of these students is not currently known. We clearly have enough knowledge about "what works" for these children to apply it on a large scale.

The most pressing problems at present are related to the twin challenges of implementing high-quality initial reading instruction in every classroom and identifying the resources and personnel to provide intensive reading interventions for all students that need them in schools. Within this broad set of challenges, a shortage of highly skilled intervention specialists and a lack of financial resources to support the additional instructional time and smaller instructional groups required by many students may be the most difficult.

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Chinese Language and Remediation Support for Children with Dyslexia in Singapore

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Abstract

The research presented here is targeted towards a better understanding of how students with dyslexia learn Chinese language as a second language. The research and development consisted of a preliminary survey and two studies, to identify difficulties that are unique to dyslexia in learning Chinese and develop an effective intervention programme that caters to the needs of students. The first study identified significant impairments in visual processing in children at high risk of dyslexia, associated with significant deficits in phonetic decoding, in a sample of 45 nine-year-old children including students drawn from the Dyslexia Association of Singapore (DAS) and matched controls. The insights from this study were used to develop an intervention programme in the second study, where significant improvements in targeted skills were found for 16 children aged six to twelve. Implications for further development are discussed.

INTRODUCTION

Dyslexia and Chinese language

Dyslexia is believed to be a universal language learning disability that varies across different languages, depending on the diversity of the writing systems. Most of the studies on dyslexia and reading development derive from English speakers with attempts to generalise these findings and theories or models to other alphabetic languages (Brunswick, 2010). Some researchers have found that dyslexia varies across languages and the differences can be due to different characteristics of the languages (Cell Press, 2009; Hu et al., 2010). Goswami

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(2010) indicated that many cross-language studies show more similarities in phonological awareness because of the psycholinguistic grain-size theory – whereby the grain size of syllable and onset-rime were found to be similar universally, while the grain size of phoneme was found to be dependent on the language-specific orthographic effects on reading acquisition. Alphabetic writing systems such as Italian, German and English represent phonemes more consistently than others, as there is more direct mapping of letters to speech sounds, compared to logographic or syllabic writing systems that have larger phonological granularity, such as Japanese, Korean and Chinese. Therefore, dyslexics in all languages seem to experience phonological deficits – a common neuro-anatomical origin, and the extent to which language acquisition is impacted depends on the depth of the orthographies, because they also tend to have difficulty with the written forms of words – orthography (Brunswick, 2010).

While there is an universal large-to-small phonological development across languages seemingly shaped by the orthographic structure of the native language (Duncan, 2010), Hu et al. (2010) found that both Chinese and English dyslexics have notably similar areas of brain activation which are responsible for semantic processing of orthography and these activations are culturally independent. This shows that there is a common pattern in the neural mechanism impacting their phonological, verbal and/or visuo-spatial working memory processes. They further found that the slight difference in brain activation for both groups of normal readers indicated that Chinese language processing require greater reliance on visuo-spatial memory – a neural processing of perceptual information uniquely for Chinese language learners.

Additionally, Cell Press (2009) cited researchers, Siok and Tan, that the visual cognitive system is activated to perform a fine-grained visuo-spatial analysis on the Chinese characters' phonological and semantic information. Thus, Chinese dyslexics may have disordered phonological processing that commonly coexists with abnormal visuo-spatial processing ability, as compared to English dyslexics. Ho and Fong (2005) found high concomitance of reading difficulties in both Chinese and English languages, with phonological deficit (especially phonemic awareness) more specific to English reading and visual-orthographic deficits more specific to Chinese reading and rapid naming deficit as a common cause in both languages. Similarly, Chung and Ho (2010) found that Chinese-English learners with dyslexia generally have weak rapid-naming, visual-orthographic knowledge, and phonological and morphological awareness in both languages, with phonological difficulties relating less to Chinese language than English language. Furthermore, their results also suggested that naming speed is a general form of processing skill common for any language script but other metalinguistic processes may be specific for each language acquisition. However, in both studies, the transference of processes was investigated on Chinese as a first language and English as a second language, and thus, one might question whether such transference is bidirectional.

Variation between languages was found by Comeau, Cormier, Grandmaison and Lacroix (1999) who developed a model of three intercorrelated domains of phonological awareness, phonological access in lexical entry and phonological processing in verbal working memory. Although the Chinese language is not an alphabetic language, their findings provided evidence for cross-language transfer of phonological awareness, suggesting that phonological awareness in the native language is strongly related to successful acquisition of second language. McBride-Chang (2011) highlighted the similarities and differences in language transfer between native language and second languages, and found that the overlap of metalinguistic skills between Chinese-English learners was roughly 32-37% while Spanish-English learners was roughly 50% or more. That means, although metalinguistic skills transfer across languages, variations in the transfer are difficult to estimate due to the diversity in the orthographic nature of different languages (Koda, 2011). Therefore, with a deficit of phonological cognitive processing, dyslexics would very likely face difficulties in language learning in general.

Although it has been claimed that incidence of dyslexia will be low in languages which are transparent and with coarse granularity in their phonology (Brunswick, 2010), the challenge faced by dyslexics to overcome language difficulties is much greater and more complex for opaque languages regardless of coarse or fine phonological granularity (i.e. English and Chinese). English is an atonal alphabetic language and its letter-sound relationship makes pronunciation of visual words possible. By contrast, Chinese is a tonal language that contains single or multiple syllables in a single or multiple morphemic characters in a morphographic script (Yin & Weekes, 2004). English language adopts an alphabetic writing system (i.e. 'sounding out' of individual letters) while Chinese language adopts a logographic writing system where most of the characters contain a semantic element to provide the meaning and a phonetic element to provide the pronunciation. Thus the Chinese language is linguistically more opaque than the English language, despite both having deep orthographies (Brunswick, McDougall & de Mornay Davies, 2010). The Chinese language is also considered to have a morphosyllabic writing system because the majority of the characters can be represented as a morpheme – the smallest pronounceable unit is also associated with meaning, making the script morphographic (Shu, Meng, Chen, Luan & Cao, 2005).

The characters in the Chinese language have been classified into six kinds (McNaughton & Li, 1999; Lee, 2008; Han, 2008). The simpler form of Chinese characters derived from the objects they describe (Ning, 2001), such as "人" which looks like a stick drawing of "man", then followed by Chinese characters in symbolic forms (McNaughton & Li, 1999), such as "一、二、三" for "one, two, three". The other four are meaning-compounds such as "日" [sun] + "月" [moon] = "明" [bright], phonetic-loans such as "足" /zú/ which has both meanings of "feet" and "sufficient", semantic-phonetic-compounds such as "女" [girl] + "家" [house] = "嫁" [being married], and mutually-interpretive forms such as "乐" which means "music" and "enjoyment".

With Chinese language being a logographic and morphosyllabic language, unlike the English alphabetic language, it is believed that other cognitive abilities than phonological deficits would affect language acquisition, especially visual perceptual skills. The Chinese script can have many homophones that are visually-dissimilar, as well as visually-similar characters that are not homophonous, which can be difficult to know if a radical is phonetic or semantic (Su, Klingebiel & Weekes, 2010). Knowing how to read a Chinese character correctly requires a learner to know the pronunciation as a whole, and knowing how to write a Chinese character correctly requires a more complicated set of processes to understand both phonetic and semantic information to differentiate the characters.

Ho (2003) investigated the cognitive deficits in Chinese dyslexics which provided more clues to the cognitive processes underlying reading and writing Chinese language, namely visual skills, phonological skills, phonological awareness, phonological memory, and phonological retrieval. There have been greater emphases on the phonological aspects of Chinese language which affect reading accuracy (e.g. Ho & Lai, 1999; Ho & Ma, 1999; Meng et al., 2005). Studies have demonstrated that training in phonological strategies did show improvement in Chinese dyslexic children's character reading skills, but only for phonologically regular characters, not the irregular ones (Ho & Ma, 1999; Ho, 2003). Phonologically regular characters contain phonetic radicals to give a clue on how to pronounce it, but phonologically irregular characters do not produce sounds that are similar to their phonetic radicals (e.g. "理" /lǐ/ is pronounced the same as "里" /lǐ/ in it, but "埋" /mái/ is pronounced differently). Additionally, although there have been many fewer brain studies on Chinese dyslexics, there has been evidence of lower activation in brain areas responsible for lexical and phonological processes, similar to English dyslexics (Cao, 2011).

McBride-Chang et al. (2011) have demonstrated a broad array of metalinguistic and cognitive skills that are important for learning Chinese language and proposed that although phonological sensitivity is developmentally vital for learning to read Chinese characters, because of the unreliable phonological cues to Chinese words, it may be essential to look at other indicators of reading acquisition, such as morphological awareness and visual skills. Morphological awareness is seen as important for learning Chinese as a heritage language, because many characters are formed by two or more graphic components and can be combined to form new words (Koda, 2011). McBride-Chang (2004) discussed how morphological awareness and morphological instruction may help children in learning to read, especially in languages that have orthographic patterns, like Chinese. Children with dyslexia are also found to perform poorly on tone detection, morphological awareness and word recognition, and tests of tone detection and morphological awareness are proposed to be the clinical assessment tools to detect children who are at risk of reading problems in Chinese (McBride-Chang et al., 2008). However, this proposal and discussion are based on traditional Chinese script that contains more complex visual features and stroke patterns but with greater retention of semantic association. Thus, McBride-Chang (2004) also concluded the importance of visual and orthographic skills in reading and writing Chinese characters, whereby serial visual memorisation may be required to focus on visual details and shape constancy of stroke patterns. McBride-Chang et al. (2010) suggested the possibility of simplified script making greater demands on basic visual attention and perception in beginning readers when another study showed that mainland Chinese students were stronger than those from Hong Kong in terms of their visual skills (McBride-Chang, Chow, Zhong, Burgess and Hayward, 2005). This could be because characters in the simplified script have less strokes, resulting in less points of distinction.

Other studies, though comparatively fewer, investigated visual skills in relation to reading and dyslexia, and suggested the importance of visual skills in successful Chinese language acquisition (e.g. Woo & Hoosain, 1984; Huang & Hanley, 1995; Ho & Bryant, 1999; Siok & Fletcher, 2001). Because graphic componential complexity is the distinct feature in Chinese characters, visual recognition of the character components for analysis and identification as a phonetic and semantic function is found to be of great importance (Feldman & Siok, 1997). Ho and Bryant (1999) examined three different visual skills in reading of English and Chinese words, due to the presence of differential processing demands on different orthographies, and found visual constancy of shape to be the strongest predictor of Chinese reading performance while visual figure ground and visual-spatial skills reliably predicted English reading performance. McBride-Chang, et al. (2005) also investigated three visual skills (i.e. visual discrimination, visual-spatial and visual closure) in reading two different Chinese scripts and found visual-spatial skill to have the strongest association with both scripts. According to their findings, visual-spatial skill is a good predictor of Chinese reading acquisition in inexperienced Chinese readers, such as dyslexics and second language learners.

For orthographic structure awareness, Yeh and Li (2002) considered three aspects of Chinese character which are the radical, the phonetic and the structure, and for structure, they specified three main types which are horizontal, vertical d bounded. For example, the structures can be in the shapes of ⿱, ⿳, ⿰, ⿲ and ⿴ (谢, 2002). The most dominant orthographic structure of Chinese characters in the Chinese language was found to be the semantic-phonetic horizontal-type structure (Bai & Schreuder, 2011). However, within the structure, there is a need for visual recognition and orthographic knowledge to identify the types of radicals in order to process the Chinese character. Semantic radicals provide the meaning information of the character that represents and phonetic radicals provide the pronunciation needed to read the character, which could be similar to the grapheme-phoneme correspondences applied in alphabetic languages, such as English (Zhou & Marslen-Wilson, 1999).

Ho, Chan, Tsang and Lee (2002b), and Ho, Chan, Tsang and Lee (2004) demonstrated a subgroup of Chinese dyslexics who had greater visual-orthographic difficulties than phonological processing deficits, and Chung et al. (2008) found that visual temporal processing is likely to be associated with Chinese character recognition. Similarly to Ho et al. (2002b) and Ho et al. (2004), Chung, Ho, Chan, Tsang and Lee (2009) found five reading-related cognitive skills that could be necessary for Chinese language acquisition, in their comparison study on Chinese dyslexics and normal readers: (1) visual-orthographic awareness, the most predominant characteristic, on the knowledge of orthographic structure and implicit knowledge of radical positions in Chinese characters, (2) rapid naming, the second most dominant skill, reflecting abilities in phonological representations, automatic processes of extraction and induction of orthographic patterns, and lexical access, (3) morphological awareness, the third dominant skill, in morphemic identification, discrimination, manipulation and generalisation based on understanding of radial roles and morphological relations, (4) verbal memory for short-term storing of phonological information and making associations between visual symbols, speech sounds and meaning, and (5) phonological awareness, being the least common, due to the lack of a phonemic coding system in the Chinese language. Furthermore, they have confirmed that developmental dyslexia in Chinese could not be outgrown, just as it has been claimed as a persistent difficulty in all language, but problems in visual-orthographic knowledge and rapid naming might have greater effect than phonological skills on language learning.

Chinese language acquisition in Singapore

Singapore is a culturally diverse and a highly reported multilingual society. The resident population is made up of Chinese (74.2%), Malay (13.3%), Indians (9.1%) and other races (3.3%) (Singapore Department of Statistics, 2013). This makes it the only Asian country outside of China where Chinese is the predominant race (王 & 余, 2007). As a result of the bilingual language policy, Singaporeans grow up in a very diverse linguistic environment with English as an alphabetic language, Chinese as a logographic language, Malay as a Roman alphabetic language and Tamil as a syllabic Brahmi language (Curdt-Christiansen, 2011).

The bilingualism policy, especially with its promotion of Chinese language among Singaporean Chinese, is associated with the rise and success of China that presents many economic opportunities for bilingual Singaporeans (Lee, 2012). Thus, Singapore adopts the same simplified Chinese writing system as China, and 'hanyu pinyin' phonetic symbols in its bilingual educational programme. As such, the medium of instruction in schools became English and their ethnic language was learned as Mother Tongue, a second language, as part of the curriculum. The reason for making the learning of mother tongue language mandatory was to preserve ethnic identity, which is characteristic to Singapore.

With English language as the major medium for educational and social communication, Singaporean Chinese children found the Chinese language difficult and less interesting to learn, which in turn decreased their motivation and willingness to learn their 'Mother Tongue' (刘, 吴 & 张, 2006). Thus, in 2007, the Ministry of Education made changes to the Primary School syllabus for Chinese and Higher Chinese subjects, with the main objective of promoting efficiency and practicality in the use of the Chinese language in Singapore (王, 2010). The Chinese Language Curriculum and Pedagogy Review Committee (2004) changed the educational focus on developing listening, speaking and reading skills, so as to facilitate an easier alternative to learning Chinese language and characters (cited in Zhang & Liu, 2005). Currently, Chinese language is taught as either a standard subject or foundation subject to match the varied abilities of the children, and to ensure that all children are given educational access to their 'Mother Tongue' in the curriculum (Ministry of Education [MOE], 2014). Furthermore, it was also found that implementation of student-centered teaching through use of 'hanyu pinyin' in early literacy, technological intervention tools and contextual-based verbal discussions could be a successful approach for children learning Chinese as a second language in Singapore (Zhang & Liu, 2005; 刘 & 赵, 2007).

The learning of mother tongue language begins as early as nursery (three years old) and spans the secondary school years and for some, till the end of their pre-university education. At upper primary school and secondary school levels, students are streamed into three main categories for learning Chinese as a language subject – namely, Standard Chinese, Higher Chinese and Foundational Chinese (MOE, 2014). Students diagnosed with dyslexia are allowed to be exempted from the studying of their mother tongue language upon recommendation of educational psychologists on the basis of their difficulty in learning English (Liew, 2011), the most important language of communication in Singapore. However, some would still cope with two languages in school till upper primary levels because of the societal pressures of living in a multilingual society (Dixon, 2005).

In Singapore, if the child's parents do not speak in Chinese at home with the child, the child only receive six hours of input in Chinese a week from mother tongue lessons. The number of hours of instruction progressively decrease as the child grows older to as low as 2.5 hours per week for students learning the language at the foundational level. Thus, the bilingual education policy adopted in Singapore has put many Chinese children in a very unique position from other Chinese children of countries where Chinese language is the first language, such as China, Taiwan and Hong Kong. Due to the differences in linguistic environment, students in these countries receive much more exposure to the language in daily usage with Chinese the only language spoken in their society. Chinese language in Singapore is considered a second language, despite being the native language for Chinese ethnics, while English language is considered the first language and medium for societal communication and school instruction (Lee, 2012). Thus, this has provided our dyslexic Chinese children an even more perplexed situation for acquisition of both languages.

Empirical motivation of the Research

Therefore, the research study covered two phases that aim to investigate whether visual perceptual abilities do play an important role in the learning of Chinese language, especially in Singapore's context and despite the presence of dyslexia as a learning difference. It also hopes to develop a remediation programme for Chinese language that caters to the unique profile of children with dyslexia learning Chinese language as a second language in Singapore. As there have not been any literacy assessments for or literature on Chinese literacy skills of Chinese children in Singapore, this would be also be another interesting exploration of the appropriateness of newly created or adapted Chinese literacy assessments for Singaporean bilingual children in assessing their literacy skills. Thus, it is also an exploratory study to validate this battery of tests of Chinese literacy skills to examine differences in Chinese literacy skills between dyslexic and non-dyslexic children, as well as to profile literacy needs of dyslexic children when learning Chinese language.

Preliminary Survey

In 2009, the team conducted a preliminary survey with over 400 parents of our dyslexic students at the DAS. The survey aimed to find out more about the struggles of our students as well as the kind of support they are receiving, before conducting the research study. A random sample of the surveys (n = 160) showed that almost half of our students had no support or remediation in Chinese, about 85% of them did not speak Mandarin as Home Language and about 75% of the parents were interested in Chinese classes. At the same time, the survey showed that our students had difficulties across most aspects of the language, including basic reading and spelling of Chinese characters, as well as comprehension of Chinese passages and oral skills. Some parents also provided feedback that their children lack interest and/or motivation in learning Chinese.

With the survey results in mind, the team conducted a research study in 2010 and 2011 with the aim to better understand the difficulties our dyslexic students face in learning Chinese and whether visual perceptual ability affects the learning of Chinese characters. The study was conducted with 95 Primary Four students, from the DAS as well as mainstream primary schools. The study included a selection stage where students were screened using the LUCID Rapid dyslexia screening test and the Test of Visual Perceptual Skills. The selection stage was necessary because the purpose of the study was to find out whether difficulties faced by DAS students in learning the language are unique to dyslexia.

STUDY 1

Methodology

The research phase adopted a quantitative two-way research design. A total of 45 students from DAS and other mainstream primary schools voluntarily participated in the study. 19 DAS students (13 boys and 6 girls) and 26 non-DAS students (18 boys and 8 girls) were selected through the use of Lucid Rapid Screening test (LUCID Research Ltd, 2010) and respectively categorised into 'at-risk' and 'low-risk' groups. The third edition of Test of Visual Perceptual Skills (non-motor) (TVPS-3) (Martin, 2006) and newly developed or adapted battery of Chinese literacy tests were used in assessing the students for statistical comparison and correlational analyses. The mean ages of DAS students (experimental group) and mainstream primary students (control group) were 9.85 years (S.D. = 0.29 years) and 9.84 years (S.D. = 0.43 years) respectively. The purpose of having the control group is to confirm the hypothesis that poor visual perceptual skills affect Chinese literacy performance, is not confined to dyslexic children.

The second edition of 'The Hong Kong Test of Specific Learning Difficulties in Reading and Writing' (Ho et al., 2007) and 'The Hong Kong Specific Learning Difficulties Behaviour Checklist (For Primary One Pupils)' (Ho, Chan, Tsang & Lee, 2002a) are currently utilised and conducted in 'Cantonese' for diagnosing Hong Kong Children with dyslexia. Other assessment tools in Chinese were also found available in China and Taiwan (King-May Psychological Assessment, 2010; Psychological Publishing Co., Ltd., 2006), such as the Chinese-grade literacy scale (中文年级认字量表) (黄, 2001), the Comprehensive test of basic reading and writing words (基本读写字综合测验) (洪, 张, 陈, 李 & 陈, 2003) and the Written language ability diagnostic test for children – second edition (国小儿童书写语文能力诊断测验 - 第二版) (杨, 李, 张 & 吴, 2003). As the assessment tools were developed according to the norms of the respective countries, the Chinese language used in these tools is in traditional script and 'zhuyin fuhao' was used to denote the phonetic symbols for pronunciation of Chinese characters, instead of 'hanyu pinyin'. For example, traditional script uses "糸" while simplified script uses "纟" for one of the semantic radicals. Nonetheless, these existing assessment tools serve as a good reference for new test development and other test adaptation of the battery of Chinese literacy tests to the local context in this research phase.

Therefore, a battery of Chinese literacy tests that consists of three tests was developed and adapted:

1. Chinese character structure awareness test (中文字形结构识别能力测验)
   Most parts of this test were newly developed and based on the Ministry of Education (MOE) Primary School syllabus for Chinese and Higher Chinese subjects (2007). This is so that the Chinese characters or radicals are appropriate for the students at primary school level and their performance in this test could relate to their academic learning in

mainstream primary schools. The test items in the subtests were developed with greater relation to visual perceptual skills in terms of Chinese character orthographic structure, radicals and shapes.

2. Reading of single Chinese characters (中文年级认字量表)
The list of Chinese characters was adapted with reference to the MOE Primary School syllabus for Chinese and Higher Chinese subjects (2007), MOE Chinese character lists for Primary and Secondary Schools (2002), as well as the character frequency distribution analysis by 王 and 余 (2007), in order to match the local context of Singapore and so as to ensure that they are appropriate for the language proficiency level of the Singaporean students.

3. Comprehensive test of basic reading/writing words (基本读写字综合测验)
This test was adapted to assess the students' spelling ability (counter measured with aural and phonetic symbols – 'hanyu pinyin') and copying skills with regards to visual perception.

As the battery of Chinese literacy tests was not standardised and had no standard set of scores, inter-scorer agreement was reached to derive inter-scorer reliability, so as to ensure consistency in scoring between the team members. In addition, training was given to all team members to ensure that the administration of tests and derivation of test scores was undertaken in a systematic, efficient and consistent way.

Results

To determine students with high and low visual perceptual skills, a median split was conducted on the overall scores of the TVPS assessment test. Students who scored lower than the median was categorized as 'low visual perceptual skills', and those who scored higher than the median was categorised as 'high visual perceptual skills'. This resulted in 21 students being categorized as 'low visual perceptual skills' and 24 students being categorised as 'high visual perceptual skills'. The number of 'low-risk' and 'at-risk' students categorised by their visual perceptual skills is summarized in Table 1.

Table 1. 'Low-risk' and 'At-risk' Students Categorised by Visual Perceptual Skills

	Low Visual Perceptual Skills	High Visual Perceptual Skills
Low-risk for dyslexia	7	19
At-risk for dyslexia	14	5

To compare performance on different assessment tests between the 'low-risk' and 'at-risk' groups based on their visual perceptual skills, 2 x 2 randomised ANOVA with Student Group (low-risk vs. at -risk) and Visual Perceptual Skills (low vs.

high) as the independent variables (IV) were conducted on the Chinese Literacy tests. Further comparison was also conducted on the subtests of the Lucid Rapid screening assessment.

For the Literacy assessment test, the mean scores of the 'low-risk' students was higher than 'at-risk' students, $F(1, 41) = 46.51$, $p < .001$. However, there was no difference in the mean scores between students of low and high visual perceptual skills, $F(1, 41) = 0.70$, $p = .41$. The interaction effect between Student Group and Visual Perceptual Skills was also not significant, $F(1, 41) = 0.0017$, $p = .97$.

As a secondary analysis to further understand the performance of students with high and low visual skills on the Lucid screening assessment, 2 x 2 randomised ANOVA with Student Group (low-risk vs. at -risk) and Visual Perceptual Skills (low vs. high) as the independent variables (IV) were also conducted on subtests of the Lucid Rapid screening assessment.

For the Lucid Rapid Phonological Processing (PHP) subtest, the mean scores of the 'low-risk' students were higher than 'at-risk' students, $F(1, 41) = 69.39$, $p < .001$. However, there was no difference in the mean scores between students of low and high visual perceptual skills, $F(1, 41) = 0.82$, $p = .37$. The interaction effect between Student Group and Visual Perceptual Skills was also not significant, $F(1, 41) = 3.07$, $p = .08$.

For the Lucid Rapid Auditory Sequential Memory (ASM) subtest, the mean scores of the 'low-risk' students were higher than 'at-risk' students, $F(1, 41) = 21.08$, $p < .001$. However, there was no difference in the mean scores between students of low and high visual perceptual skills, $F(1, 41) = 1.15$, $p = .29$. The interaction effect between Student Group and Visual Perceptual Skills was also not significant, $F(1, 41) = 0.0093$, $p = .92$.

For the Lucid Rapid Phonetic Decoding Skill (PDS) subtest, the mean scores of the 'low-risk' students were higher than 'at-risk' students, $F(1, 41) = 30.29$, $p < .001$. However, there was no difference in the mean scores between students of low and high visual perceptual abilities, $F(1, 41) = 0.035$, $p = .85$. The interaction effect between Student Group and Visual Perceptual Skills was significant, $F(1, 41) = 5.70$, $p < .03$. Further simple effects analysis demonstrated that for students of low visual perceptual skills, 'low-risk' students scored higher than 'at-risk' students, $t(19) = 6.46$, $p < .001$, and that for students of high visual skills, there was no difference between 'low-risk' and 'at-risk' groups, $t(22) = 1.41$, $p = .17$.

In order to compare the performance of the TVPS-3 assessment test between the 'low-risk' and the 'at-risk' groups, a randomized sample t test was performed on the overall score of the TVPS-3 assessment test. The 'at-risk' group had lower mean scores for the TVPS-3 assessment test (mean = 94.7, s.d = 2.76) compared to the 'low-risk' group (mean = 105.2, s.d. = 2.18), $t(44) = 53.16$, $p < .001$. This suggested that the 'at-risk' group performed worse on the assessment test compared to the 'low-risk' group.

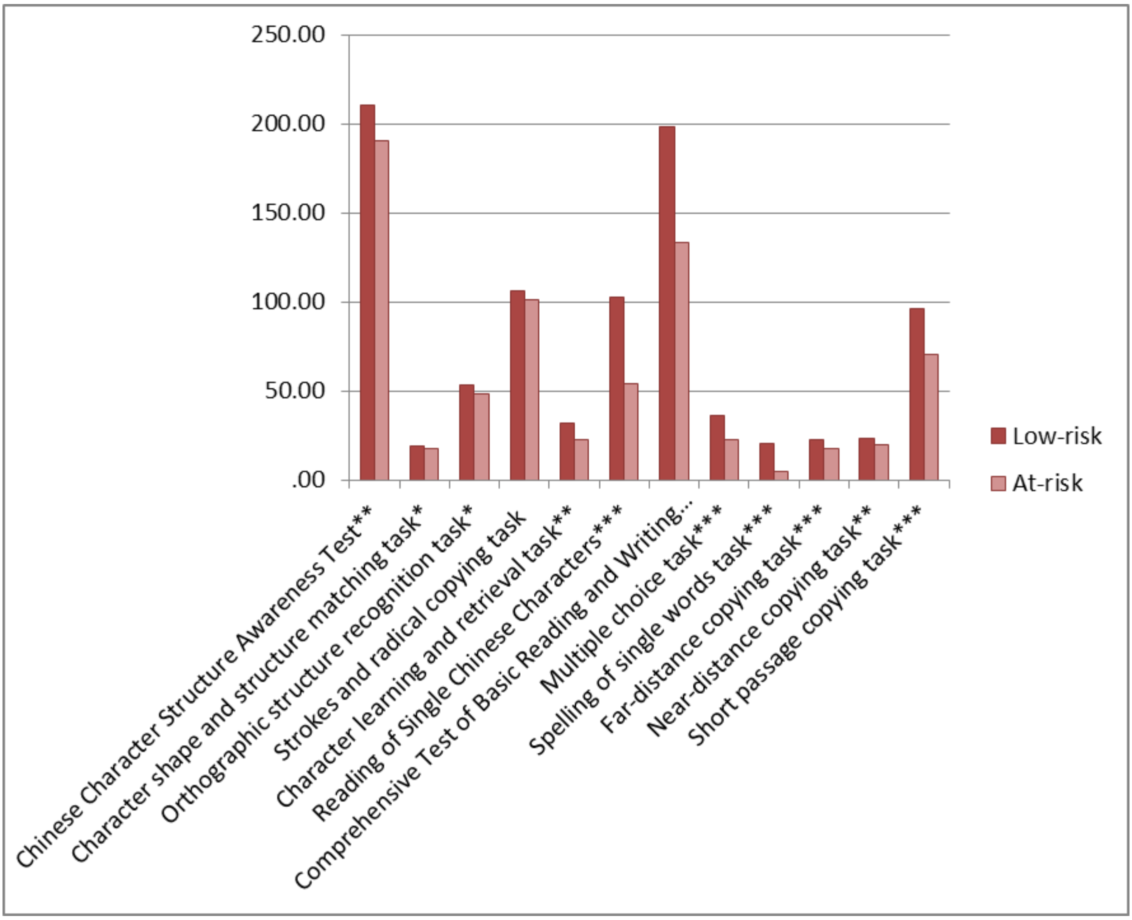
Overall, for the mean scores of the different assessment tests, 'low-risk' students scored higher than 'at-risk' students. The difference in visual perceptual skills did not affect the scores for most of the assessment tests, with the exception of the Lucid Rapid PDS subtest, where it suggested that 'at-risk' students of low visual perceptual skills performed poorer in phonetic decoding than 'low-risk' student of low visual perceptual skills.

In order to compare the mean scores of each Chinese literacy test and subtest, an independent sample t-test was conducted. There was a significant difference in the *Chinese Character Structure Awareness Test (中文字形结构识别能力测验)* scores for the 'low-risk' group (mean = 210.31, s.d. = 15.75) and the 'at-risk' group (mean = 190.47, s.d. = 20.095); $t(43) = 3.71$, $p < 0.01$. For its subtests, there were also significant differences in the *Character shape and structure matching task (部件组合形式)* scores; $t(43) = 2.39$, $p < 0.05$, *Orthographic structure recognition task (识别汉字结构)* scores; $t(43) = 2.34$, $p < 0.05$, and *Character learning and retrieval task (提取新学单词)* scores; $t(43) = 3.71$, $p < 0.01$. There was no significant difference in the *Strokes and radical copying task (基本笔画与部件抄写)* scores, $p > 0.05$.

For the *Reading of Single Chinese Characters (中文年级认字量表),* there was a significant difference in the scores for the 'low-risk' group (mean = 102.85, s.d. = 29.261) and the 'at-risk' group (mean = 53.95, s.d. = 20.805); $t(43) = 6.22$, $p < 0.001$. For the *Comprehensive Test of Basic Reading and Writing Words (基本读写字综合测验),* there was a significant difference in the scores for the 'low-risk' group (mean = 198.65, s.d. = 25.371) and the 'at-risk' group (mean = 132.95, s.d. = 38.895); $t(43) = 6.86$, $p < 0.001$. For its subtests, there were also significant differences in the *Multiple choice task (找出正确的字)* scores; $t(43) = 7.47$, $p < 0.001$, *Spelling of single words task (听/看汉语拼音写单字)* scores; $t(43) = 6.40$, $p < 0.001$, Far-distance copying task (远端抄写) scores; $t(43) = 5.12$, $p < 0.001$, *Near-distance copying task (近端抄写)* scores; $t(43) = 3.76$, $p < 0.01$, and *Short passage copying task (短文抄写)* scores; $t(43) = 4.32$, $p < 0.001$.

The above results suggested that the 'at-risk' group performed worse in most of the Chinese literacy tests and subtests than the 'low-risk' group, except for copying of strokes and radicals, implying that the 'at-risk' group are poorer in most of the Chinese literacy skills as compared to the 'low-risk' group. A graphic representation of the means comparisons for each Chinese literacy tests and subtests between both groups is shown in Figure 1.

In order to compare the mean scores of each reading error miscue, an independent sample t-test was also conducted. There was a significant difference in the *visually-similar errors* for the 'low-risk' group (mean = 11.31, s.d. = 6.632) and the 'at-risk' group (mean = 7.05, s.d. = 4.743); $t(43) = 2.38$, $p < 0.05$, especially for its subtype, *same-radical characters;* $t(43) = 3.23$, $p < 0.01$. This suggests that 'at-risk' students tend to make less visually-similar and phonetically-similar errors than 'low-risk' students, especially with characters that contain the same radicals when making



*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Figure 1. Comparison of means on 'Chinese literacy' between 'risk of dyslexia'

visually-similar errors. There was also significant difference in *unknown errors* between 'low-risk' group (mean = 73.38, s.d. = 36.057) and the 'at-risk' group (mean = 127.37, s.d. = 29.934); $t(43) = -5.32$, $p < 0.001$. This suggests that 'at-risk' students make more unknown errors than 'low-risk' group when reading Chinese characters. There was no other significant difference in the rest of the error miscues, $p > 0.05$.

In order to compare the mean scores of each spelling/writing error miscue, an independent sample t-test was also conducted. There was a significant difference in *wrongly written characters* for the 'low-risk' group (mean = 11.08, s.d. = 5.932) and the 'at-risk' group (mean = 17.21, s.d. = 10.266); $t(43) = -2.53$, $p < 0.05$, especially for its subtype, *structure errors*; $t(43) = -3.76$, $p < 0.01$. This suggests that 'at-risk' students tend to write characters that are non-existent in the Chinese language, especially with regards to the orthographic structure and position of radicals within a character. There was also a significant difference in *incorrect characters* for the 'low-risk' group (mean = 11.08, s.d. = 5.932) and the 'at-risk' group (mean = 17.21, s.d. = 10.266); $t(43) = -6.94$, $p < 0.001$. For its subtypes, there were significant differences for *visually-similar-phonetically-different characters;* $t(43) = -3.28$, $p < 0.01$, *visually-different-phonetically-similar characters*; $t(43) = -2.297$, $p < 0.05$, *visually-different-phonetically-same characters*; $t(43) = -3.82$, $p < 0.001$, *similar-semantic-different-phonetic characters*; $t(43) = -5.10$, $p < 0.001$, and *visual-semantic-phonetic confusion*; $t(43) = -3.47$, $p < 0.01$. This suggests that 'at-risk' students tend to write more incorrect characters that are mainly homophones or irregular characters, and semantically related characters, as compared to 'low-risk' students.

There was significant difference in *incomplete response* for the 'low-risk' group (mean = 15.23, s.d. = 13.776) and the 'at-risk' group (mean = 29.26, s.d. = 32.978); $t(43) = -2.86$, $p < 0.05$. There was also significant difference in *unknown errors* for the 'low-risk' group (mean = 8.77, s.d.=10.727) and the 'at-risk' group (mean = 37.84, s.d. = 19.828); $t(43) = -4.92$, $p < 0.05$. This suggests that 'at-risk' students tend to be unable to complete writing a Chinese character or make more unknown errors than 'low-risk' group when reading Chinese characters. There were no other significant differences in the rest of the error miscues, $p > 0.05$.

In view of the insignificant interaction results, correlational analyses were conducted for all subtests of different assessment tests as an exploratory study to understand the possible relationships between different visual perceptual skills, phonological processing, auditory sequential memory and phonetic decoding skills, with different Chinese literacy skills.

As visual perceptual skills are the main interest of this research study on Chinese characters, Spearman correlation analyses were performed between the scores of the TVPS-3 assessment subtests with the Chinese Literacy tests scores. There was a significant correlation between the scores on the TVPS-3 Visual Memory subtest with the Literacy assessment test, $r_s = .33$, n = 46, $p < .03$. No other significant correlation was found between the other TVPS-3 subtests (i.e. other visual perceptual skills) with the Chinese Literacy tests scores. In order to better understand the relationship between the Chinese Literacy subtests with the TVPS-3 Visual Memory subtest, further Spearman correlation analyses were conducted with all the subtests of the Literacy assessment test and the TVPS-3 Visual Memory subtest. the TVPS-3 Visual Memory subtest score is positively correlated with most of the subtests in *Chinese Character Structure Awareness Test (中文字形结构识别能力测验),* with the exception of the *Orthographic structure recognition task (识别汉字结构)* subtest, the number of correct sequence of strokes in the subtest of *Strokes and radical copying task (基本笔画与部件抄写)* and the *Character learning and retrieval task (提取新学单词)* subtest. The TVPS-3 Visual Memory subtest score is not correlated with the test of *Reading of Single Chinese Characters (中文年级认字量表).* This suggested that visual memory played a role in the students' structure awareness of Chinese characters. For the cluster of subtests in *Comprehensive Test of Basic Reading and Writing Words (基本读写字综合测验),* the TVPS-3 Visual Memory subtest score *is* positively correlated with the *Multiple choice task (找出正确的字)* subtest and the *Short passage copying task (短文抄写)* subtest. This could suggest an interesting relationship between visual memory and accurate identification of Chinese characters, and copying of more meaningful text than single characters.

Additionally, Spearman correlation analysis tests were also performed on the scores of the Lucid Rapid screening subtests with the Chinese Literacy tests. There was a significant correlation between the scores on Lucid PHP with the scores on the Chinese Literacy tests, r_s = .54, n = 46, p < .001, between the scores on Lucid ASM with the scores on the Chinese Literacy tests, r_s = .63, n = 46, p < .001, and between the scores on Lucid PDS with the scores on the Chinese Literacy tests, r_s = .43, n = 46, p < .001. This suggested that students who scored well on the Chinese Literacy tests tend to score well on the Lucid Rapid subtests.

Discussion

The results have revealed that 'low-risk' students have better Chinese literacy skills than 'at-risk' students, showing the probable effect of dyslexia on Chinese language acquisition. Moreover, results also have shown that visual perceptual skills differ between these two groups, with 'low-risk' students having better visual perceptual skills than 'at-risk' students, further suggesting probable effect of dyslexia on other cognitive abilities such as visual perceptual skills, on top of its main effect on phonological processing abilities. However, the 2-way ANOVA has found no significant difference in Chinese literacy skills regardless of high or low visual perceptual skills with the presence of dyslexia. This shows that despite the existence of different cognitive profiles of dyslexia, the interaction effect of visual perceptual skills on Chinese literacy skills with dyslexia were not substantiated in this research study. Furthermore, the sample size may seem too small for any significant effects to be found, after the median split.

Studies that involved indirect links between visual skills and reading ability on Chinese dyslexic children (Huang & Hanley, 1997; Huang et al., 2008; Li et al., 2009) have shown that dyslexics and poor readers have weaker visual skills as compared with normal readers. Similar findings had also emerged from this research study, but had not demonstrated differing visual skills within each group on literacy skills. Therefore, this may imply that the visual aspect of individualistic cognitive profiles of dyslexia is not one of the main factors in coping with Chinese language and/or characters.

On the other hand, at a further look into the interaction between visual perceptual skills and phonological awareness for both 'low-risk' and 'at-risk' children, an interesting interactive effect on phonetic decoding skills was discovered in the comparison between both 'low-risk' and 'at-risk' groups of students who have low visual perceptual skills. As dyslexia is generally characterised by phonological deficits in cognitive processing of languages (Lyon et al., 2003; The International Dyslexia Association, 2007; Dyslexia Association of Singapore, 2009) and phonetic decoding skills is a higher order phonological awareness (Adams, 1990), it seems that this finding is in agreement with other researchers that visual perceptual skills are not a major predictive factor for learning difficulties (Huang & Hanley, 1997; Amitay, Ben-Yehudag, Banai & Ahissar, 2003; Martin, 2006) and that poor visual aspects in cognitive processing could just be one of the effects of dyslexia. This further implies that visual perceptual skills tend to be lower with the presence of dyslexia which may be a partial reason for the learning difficulty in language orthographies.

Furthermore, comparison of means in the Chinese literacy performance to understand the difference in the Chinese literacy skills and error miscues between the two groups of students can begin to create a profile of dyslexia in Singapore. The results have shown that 'at-risk' students are weaker in their orthographic structure awareness (i.e. recognising shapes and structure and radical positional knowledge), learning and retrieval of characters, and even weaker in their reading, spelling and writing abilities, than 'low-risk' students. In fact, this study looks at writing and spelling that involve necessary knowledge of semantic radicals and phonetics that include writing and checking to see if the character looks correct (Ehri, 2000, cited in McBride-Chang, 2004). Therefore, the comparison results suggest that deficits in structural and radical positional knowledge, learning and retrieval ability, reading accuracy, selecting and writing of characters based on orthographic to phonetic and semantic cues, and visual-motor integration (copying) skills are observed with the presence of dyslexia.

Reading and spelling errors that did not fit in any of the categories on error types and non-attempts were all classified under unknown errors. The results have shown that although the 'at-risk' students make more errors than 'low-risk' students based on their Chinese literacy performance, the significant difference in the unknown errors seems to suggest that 'at-risk' students tend to make more errors in their reading generally and skip unfamiliar characters easily, while 'low-risk' students were able to read more accurately and only skip genuinely unfamiliar characters. This also implies that even if unfamiliar characters were analysed and guessed, visual-orthographic skills are needed to recognise the Chinese characters to read as accurately as possible, and the presence of dyslexia makes such processing more difficult. Also, in the process of analysing and guessing, 'low-risk' students tend to make more errors that are visually-similar for characters with the same radicals (e.g. "他" /tā/ read as "地" /dì/) and phonetically-similar in terms of tone, articulation and sound omission or insertion (e.g. "肉" /ròu/ could have been read as /róu/, /lòu /, /rù/ or /riòu/). The latter error could sometimes due to local accent but would be penalised if inconsistency in pronunciation was observed.

The results of the spelling/writing error miscue analysis have shown that 'at-risk' students tend to make more errors in spelling and writing as compared to 'low-risk' students and the errors made were varied. The errors include writing non-existent characters, homophones and/or its alikes (visually-different-phonetically-same characters, e.g. "合" /hé/ was written as "和" /hé/, and visually-different-phonetically-similar characters, e.g. "亲" /qīn/ was written as "青" /qīng/), irregular characters (visually-similar-phonetically-different characters, e.g. "具" /jù/ was written as "真" /zhēn/), semantically related characters (similar-semantic-different-phonetic characters, e.g. "课[本]" /běn/ [schoolbook] was written as "书" /shū/ [book]) and also general confusion with characters that are visually, phonetically and semantically similar. McBride-Chang (2004) highlighted the complication of Chinese spelling and possibility of invented spelling by combining various semantics and phonetics to create new pseudo-characters. This shows that these spelling errors are characteristic of dyslexia and not only phonological in nature for Chinese language.

Based on the above interpretation thus far, processing of Chinese language and/or characters includes other cognitive and metalinguistic skills, besides visual perceptual skills. Meng, Cheng-Lai, Zeng, Stein and Zhou (2011) demonstrated the extent to which the impact of visual perception and its underlying neural substrates on Chinese reading development and dyslexia depends partly on orthographic structure awareness in lexical processing of the writing system. Additionally, deficits in temporal processing that are responsible for visual and auditory stimulation were likely to be associated with reading disability (Chung et al., 2008). McBride-Chang (2011) stated that metalinguistic skills do transfer across Chinese and English languages (i.e. phonological awareness, vocabulary and naming speed) but dyslexics were found to have poorer morphological skills for Chinese language. Thus, 'at-risk' students in this study were found to have poorer abilities in orthographic and structural analysis, reading and spelling, visual-motor integration in copying, learning and retrieval.

It is also believed that visual-orthographic skills do play a role in Chinese character reading (Taft & Zhu, 1997; Perfetti & Tan, 1998; Ho et al., 2002b; Ho et al., 2004; Perfetti, Liu & Tan, 2005; Siok & Fletcher, 2001). Therefore, there was an interest to find out which specific aspect of visual perceptual skills play a role in processing Chinese language and/or characters. The correlational study had shown a significant relationship between visual memory and some Chinese literacy skills and visual memory seemed to be involved in the following processes: identifying shapes and structures of Chinese characters (but not the orthographic structure and positions of radicals), copying of strokes and radicals, learning and retrieval of Chinese characters, selecting correct Chinese characters to phonetic cues, and copying of meaningful text (but not single Chinese characters). Furthermore, the results demonstrated relatively stronger relationships between visual memory and copying of strokes and radicals, and learning and retrieval of Chinese characters.

Pak et al. (2005) found that visual chunking skills advance over time as children mature gradually from processing of Chinese characters by stroke to semantic and phonetic radicals with the involvement of working memory, so as to facilitate quicker and more accurate copying and reading when they grow older. In other words, chunking of visual features of Chinese characters through the use of working memory could be based on visual memory.

Interestingly, despite the research findings on visual skills and reading ability (Huang & Hanley, 1997; Huang et al., 2008; Li et al., 2009), no relationship between visual memory and reading accuracy was found from this research study. It is highly likely that visual memory does not play a direct role in Chinese character identification and reading accuracy, but other cognitive processes do. Likewise, the Chinese literacy subtest that measures orthographic structure and radical positional awareness did not show any relationship with visual memory as well. Zhang and Simon (1985) had verified that there is some involvement of visual or semantic memory which retains visual chunks (i.e. radicals of a Chinese character) while processing the Chinese character phonologically. Yeh et al. (2003) further concluded that the visual aspect of Chinese characters is more related to the cognitive process in pattern recognition while the orthographic structure aspect is more related to the cognitive linguistic process. Therefore, this probably explains the significant relationship with *Character shape and structure matching task (部件组合形式)* but not in the *Orthographic structure recognition task (识别汉字结构),* implying that other cognitive skills are required in understanding the orthographic structure and radical positions within a Chinese character.

Besides visual memory, there is an overall positive correlation between the LUCID scores and the Chinese literacy scores. With the fact that 'low-risk' students scored higher and make less errors on the Chinese literacy scores compared to 'at-risk' students, it suggested that impairment in language processing for dyslexia is not language specific. That is, bilinguals with dyslexia could do badly across different languages. Moreover, both auditory and phonological awareness were found to be associated with word reading across languages (Chung, Mc-Bride-Chang, Cheung & Wong, 2011). In an fMRI study by Tham et al. (2005), there were several distinct areas of brain activation in both hemispheres for both Chinese and English languages which are mainly for phonological processing. Thus, with dyslexia being characterised with deficits in the phonological component in language processing (Lyon et al., 2003; The International Dyslexia Association, 2007; Dyslexia Association of Singapore, 2009), it is believed that dyslexics would face difficulty in language acquisition in general.

In the correlational analysis for LUCID sub-scores, the generally stronger and more consistent positive relationships between phonological processing and auditory sequential memory probably suggested that processing of Chinese language (i.e. reading and writing Chinese characters) does not necessarily involve phonetic decoding skills, unlike English language which uses an alphabetic system with letter-sound correspondence. The linguistic properties of both languages are opposite to each other – Chinese is an analytic, tonal and non-inflected language whereas English is a synthetic, atonal and inflected language (Chung et al., 2011). Studies have shown that Chinese children learning to read Chinese characters need to be sensitive to the phonological components of the lexical processing at the awareness level of syllables with onset and rime, rather than phonemic awareness level (McBride-Chang & Ho, 2000; Siok & Fletcher, 2001; Leong, Cheng and Tan, 2005). A general auditory processing skill was also found to be an underlying factor – a shared phonological skill in onset and rime segmentation, and Chinese tone detection and matching – that links the acquisition of both Chinese and English reading together (Wang, Perfetti and Liu, 2005).

In summary, the study yielded the following findings:

1. Language processing impairment persists across different languages (namely English and Chinese).
2. Literacy skills such as visual-orthographic skills, morphological awareness and visual-motor integration skills, were the observed differences with regard to "risk of dyslexia" in Chinese language acquisition.
3. Some aspects of the processing of the Chinese language require visual memory, which was found to be relatively weaker in the dyslexic students of the study.

Therefore, the first steps to literacy in a Chinese classroom is to begin with learning of strokes in direction and order, pictographic characters such as “山” (mountain) and “火” (fire), radicals of complex characters, and simultaneously with introduction of ‘hanyu pinyin’ through rhymes, syllables and tone diacritics (Ingulsrud & Allen, 2003). Chen and Lin (2009) argued that literacy intervention for Chinese children should cover three main areas that may be most beneficial. Firstly, phonological awareness intervention focuses on syllable awareness and progresses gradually to onset-rime awareness and tone awareness. Chinese tone detection – a new and more complex form of phonological process in the Chinese language, was found a predictive factor for acquiring English reading and future research was suggested in helping dyslexic children to improve their reading ability by training in Chinese tone detection (Wang et al., 2005). Secondly, building awareness of Chinese character orthographic structure as the majority of Chinese characters consist of radicals that are semantic-phonetic in nature. Visual-orthographic skills are skills needed to recognise shapes and structure of a Chinese character and understand radical positional rules (e.g. where is 氵?). This allows for the strategic attempt of “splitting into parts” when reading Chinese as accurately as possible (e.g. 也、他、地).

Thus, training of phonological strategies can be done simultaneously while children learn to identify and analyse meaning and pronunciation of semantic-phonetic radicals within the characters.

Last but not least, morphological awareness intervention is helpful, because another salient feature of Chinese language is the large number of homophones, such as /jǐu/ can be "九", "酒" or "久" which means "nine", "liquor" or "long (time)" respectively. This also helps to clarify rules and expand knowledge. For example, when a character is read (e.g. "大" /dà/ [big]), two characters can be formed with another character (e.g. "大象" /dà xiàng/ [big elephant] and "伟大" /wěi dà/ [great or mighty]). Having such awareness allows for visual chunking skills to process Chinese characters efficiently and accurately, especially in reading fluency and writing (i.e. copying, spelling and even learning and retrieval). Poor visual chunking skills also indicate lack of sufficient morphological awareness in orthographic and radical positional and functional knowledge to process Chinese characters efficiently and accurately (McBride-Chang, 2011; Cao, 2011). Thus, children can be taught to identify and differentiate by forming new words with a character and analysing the relationship of the words, simultaneously with character orthographic structure training. A well-structured pedagogy of morphological instruction was found to be useful for children with dyslexia in Beijing and Hong Kong (Cheng-Lai, 2010). Studies in mainland China (Shu, McBride-Chang, Wu & Liu, 2006) and Hong Kong (Chung et al., 2008) have pointed out morphological awareness as a point of distinction of children with and without dyslexia. As morphological awareness is a key contributor to reading development in Chinese, it is then essential that intervention targets this area of difficulty.

Lin et al. (2009) had identified four strategies from their study on Hong Kong mothers and children that vary in learning autonomy with age. The least effective strategies were copying and visualisation (rote memory learning through practice and test drills). The more effective strategies were segmentation of radical forms and functions, and morphological instruction due to the pictographic and semantic-phonetic componential nature of Chinese characters. On the other hand, Aram and Levin (2004) found that the quality of the latter strategies partially influence the literacy development of the children in their longitudinal study. Segmentation and morphological strategies need to be mediated well with adults clarifying rules, expanding knowledge and facilitating these children with tools to cope in literacy tasks, rather than mere modelling of procedures of character deconstruction.

Overall, Chinese literacy instruction should encompass all the above propositions with the acknowledgement that Chinese language and/or characters processes engage in the activation of visual, phonological and semantic nodes in working memory, according to the EPAM theory (Feigenbaum & Simon, 1984; Best, 2006), lexical constituency model (Perfetti & Tan, 1998), interactive activation model (Taft & Zhu, 1997) and polysyllabic-character visual recognition framework (Tan & Perfetti, 1999). Ng, Varley and

Andrade (2000) found an effective way of mediating information for recognition to be finger tracing as it stimulates both spatial and sequential awareness of the strokes in a character through kinaesthetic feedback. They reiterated its effectiveness for a subgroup of dyslexics with visual deficits by stating that 'this proprioceptive channel may be an augmentation to their deficient visual processing route and finger tracing may be a useful intervention method to alleviate reading difficulties' (Ng et al. 2000, p.569). In other words, it was suggested the beneficial effect of finger-tracing to improve writing or remembering Chinese characters as the sequence and spatial information embedded in the kinaesthetic-tactile movements can be a part of mediating visuo-spatial information, implying the importance of visual skills in Chinese language acquisition. Moreover, simultaneous multisensory approaches to learning have been proven effective for dyslexic learners (Gillingham & Stillman, 1997). Visual-integration skills are basically copying and writing skills, such as producing a Chinese character with strokes that are in the correct direction, sequence and proportion and learning and retrieval of Chinese characters. McBride-Chang (2011) illustrated a study conducted in Hong Kong which investigated paired-association and visual -motor integration skills of dyslexics and non-dyslexics through use of nonsense names with pictures and unfamiliar languages. It was found that dyslexics' poor performance was not because of inexperience with print but the orthography and paired-association learning of language in general.

Another question related to Chinese language acquisition in Singapore is the implication of Chinese being a second language on experience with print. Poor performance in language could be due to learning difficulties such as dyslexia or experience with print. Given that dyslexia is a lifelong condition and its rate of occurrence in the population, it is important and vital that intervention is done early and is effective. Early intervention improves the rate of success by close to four times (Hall & Linch, 2007) and other benefits includes earlier development of compensatory strategies, and lowered risk of development of emotional and behaviour problems. As such, intervention programmes need to be measured for effectiveness to ensure that these students benefit from intervention. The use of the response-to-intervention model has been on the rise in the recent years, especially on individuals with learning difficulties.

Ho (2010) developed a three-tiered response-to-intervention model to identify and teach children with learning disabilities in Hong Kong. A total of 573 participants who were in Grade 1 contributed to the study. The results of the study showed that oral language, morphological awareness and orthographic skills made significant contributions to Chinese word reading and dictation. In addition, it was also found that syntactic awareness made significant contribution to reading comprehension, reading fluency and simple writing. As such, it was concluded that oral language, morphological awareness, orthographic skills and syntactic awareness are significant reading-related cognitive-linguistic skills in mastering Chinese. Similar to Ho's study, the aim of this study is to measure students with dyslexia's response to intervention and if it is effective in developing skills critical to the mastery of Chinese language.

STUDY 2

DAS Chinese Remediation Programme

Following the findings from the preliminary survey and previous study, the team started developing a remediation programme in 2012 focusing on oracy and word recognition components, as well as building interest in the Chinese language. The Chinese remediation programme started in January 2013 and emphasises three main aspects:

1. Common vocabulary and sentence structure to enhance the student's expressiveness using Chinese language.
2. Character structures, radicals and stroke patterns to enhance the student's word recognition skills.
3. Morphological awareness to help expand the student's vocabulary network.

The aim of the programme is to help students become independent and inquisitive learners in Chinese language. Students are taught the orthographic structures of Chinese characters, based on 谢 (2002) who named 14 basic structures that help with visual chunking in order to identify types of radicals. At the same time, students are taught the different types of radicals and their legal positions in order to decipher the semantic and phonetic components within the Chinese characters. According to Ho, Yau and Au (2003, cited by McBride-Chang, 2004), orthographic knowledge development for reading and spelling skills involve a progressive set of processes: (1) character configuration knowledge – rudimentary orthographic skill that differentiates writing from drawing of Chinese characters, (2) structural knowledge – understanding of Chinese characters being compounded with two or more separate components called radicals, (3) radical information and positional knowledge – understanding of the meanings of semantic radicals and their legal positions within the Chinese characters, (4) functional knowledge – ability to associate phonetic radicals with particular sounds and semantic radicals with particular meanings, (5) amalgamation stage – combining knowledge of forms, functions and positions of phonetic and semantic radicals, and (6) complete orthographic knowledge – ability to read and write correct Chinese characters consistently and logical understanding of semantic and phonetic radicals in pseudo-characters. Thus, students are also taught to produce strokes and stroke patterns (e.g. 亅, 丷 and 钅) in proper direction, sequence and proportion.

With the Orton-Gillingham teaching principles (Gillingham and Stillman, 1997) adapted in the remediation programme, students are taught through hands-on activities, educational games, storytelling, as well as tracing and tracking of characters/words. These aspects are delivered through themes that surround the student and his/her everyday life (e.g.

myself, home, school, neighbourhood, etc). The focus of these teaching methods is for the students to find the language more meaningful as they relate what they are taught in class to themselves and their surroundings, and hence gain interest in using the language. The teachers are effectively bilingual to facilitate teaching. This allows for the teachers to be able to tap into their English vocabulary and help the students to express themselves in Chinese.

While the programme does not follow the school's curriculum, the coverage of the vocabulary used is based on the Ministry of Education (MOE) Primary school syllabus for Chinese (2007). This programme is also designed to suit the varied profile of our students. To date, there are 53 students enrolled in the Chinese remediation programme. Most of the students often speak English (62%), sometimes speak Mandarin (63%) and never speak a dialect (83%) at home. These were reported by parents when they enroll their children for the programme.

As Study 1 was only conducted with Primary Four students, whose mean age was about 9 years, further research is needed to gain greater understanding about the difficulties of dyslexic students in the Chinese language as well as to study the effectiveness of the programme. In addition, the Chinese remediation programme is the first intervention programme developed for students with special needs in Singapore by the DAS. Thus, pre- and post-tests are conducted for students who are on the Chinese remediation programme in order to monitor their progress. The assessments for pre-testing are also used to profile the students according to their strengths and weaknesses so that intervention can be better targeted. Parents who enrol their children in the programme are aware that their children will be contributing to the evaluation study on its effectiveness.

Methodology

Participants

A total of 16 participants (4 females, 12 males) with a diagnosis of dyslexia were involved in the study. Participants were between the ages of 6 to 12, the majority were in Primary 3 and 4, and are enrolled in a local primary school. Gender was not controlled as it is not considered as a factor in the study. Nevertheless, the sample used is representative of a dyslexic population, with more males than females.

Procedure

The purpose of the pre- and post-test carried out on the participants was to measure the effectiveness of intervention in helping primary school students with dyslexia. The pre-test was conducted prior to the start of intervention. After which, participants received remediation once a week for an hour. The post-test was then carried out after at least six months of intervention. If the participant was unable to undergo the post-test within nine months of intervention, their results were omitted. On average, participants underwent remediation for 8.19 months prior to post-testing. At the stage of post-testing, participants were at a mean age of 9.71 years old.

Assessment tools and administration

The testing tool used was The Revised Battery of Chinese Literacy Tests based on Study 1 conducted from 2010 to 2011.The test takes about 60 to 90 minutes long to administer. All instructions given for the test were provided in the assessor's guide to ensure that the same instructions were given to all participants and at both pre and post testing, so as to minimise any tester bias. In addition, practice questions were used to ensure that participants understood the instruction given. The test was carried out in Chinese language as much as possible and in instances that the participant has great difficulty in understanding Chinese language, instructions were translated into English.

The assessment can be broken down into four main tests measuring Chinese character orthographic awareness, character reading and vocabulary, basic Chinese character reading and writing and picture sequencing and verbal expression. Table 2 below illustrates the components assessed in each main test.

Results

In order to assess the effectiveness of the programme and whether students are benefiting from the intervention, mean scores of their pre- and post- tests were compared using within-samples t-tests. There was a significant difference in overall Chinese Literacy scores, between pre-test (mean = 313.75, s.d. = 91.46) and

Table 2. Main tests and components

Revised Battery of Chinese Literacy Tests	**Components Assessed**
1. Chinese Character Orthographic Awareness	a. Shape and Structure Matching b. Orthographic Structure Recognition c. Strokes and Radicals Copying d. Character Learning and Retrieval
2. Chinese Character Reading Test	a. Reading of Characters b. Vocabulary Knowledge Test
3. Basic Chinese Character Reading and Writing	a. Multiple-choice Spelling b. Free Recall Spelling c. Short Passage Copying
4. Picture Sequencing and Verbal Expression	a. Picture Sequence and Description b. Freedom of Expression

post-test (mean = 354.44, s.d. = 93.47), $t(15) = -5.13$, $p < .001$. This suggests that the students' Chinese literacy skills have improved significantly after receiving intervention.

The pre- and post- test mean scores for each main test and their components in the Revised Battery of Chinese Literacy Tests were also compared to better understand the areas in which students had benefited from intervention. The results showed that there is a significant improvement in "Chinese Character Orthographic Awareness Test", $t(15) = -5.24$, $p < .001$. For its components, there is significant improvement in the mean scores of "shape and structure recognition" and "strokes and radical copying", $t(15) = -3.47$ and $t(15) = -2.94$, $p < .01$ respectively. There is also improvement in the mean scores of "Character learning and retrieval", $t(15) = -2.72$, $p < .05$. A graphic representation of the means comparisons is shown in Figure 2.

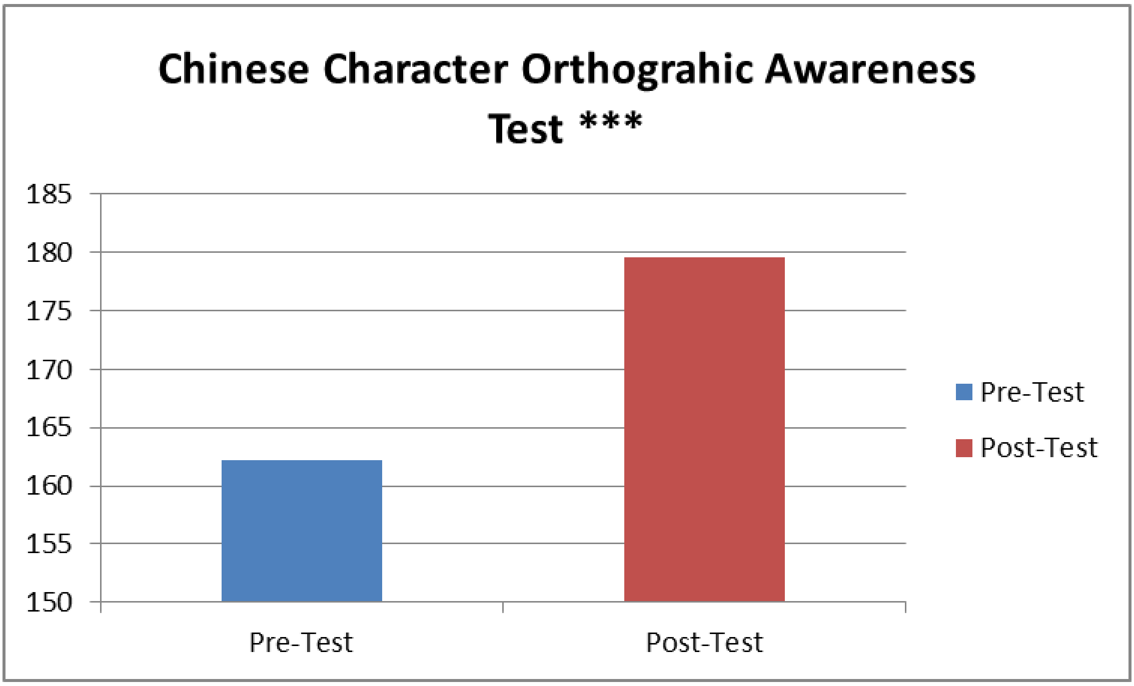
In the "Chinese Character Reading Test", mean scores showed significant improvement, $t(15) = -4.04$, $p < .001$. Students were also better able to form meaning to characters that they read, as the scores of "Vocabulary Knowledge Reading Test" have significantly improved, $t(15) = -3.09$, $p < .01$. A graphic representation of the means comparisons is shown in Figure 3.

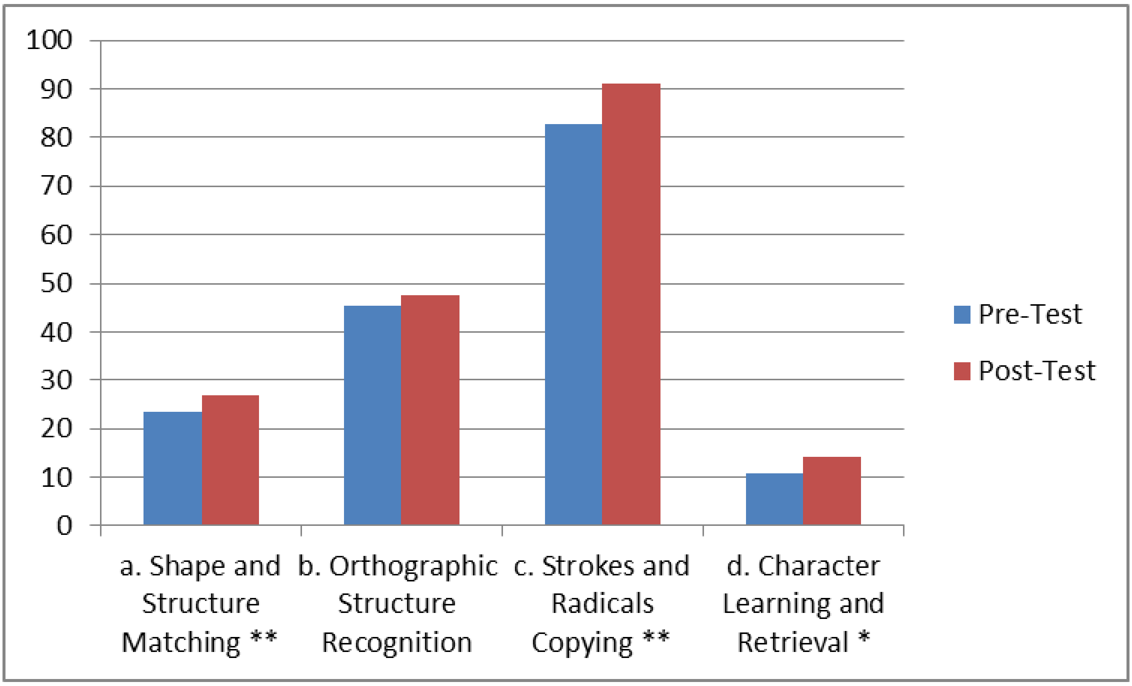
However, there were no other significant results for writing and oral tests, and although the results showed an increase in scores at post-test, these are not statistically significant.

Comparison of mean scores was also conducted for Reading errors, and there was a significant difference between pre-test (mean = 155.94, s.d. = 25.80) and post-test (mean = 148.56, s.d. = 25.98), $t(15) = 4.066$, $p < .001$. Although the mean number of errors made in the post-test was comparatively less than those made in pre-test, only the Phonetic-Semantic Error showed a significant difference, $t(15) = 4.16$, $p < .001$.

In order to yield greater analysis of the programme effectiveness, Pearson correlations between the main tests were conducted so as to have a better understanding of how the participants have benefited from the programme. Statistical results have shown interesting findings.

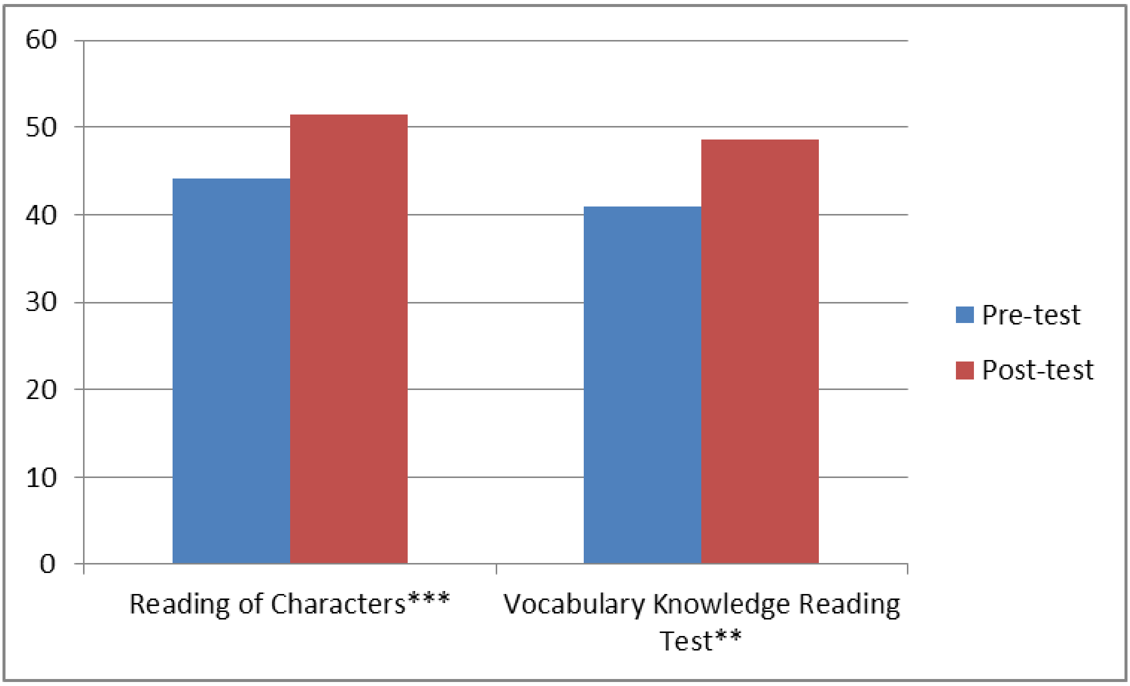
In the pre-test, there were significant correlations between "Chinese Character Orthographic Awareness Test" and the components of "Chinese Character Reading Test" – with "Reading of Characters", r = .67, n = 16, $p < .01$, and with "Vocabulary Knowledge Reading", r = .71, n = 16, $p < .01$. The components of "Chinese Character Reading Test" also correlate significantly with "Basic Character Reading and Writing Test", r = .57, n = 16, $p < .05$ and r = .67, n = 16, $p < .01$ respectively. In addition, the "Picture Sequencing and Verbal Expressions Test" correlates significantly with "Chinese Character Orthographic Awareness Test", r = .66, n = 16, $p < .05$, with "Reading of Characters", r = .56, n = 16, $p < .05$, as well as with "Vocabulary Knowledge Reading", r = .62, n = 16, $p < .05$.





$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Figure 2. *Comparison of Pre-test and Post-test scores (Test 1 - Chinese Character Orthographic Awareness Test)*



*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Figure 3. Comparison of Pre-test and Post-test scores (Test 2 - Chinese Character Reading Test)

In the post-test, correlations between "Chinese Character Orthographic Awareness Test" and components of "Chinese Character Reading Test" remain significant – with "reading of Characters", r = .69, n = 16, $p < .01$, and with "Vocabulary Knowledge Reading", r = .62, n = 16, $p < .05$. Similarly, the correlations between the components of "Chinese Character Reading Test" remain significant with "Basic Character Reading and Writing Test", r = .65, n = 16, $p < .01$ and r = .67, n = 16, $p < .01$ respectively, indicating a stronger relationship as compared to pre-test. Interestingly, new significant correlations were found between "Chinese Character Reading Test" and one of the components of "Basic Character Reading and Writing Test" which is the "Short Passage Copying" (number of correct words copied and copying speed), r = .53, n = 16, $p < .05$ and r = .54, n = 16, $p < .05$ respectively. The correlations of "Picture Sequencing and Verbal Expressions Test" with "Chinese Character Orthographic Awareness Test", "Reading of Characters" and "Vocabulary Knowledge Reading" also remain significant, r = .52, n = 16, $p < .05$, r_s = .53, n = 16, $p < .05$ and r = .55, n = 16, $p < .05$ respectively.

Discussion

Participants showed improvements in their overall literacy skills after intervention, suggesting that the remediation programme had been effective for them. The significant improvement in mean scores of components in the "Chinese Character Orthographic Awareness Test" suggests that participants have gained better awareness of how characters are formed through strokes and stroke patterns, which may also have helped them to learn and remember an unfamiliar character.

Participants' reading of Chinese characters and ability to build vocabulary knowledge showed significant improvement. That is, they are able to recognise more Chinese characters and form meaning (e.g. 他 /tā/ ➔ 他们, instead of 地 /dì/). Although the improvement "Basic Character Reading and Writing Test" which assesses writing aspects of Chinese language was not significant, studies have also shown the relationship between orthographical awareness and reading/writing of Chinese characters (Li, Shu, McBride-Chang, Liu & Peng, 2012; Tong & McBride-Chang, 2014; Packard, Chen, Li, Wu, Gaffney, Li & Anderson, 2006)

Moreover, the significant decrease in mean number of Reading errors suggests that students tend to make less wild guesses on or 'skip' unfamiliar Chinese characters when reading. In other words, participants seem to be able to recognise more Chinese characters and are better able to apply orthographical and morphological skills in reading. In addition, the significantly lower number of Phonetic-Semantic Errors in the post-test suggests that students are less confused by homophones as well as semantically-related characters caused by mispronunciation. According to Tzeng (1994), learning the logographs (i.e. orthographical symbols) of Chinese characters also involves phonological understanding of the language. Hence, together with morphological skills training, confusion and mispronunciation of homophones have significantly reduced.

Though there are improvements in orthographical awareness, morphological skills and reading, these do not seem to be translated into areas of spelling and writing as well as verbal expressiveness. A further analysis on the relationship between scores on the Chinese character orthographic awareness test with reading and spelling scores yields some understanding. The relationship found between "Character Reading Test" and "Basic Character Reading and Writing Test" scores reflecting the strong relationship between understanding orthographic structure and morphologic awareness of Chinese characters in order to be able to read and write. Li et al. (2012) found that morphological construction and orthographic skills are important in literacy development for Chinese language, though the latter was found more prominent particularly in primary school.

Furthermore, the comparison between the pre- and post-tests and stronger relationship between the "Chinese Character Reading Test" and "Basic Character Reading and Writing Test" in the post-test analysis indicate that the intervention was effective for the participants in building Chinese literacy skills. Packard et al. (2006) found in their experimental study that increased knowledge of orthographic and morphological structure of Chinese characters improved children's ability to copy and write from memory. They also provided some educational implications of such explicit instruction in getting children to learn to write. Hence, this research study can deepen our understanding of the sub-skills that are important in development of competence in spelling and writing in Chinese. Implications of this research study are discussed in the following section.

CONCLUSION AND FUTURE IMPLICATIONS

Despite the small sample sizes, findings of both Study 1 and Study 2 have provided valuable insights on the difficulties of Chinese language acquisition that are unique in the presence of dyslexia and the effectiveness of intervention developed for the DAS Chinese remediation programme.

A study done by Goswami, Wang, Cruz, Fosker, Mead and Huss (2011) supported the language-universal theory of identifying phonological awareness as the most significant predictor of language acquisition despite the phonological and orthographical differences between different languages. A study on dyslexic Hong Kong Chinese children by Chung and Ho (2010) also found evidence for different units of phonological awareness that are related to the characteristics of the different languages being learned, supporting the theories of psycholinguistic grain size and linguistic coding differences. In a similar study, Wang, Georgiou, Das and Li (2012) found phonological processing significantly poorer in dyslexic children than their normal peers, including other processes such as orthographic processing and successive and simultaneous processing. Ho and Yan (2014) also found similar results to Study 1 that children with learning difficulties may not prefer to use orthographic processing in learning Chinese characters, in comparison to their other peers without learning difficulties. These studies supported the findings of Study 1 that our students do struggle with learning of Chinese due to dyslexia and their difficulties can be unique from those without dyslexia.

Goswami et al. (2011) added that remediation strategies that involve rhythmic perception and syllable segmentation according to the nature of language should benefit learners in their linguistic development. Tong and McBride-Chang (2010) suggested best-fitting models that benefit Hong Kong students (from Kindergarten to fifth graders) generally involve metalinguistic constructs that involve orthographical and morphological processing. A cross-sectional study conducted by Liao (2007) on Taiwanese children found that phonological awareness and rapid naming are important skills for Chinese literacy development and that systematic understanding of radical function and internal orthographic structure of characters develops greater reading proficiency. These studies have also supported the direction in which the DAS

Chinese Remediation Programme is developed and the positive results yielded in Study 2.

To supplement the overall findings, feedback on students' academic achievements in school as well as testimonials from parents and educational therapists were gathered during DAS' biennial Parent-Therapist Conference. All written records of the discussions were collated and summarised. According to feedback from parents, the students have shown improvement in their Chinese grades in school, especially in their oral scores. One student (Primary 3) was awarded the Most Improvement Award in Chinese for his level. And another student (Primary 3) scored the second highest in his Chinese class. Moreover, parents have reported an increased interest in their children in learning Chinese after starting classes at the DAS. They are generally happy with the improvement in their children in terms of verbal expressiveness and confidence in speaking Mandarin in social settings. Further feedback has suggested that the effectiveness of the remediation support and intervention could be further developed to higher level of learning. Parents have asked for longer classes so that their children could have greater exposure to Chinese language and more in-depth learning. Some parents are requesting more support beyond oracy with literacy components such as comprehension skills and composition writing, as well as strategies to prepare students to cope with Chinese language papers at the Primary School Leaving Examinations (PSLE).

Therefore, the Chinese remediation programme should continue to be researched and reviewed, by looking into enhancing other literacy skills such as writing, as writing is required to gain mastery of the language. More emphasis on writing and comprehension components should also be considered in remediating and assessing the students, in response to the feedback received from parents. As students' views on the Chinese language have not been reflected or captured in this research study, it would be vital that we gather such information to evaluate if we have been successful in meeting the objective of building their interest in the language. It would also serve to inform the educational therapists of the attitude of students towards the language and provide useful insights on what matters in developing literacy skills in Chinese in learners with dyslexia.

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Factors related to reading comprehension weaknesses in Persian speaking Primary school children

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The work reported in this paper investigated potential influences of word-level and understanding-level processes on reading comprehension deficits identified in monolingual Persian primary school children. The research contrasted the performance of average comprehenders (N=173) with those with poor text reading comprehension scores (N=33) to identify underlying cognitive deficits associated with text comprehension problems in this language. Two measures of reading comprehension (one involving passage reading and question answering, the other sentence completion) were used to identify reading comprehension weaknesses. Poor comprehenders were considered as those who performed within the bottom 15% of the cohort in both measures. These poor comprehenders were then divided into those with weak decoding skills (one standard deviation below average on a measure of non-word reading) and those without. The performance of the selected groups on measures of phonological and orthographic processing, linguistic ability and speed of processing was contrasted. Findings indicated that children with comprehension problems showed difficulties in language skills related to listening comprehension. Those with additional weaknesses in decoding also showed deficits in phonological areas, whereas those without decoding weaknesses were more likely to show additional problems with orthographic processing. Implications for theoretical perspectives on reading comprehension deficits and practice will be considered.

Key words: Reading comprehension; Poor comprehenders; Persian children

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Introduction

Early reading acquisition starts with the individual learning to map letters (or graphemes) onto language sounds in order to decode and recognize words. However, reading words accurately is not sufficient for text comprehension. It is also necessary to understand comprehension processes when considering the underlying skills that support text reading. This may be of particular importance when attempting to determine the underlying reasons for reading comprehension difficulties, as in educational assessment practices targeted at children with developmental learning problems. For example, research in the UK suggests that a reasonably large number of children (possibly as many as 10% of primary school children) show a profile of comprehension deficits relative to age-appropriate word reading/decoding accuracy (Cain & Oakhill, 2007; Nation & Norbury, 2005; Yuill & Oakhill, 1991).

This potential dissociation between decoding/recognition and understanding/comprehension can be represented by the simple view of reading (SVR) which emphasizes the importance of decoding and linguistic comprehension processes (see also Bishop & Snowling, 2004; Gough & Tunmer, 1986; Hoover & Gough, 1990; Nation & Norbury, 2005). Children can show variability in one or both sets of skills (i.e., decoding and linguistic comprehension) which will be associated with poor to good reading comprehension. According to the SVR, a child with good skills in decoding and language comprehension should have no reading comprehension difficulties (Hoover & Gough, 1990). In contrast, those who have poor decoding skills, such as children with developmental dyslexia (Castles & Coltheart, 1993), will show poor scores in measures of reading comprehension due to poor written word processing making it difficult to access the meaning of individual work, even when language comprehension is at age-appropriate levels. The opposite profile, as referred to above, is the child with good decoding skills who still has reading comprehension deficits associated with language comprehension weaknesses (Ricketts, Cocksey, & Nation, 2011). Hence, research that aims to investigate the underlying cognitive-linguistic profile of children with reading comprehension deficits (as in the present work) should consider these potentially different sub-groups of learners with reading comprehension difficulties; i.e., those with and without accompanying decoding weaknesses.

Reading comprehension is a multifaceted process that involves many of the skills that are fundamental to human cognition (Kintsch, 1988, 1998). Therefore, comprehension can fail for a variety of reasons that need to be better understood to allow research and practice to develop a poor comprehender profile. The current research aimed to inform the development of such profiles by investigating underlying skills factors potentially related to poor text reading comprehension in primary level children in Iran learning to read and write in Persian. This context was chosen due to the relative lack of research specifically on Persian reading comprehension difficulties and because of features of the Persian writing system that may lead to skills developing differently from those predicted by current models of reading derived from English. There is a history of identifying reading problems and providing support for those with early literacy learning problems in Iran (see discussion in Tehrani, 2007); however, this has focused on word-level reading and related phonological skills, with interventions targeting phonological decoding processes. Hence, although the term dyslexia is not widely used in Iran, the emphasis is on those difficulties more associated with dyslexia. There is little work investigating underlying factors related to reading comprehension difficulties in young children, which is the focus of the present study.

The Persian orthography has relatively direct (one-to-one) correspondences when translating from graphemes into phonemes in its fully vowelized form – although, there are individual phonemes that can be represented by more than one grapheme, which can create more problems for spelling. The orthography is cursive (most letters change their shape when connecting to letters around them) and uses combinations of dots and marks within and around basic symbol shapes to distinguish letters, determine pronunciation, and represent syntactic rules and morphological forms. In addition, several such marks are used to represent short vowel sounds and these vowel markers are not always included in written text, particularly in passages targeted at readers beyond the beginner stage (after grade one in the present context). The elimination of short vowel markers leads potentially to written text that has a large number of letter strings with several possible pronunciations (i.e., homographs). This means that, at least after first grade, Persian children will need to learn to infer pronunciation and meaning from the context within which a word is written. Hence, the current research focused on young learners of Persian from grade 2 to 5, the early years of reading acquisition when basic skills can be investigated, but following the point (after grade 1) when there is a need to start using text inference strategies to support the accessing of the pronunciation and meaning of individual words. This provides a relatively unique context in which to study the interaction between word-level and comprehension-level processes as well as to consider manifestations of reading comprehension deficits.

The current research, therefore, targeted both word-level and language understanding processes in order to investigate their potential influence on reading comprehension in Persian. As suggested by the SVR, poor comprehenders can demonstrate weaknesses in comprehending orally presented sentences and discourse, which can be assessed by listening comprehension measures (Catts, Adlof, & Weismer, 2006), despite good decoding skills (Nation & Snowling, 2004). However, inclusion of other aspects of language seems also necessary in order to produce a more reliable index of linguistic competence (see Kirby & Savage, 2008; Ouellette & Beers, 2010 for a review). Therefore in the current study vocabulary measures along with listening comprehension were utilized; and vocabulary has been found to explain unique variance in reading comprehension (Nation & Snowling, 2004). The inclusion of vocabulary and listening comprehension has the added benefit of allowing comparisons of processing meaning related to individual words versus meaning related to text (see discussions in Cain & Oakhill, 2007).

At the word level, reading requires knowledge of print and spoken forms of the language; that is, the rules that relate print to the spoken form (Frost, 2012; Juel, Griffith, & Gough, 1986). Learning to read is learning how one's writing system encodes one's language. This claim reflects the view that reading is fundamentally about converting, or decoding, the graphic input (written characters, letters, words) to linguistic-conceptual objects (spoken words, morphemes, and their associated concepts) (Perfetti & Zhang, 1995). Decoding refers to the ability to translate letters/graphemes into appropriate language sounds.

To decode, the reader needs to be able to apply rules about the relationship between written forms and sounds (such as grapheme-phoneme correspondence rules) that allows retrieval of spoken forms plus meaning from memory. Therefore, a vital part of this process is the ability to recognize language sounds (i.e., phonological information). Early decoding is heavily dependent on letter-sound relationships; letter-sound knowledge is also essential to consolidate orthographic representations required for automatization of silent word reading or sight word knowledge (Ehri, 2005).

However, word processing need not only be performed through phonological decoding. The dual-route model (Coltheart, 1985) suggests that there are two routes to reading aloud: the direct route and the indirect route (Castles, 2006). The indirect route, also known as the non-lexical or sub-lexical route, involves the phonological processes described above and implies that the reader uses grapheme-phoneme correspondence rules to relate letters to their corresponding sounds in order to produce word pronunciation through which access to the lexicon is provided (Coltheart, 2006). The direct (or lexical) route, on the other hand, involves the pronunciation of words from their visual/orthographic form. Words learnt by the reader are stored as specific entries within the lexicon leading to this written form of a word directly activating meaning without the need to convert into a form that the verbal language system can process. This association between the written form of the word and its meaning is arbitrary and must be learnt through experience (Coltheart, Curtis, Atkins, & Haller, 1993).

This model of word reading implies the need to assess two types of word-level processes: one that requires the ability to recognise sounds within words in order to develop the knowledge of grapheme-phoneme correspondence rules used for the indirect route, and one that requires the ability to recognise orthographic word patterns to process written words into the lexicon via the direct route. Variations in the underlying processes of these two routes being related to variations in reading comprehension, particularly for readers matched on their decoding skills, would also be theoretically interesting. Hence, in order to assess both these areas, measures of phonological awareness and orthographic knowledge were including in the study.

The above word recognition processes are typically measured via tasks that require accurate processing of linguistic material – either verbally presented or written. However, fluent access to word meaning is required in text reading comprehension (Tannenbaum, Torgesen, & Wagner, 2006) and hence measures of speeded processing have also been considered in models related to the SVR (see Joshi & Aaron, 2000, for a discussion of how speed might need to be considered as an additional predictor of reading comprehension independent of linguistic comprehension and word decoding). The inclusion of measures of fluency has been seen as particularly important when assessing literacy levels among children learning more transparent, regular orthographies (Smythe et al., 2008; Wimmer & Goswami, 1994).

Given that early learning of Persian literacy involves the use of vowelized words, which are highly regular in terms of decoding, then fluency may also be predictive of variability in reading levels. However, the relationship between speeded naming and reading may be dependent on whether or not letter strings are the items to be processed quickly. Therefore, in order to study how Persian poor comprehenders perform on rapid naming tasks, the current study included measures of speeded word naming (reading fluency) and speeded object naming (RAN).

Therefore, the current study was designed to further investigate poor comprehender profiles by contrasting different groups of poor comprehenders on their underlying language and word processing skills within a language that has been relatively under-researched, but which uses an orthography that has the potential to produce different relationships between word-level and text-level processes to those found in English.

The skills targeted were derived from a working model of Persian reading (see Sadeghi, Everatt, and McNeill, submitted) based on current models of reading that have been used effectively in cross-language research: specifically the simple view of reading and the dual route model. The measures included in the study were taken from previous work that has involved the development of Persian language materials (see Sadeghi, Everatt, McNeill, and Rezaei, 2014; Sadeghi et al., submitted) and included assessments of reading comprehension and decoding, as well as measures of oral language skill, phonological awareness, orthographic processing and rapid naming.

Hence, the present research provides a basis on which to assess the potential usefulness of models, such as the simple view of reading and the dual route model, for developing ways of identifying children with specific reading comprehension deficits across different languages/orthographies. It should also provide the basis on which to develop assessment tools targeted at identifying children with specific reading comprehension deficits learning the Persian orthography.

Methods

A cohort of 206 Persian primary school children in grades 2 to 5, attending mainstream Iranian school in Tehran, was tested on two text reading comprehension measures: (i) a silent passage reading and question task (similar tasks can be found in Berown, Hammill, & Wiederholt, 2009) and (ii) a passage Cloze completion task (similar tasks can be found in Woodcock, McGrew, & Mather, 2001). Both measures required the child to understand the text in order to perform the task correctly. In the first task, the child was required to read six passages quietly and answer approximately four multiple-choice questions about the passage; a total of 23 multiple-choice questions was used in this measure. Passage length and grade level (i.e., complexity) increased across the six passages. Answers included three distracters and one correct response and questions were either referential or inferential (10 inferential questions and 13 referential questions). In the second task, children were required to read six passages silently and fill in the gaps in the passages with the appropriate word selected from a list of key words (including distracter items) presented at the beginning of each passage. A total of 26 missing words were included in the passages and any misspellings by the children were ignored in marking as long as it was clear that the child meant the correct word. Similar to the first reading comprehension task, passage length and grade level (i.e., complexity) increased across the six passages. Children who performed within the bottom 15% of their grade group in both reading comprehension measures were coded as poor comprehenders. Those who performed above the 15th centile for their grade group on one of the reading comprehension measures but poorly on the other were excluded to ensure that the procedures identified a group of children with poor reading comprehension. This procedure led to a total of 33 (seven grade 2, seven grade 3, ten grade 4 and nine grade 5) children being selected as showing evidence across the two measures of poor reading comprehension. The remaining 173 children were used as a baseline group against which to contrast these 33 children.

The 33 selected poor comprehenders were then divided into two groups based on scores in a task that assessed decoding ability. This task was given to all 206 children and comprised a simple non-word (or pseudo-word) reading task which required the child to pronounce correctly, based on Persian grapheme-phoneme conversion rules, 30 letter strings that were unlikely to be recognised by the child (see discussions of such tasks in Rack, Snowling, & Olson, 1992; and similar measures in Woodcock et al., 2001). To develop non-word items, letters from Persian words were rearranged or replaced so that they were word-like but did not have meaning, and hence would not have a lexical entry. Since, in Persian writing, the short vowels are not usually marked, all acceptable pronunciations (e.g. موک/mu:k/ or /muk/) were considered as correct responses. Participants were given non-words with various numbers of syllables (i.e., non-words with one, two, three or more syllables) and were told that they should try to pronounce the given made-up words accurately and clearly for the assessor. The time each individual spent on this task and the number of the correctly pronounced items out of 30 was recorded. The latter measure was then used with the correct score to produce a measure of decoding fluency: i.e., the number of non-words pronounced correctly per second. Scores on the non-word accuracy and fluency measures were calculated for the whole cohort to produce a mean and standard deviation for each school grade.

Those children amongst the 33 poor comprehenders who performed one standard deviation below the mean for their grade group on either the accuracy or fluency measures were considered as showing evidence of poor decoding ability. The rest of the 33 were considered as performing the non-word reading task like typical children. This procedure led to 19 (three grade 2, six grade 3, four grade 4 and six grade 5) children with evidence of poor reading comprehension but average decoding skills, with the remaining 14 (four grade 2, one grade 3, six grade 4 and three grade 5) poor reading comprehenders also showing evidence of poor decoding. (Table 1 provides basic demographic information for these two groups and the rest of the cohort of children.)

Once these three groups had been formed, they were compared on a series of measures assessing underlying

i) language skills that focused on meaning,
ii) phonological awareness skills that focused on individual sounds within spoken words,
iii) orthographic knowledge that required an understanding of the Persian orthography, and
iv) speed of processing that targeted the ability to name items as fluently as possible.

The measures of language related skills comprised listening comprehension (similar to that used in Semel, Wiig,

Table 1. Details of the number of participants (numbers of males and females) in each of the three groups, along with mean age and range in months

		Average comprehenders	Poor comprehenders	
			Average decoders	Poor decoders
Sex of child	Male	82	13	9
	Female	91	6	5
Age in months	Mean	112.49	112.36	113.71
	Range	89–136	94–133	92–133

Secord, & Hannan, 2008) and receptive vocabulary (based on Dunn & Dunn, 2007). Vocabulary was assessed using up to 100 verbally presented words (58 nouns, 22 verbs and 20 adjectives) and four pictures visually presented to the child for each word – words had been selected to cover the age range of the children in this cohort. Participants were asked to select one of the four pictures that they considered best matched the meaning of the orally presented word. The listening comprehension measure comprised six passages and 40 yes/no comprehension questions. Referential and inferential comprehension questions were used to measure the participant's understanding of the spoken passages. Similar to the reading comprehension measures, length and grade level of the passages increased throughout the test. The written forms of the passages were not provided. Once each passage was articulated, the participants were asked verbally about the content of the passages – responses were simple ticks on a response sheet that contained nothing more than a question number and yes/no. The spoken Tehrani form of Persian was used in the assessment to reflect the oral nature of the task and to ensure that the accent was familiar to the children. Scores for both listening comprehension and vocabulary were simply the number of items correct.

Phonological awareness was assessed via the child's ability to identify sounds within spoken Persian words. A sound deletion task (simialr to Taibah & Haynes, 2011) required the child to say a word without one of its basic sounds (e.g., repeating the word کتاب/keta:b/, a Persian word meaning book, without the /b/ sound, with the expected correct answer being کتا/keta:/). Fifteen items were developed which varied in their level of difficulty by increasing the number of the phonemes per word (from 5 to 9 phonemes). Phonemes were deleted from the initial, medial or final positions (5 trials each). All items were verbally presented to the child and verbal responses of the child were recorded to determine the number of correct responses.

A second phonological awareness task (based on Tehrani, 2007) involved children being presented verbally with words that they were asked to segment into the component phonemes. For example, the word /مسواک/mesva:k/, meaning toothbrush, was said to the child and they were required to state each individual phoneme: i.e., '/m/, /e/, /s/, /v/, /a:/, /k/'. Complexity of the stimuli increased throughout the test by increasing the number of the phonemes per word from those with three phonemes to words consisting of nine phonemes. There were fifteen items in this measure also so that both phonological tasks were scored out of 15.

Of the two orthographic knowledge tasks used in the study, the first required the child to distinguish whether pairs of letter strings were the same or different (as in Elbeheri, Everatt, Mahfoudhi, Al-Diyar, & Taibah, 2011). In this task, differences were kept to a minimum, with pairs differing by only one letter/grapheme (e.g., in English, 'sand send' would be a different pair). The child was required to underline the pairs that were the same. The total number of pairs was 50, and the child was given one minute to complete as many items as possible. The number of same pairs marked minus the number of incorrect pairs marked produced a score out of 25 which was used as the measure for this task.

In the second orthographic task, the child was required to underline the correct spelling from two sets of letter strings: a word and non-word homophone pair (e.g., in English: 'monk munk'). The non-words used sounded like the word if translated using Persian spelling-sound conversion rules (see Ricketts, Bishop, & Nation, 2008 for a similar task). For example, the word مدرسه/mædreseh/, meaning school, was paired with the non-word homophone مدرثه which, using grapheme-phoneme conversion rules, would produce the same pronunciation /mædreseh/. Hence, the child needs to recognise the correct item by its orthographic features, or the direct route, rather than spelling-sound correspondences. The time for this task was one minute with the score being the number of correct responses out of 30.

The final tasks involved the rapid naming of familiar words or objects (see similar measures in Denckla & Rudel, 1976). These tasks required the child to name all the items (35 words or 36 drawings of familiar objects) as quickly as possible, trying to avoid naming errors. The children were directed to name the items from right to left, the direction of Persian writing system, and the participants' ability to name the items without timing was checked prior to testing to ensure familiarity to the level of accurate naming. A stop watch was used and the time the child took to name all the items was recorded in seconds, along with any naming errors. Given the small number of naming errors, time was used as the measure for these tasks.

Results

Tables 2 and 3 present the results of the three groups of readers on the measures

Table 2. Mean scores for each group of readers on the group selection measures, with standard deviations in round brackets and the number of the individuals in square brackets

	Average comprehenders	Poor comprehenders	
		Average decoders	Poor decoders
Passage and questions reading comprehension	12.29 (4.50) [172]	6.36 (3.72) [19]	6.42 (4.07) [14]
Cloze completions reading comprehension	14.96 (6.18) [171]	10.68 (5.42) [19]	8.42 (4.05) [14]
Non-word reading score	28.36 (2.16) [167]	28.52 (1.57) [19]	24.64 (3.62) [14]
Non-word reading fluency	0.59 (.21) [167]	0.63 (.29) [19]	0.31 (.09) [14]

Table 3. Mean scores for each group of readers on the underlying skills measures, with standard deviations in round brackets and the number of the individuals in square brackets

	Average comprehenders	Poor comprehenders	
		Average decoders	Poor decoders
Listening comprehension	32.92 (4.62) [171]	30.35 (4.87) [17]	31.00 (5.09) [14]
Vocabulary (receptive)	74.94 (9.09) [167]	74.21 (10.03) [19]	72.64 (6.19) [14]
Phonological deletion	13.36 (2.03) [171]	12.73 (2.35) [19]	10.00 (4.06) [14]
Phonological segmentation	12.36 (2.09) [166]	11.73 (3.34) [19]	10.76 (2.20) [13]
Orthographic matching words	18.55 (5.47) [169]	14.50 (6.08) [16]	16.35 (7.23) [14]
Orthographic spelling choice	21.42 (7.8) [170]	15.33 (8.49) [15]	17.35 (7.92) [14]
Rapid naming of words	22.15 (8.69) [167]	23.66 (6.13) [19]	35.23 (18.22) [14]
Rapid naming of objects	34.16 (8.62) [167]	35.23 (5.50) [19]	37.12 (6.84) [14]

used in the study. Table 2 included the reading comprehension and non-word reading measures – the measures used to categorise the three groups. Table 3 consists of the results of the remainder of the measures which were used to investigate underlying skills variability across the three groups.

A series of Analyses of Covariance (ANCOVAs) were performed to contrast each poor comprehension group with the average comprehenders on the measures presented in table 3. In each case, school grade and child's sex were used as covariates to account for the effects of educational level in the measures and gender ratio differences across groups. The ANCOVA compared (i) the average comprehenders and the

Table 4. Results of analyses of covariance (with sex and school grade of child as the covariates) contrasting the two poor reading comprehender groups against the average comprehenders

	Average comprehenders vs. Poor comprehenders- average decoders			Average Comprehenders vs. Poor comprehenders- poor decoders		
Measures	F	*df* value	*p* value	F	*df* value	*p* value
Listening comprehension	8.63	1, 184	.004	3.31	1, 181	.070
Vocabulary (receptive)	1.12	1, 182	.292	1.89	1, 177	.171
Phonological deletion	1.65	1, 186	.200	16.84	1, 179	<.001
Phonological segmentation	1.08	1, 181	.299	6.44	1, 175	.012
Orthographic matching words	11.95	1, 181	.001	2.93	1, 179	.089
Orthographic spelling choice	18.55	1, 181	<.001	6.51	1, 180	.012
Rapid naming of words	.85	1, 182	.358	30.01	1, 177	<.001
Rapid naming of objects	.43	1, 182	.512	1.61	1, 177	.206

poor comprehenders with no evidence of decoding weaknesses, and (ii) the average comprehenders and the poor comprehenders who showed difficulties in their decoding skills (see table 4).

The results indicated that the children with poor comprehension levels but average range or better decoding skills showed deficits compared to the average comprehenders on the listening comprehension measure and the two orthographic processing measures. In contrast, the children with difficulties in both reading comprehension and decoding performed poorly, compared to the average comprehenders, on most of the measures except the vocabulary and objects naming tasks; although for listening comprehension and one of the orthographic tasks the differences were non-significant, suggesting that any deficits in these areas were not that severe.

Graphical representation of these results can be found in figure 1, which shows the results of the poor comprehender groups in terms of z-scores. This provides a visual comparison of the average performance of the two groups with reading comprehension difficulties against expected levels of performance represented by the zero line. A z-score for each child was calculated based on the performance of the children within the same school year/grade; that is, the difference between the child's score and the average for the grade divided by the standard deviation for that grade. Therefore, on this graph, the vertical axis indicates the number of standard deviations that each group differed from expected performance on each of the measures. A negative z-score (a score below the 0 line) indicates performance worse than that expected and a score above the line indicates performance better than that expected. Tasks are presented along the horizontal axis, with language understanding measures on the left, followed by phonological, orthographic and speeded naming measures.

Discussion

The ultimate goal of reading is comprehension, which relies on a range of different language and literacy-related skills. Investigations of these underlying

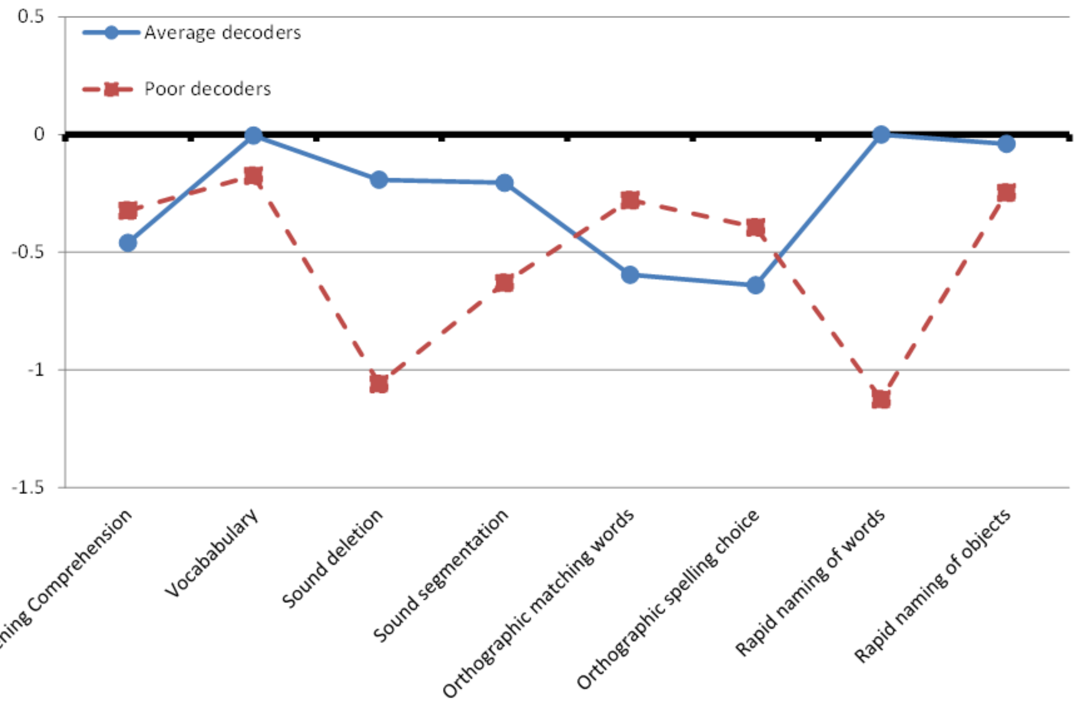

Figure 1. Standard scores of two groups of poor comprehenders on the underlying skills measures in comparison with expected performance

skills should identify those areas potentially responsible for reading comprehension deficits. The current study contrasted different groups of poor comprehenders on their underlying language and word processing skills within the Persian language; a language that has been relatively under-researched, but which uses an orthography that has the potential to produce different relationships between word-level and text-level processes to those found in English.

Overall, the findings argued for poor comprehenders with average to good decoding skills to show more specific deficits in language comprehension and orthographic processing. In contrast, poor comprehenders with weak decoding skills showed weaknesses in most areas of basic processing (phonological, orthographic and speeded written word naming), but fewer problems in language understanding. These findings were generally consistent with the contention, based on a simple view of reading (Gough & Tunmer, 1986), that there should be two types of poor reading comprehenders which show differences, as well as some level of overlap, in underlying cognitive-linguistic processing deficits. The results were also consistent with the Persian model of reading (Sadeghi et al., submitted) in arguing for both linguistic and decoding skills to be important in explaining variability in Persian reading comprehension levels in primary school children. All of the Persian language children with poor reading comprehension levels showed some evidence for weaknesses in language related skills, particularly in the area of listening comprehension, along with problems in their word recognition/ decoding skills.

The data were consistent with studies which have reported that difficulties in receptive language understanding may lead to reading comprehension problems (e.g., Stothard & Hulme, 1992). Interestingly, though, both groups of poor comprehenders showed reasonable levels of receptive vocabulary, with listening comprehension being the main area showing evidence of weaknesses. This suggests that any linguistic deficits would be more likely to be related to processing the meaning of connected text or discourse processing. Such problems potentially focus on inference making or similar concept/meaning linking processes; skills that have been proposed to be associated with this profile of weak comprehension despite good vocabulary (see Cain, Oakhill, & Bryant, 2004).

In the present data, this dissociation between comprehension and vocabulary was most evident in the poor comprehender group with no evidence of decoding problems but weaknesses in orthographic processing, arguing for a link between orthographic knowledge and these semantic linking processes. One potential explanation is that at least some children with evidence of poor reading comprehension skills may be prone to such poor linkage, even within an orthographic lexicon, which would lead to poor orthographic processing. A similar deficit may be evident in a semantic lexicon, leading to poor linkage between entries even when access to a specific entry may be as accurate as for those without comprehension deficits. An alternative explanation is that there is a reciprocal relationship between good sentence meaning processing and improved orthographic knowledge when exposed to devowelized text. Those with poor reading comprehension will be less able to use text comprehension processes to decipher individual words, which may lead to poor linkage within the lexical system and, hence, to less accurate orthographic retention.

The data also point to evidence that poor word recognition/decoding processes can be related to weak reading comprehension. Children with comprehension deficits showed difficulties in either phonological processing or orthographic processing, which may be consistent with a dual pathway model (Castles, 2006; Coltheart, 1985, 2006). Our findings suggest that those children with poor reading comprehension and associated weaknesses in decoding showed evidence of weak phonological awareness. However, those children with poor reading comprehension and normal range decoding accuracy and fluency showed deficits in measures of orthographic knowledge. These results add to the findings of previous studies (see Nation & Cocksey, 2009; Nation & Snowling, 1998) which have suggested that underlying semantic skills constrain both reading comprehension and the development of word recognition processes. For example, Nation and Snowling (1998) studied children with normal decoding skills but impaired reading comprehension and argued that these children's core difficulty is in their semantic skills. Thus, although these poor comprehenders performed at the normal level on phonological tasks, they showed an impairment of semantics that compromises the use of the semantic pathway (or direct route in the dual route model) and led to poor performance on less frequent irregular words. These Persian data suggest the same potential impairments. A reading comprehension problem in Persian may also interfere with the development of a reliable direct or semantic route to word recognition. The exact reason for this requires further investigation, but again the need to use sentence context to support the access of individual word meaning in devowelized Persian text provides an obvious focus for such future research.

The current work also has potential practical implications, particularly for the identification of children with reading problems. The present data argue that linguistic skills and early word reading processes can be indicative of reading comprehension deficits. Decoding weaknesses associated with phonological deficits in these Persian children seem resonant of profiles of children with dyslexia-related literacy learning problems. Hence, measures of early phonological processing skills (potentially prior to formal literacy instruction) offer the potential to identify reading weaknesses among Persian language children. Additionally, measures of listening comprehension and early orthographic processing also provide a basis on which to develop measures that can identify those at risk of Persian reading comprehension problems. Such specifically targeted measures would have the potential to dissociate those children with wider language problems that would include poor vocabulary from those with more specific understanding deficits that can lead to problems with text comprehension. Other areas of ability (such as non-verbal skills that may be used to assess, or control for, IQ) may be assessed in future work. Even without these additional measures, however, the current framework provides a basis on which to identify literacy problems, and potential underlying areas of weakness, which should inform assessment procedures.

Clearly, further research is necessary due to the more exploratory nature of the current study: for example, larger groups of poor comprehenders will increase statistical power and may allow explicit comparisons between groups of poor comprehenders, rather than comparing poor comprehenders against expected performance, However, these findings should provide a framework for identification, and more targeted intervention, aimed at those with literacy learning problems among children learning to read in Persian.

Given that the conclusions derived from these Persian language data were consistent with current models derived from English language research, they also provide the basis for further development of cross-language theories and tools that can be used to support children with developmental difficulties across a range of learning contexts.

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A Meta-Analysis of Technology-Based Interventions on the Phonological Skills of Children with Dyslexia

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There is a growing awareness of the need to understand how technology can help in education, especially in the area of special educational needs. The purpose of this meta-analysis is to synthesise findings from independent studies gathered by a systematic review of the literature on the effectiveness of technology-based interventions on the phonological skills of children diagnosed with dyslexia in English. Keywords for the literature search were selected that best represented the research area: technology, computer, elearning, mobile learning, ICT; intervention, instruction, remediation, therapy; phonology, phonological skills, spelling; and dyslexia. These key terms were used for the computerised search of five databases: Academic Search Premier, Education Research Complete, ERIC, PsycARTICLES and PsycINFO. The studies that met the inclusion criteria were further meta-analysed for effect sizes with a fixed effects approach weighted by sample sizes. The inclusion criteria were that the studies must involve a technology-based intervention, participants of the studies must be formally diagnosed with dyslexia in English, outcome measures used must include at least one measure of phonological skills in reading, and studies must utilise a pre-test-post-test experimental design and include means, standard deviations, and sample sizes. There were a total of four studies that met all criteria and these four studies employed six different technology-based interventions. All four studies had significant results showing that technology-based interventions positively influenced phonological skills. A grand total of 157 participants across these four studies returned a significant result for weighted pooled estimates of overall effect size on non-word decoding (a measure of phonological skills) to be d = 0.56 (ranging from d = 0.17 to 1.38), which is a medium effect size of the technology-based intervention. Thus, technology-based interventions is an effective method of remediating phonological skills of children with dyslexia.

Keywords: technology, intervention, therapy, dyslexia, phonological, reading in the identification of pre-school children "at risk" of dyslexia, albeit with some adaptations for use in the local context.

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Dyslexia is a type of specific learning difficulty identifiable as a developmental difficulty of language learning and cognition (US Department of Education, 2006). Rose (2009) identified the characteristic feature of dyslexia to be primarily in phonological awareness and the National Institute of Child Health and Human Development (2000) has identified that appropriate literacy programmes should include components of phonemic awareness and phonics training. Thus, phonological interventions have become part and parcel of the majority of dyslexia remediation programmes worldwide, including in Singapore. More than 14 years ago, it was estimated that there were more than 10,000 instructional software programmes on the market (Zhang, 2000), this number is an underestimate now. In 2008, a review of off-the-shelf software packages that assist in writing and spelling reviewed 22 such software (Peterson-Karlan, Hourcade, & Parette, 2008), suggesting that there is a growing awareness of the need for understanding how technology can help education, especially in the area of special educational needs.

Zhang (2000) used a qualitative case study approach to investigate the writing skills of five fifth-grade students with learning disabilities after using a writing programme (ROBO-Writer). The findings indicated that all five students improved their writing skills. One student was previously labelled as lazy and ill-behaved. After using ROBO-Writer, the student wrote a 350-word essay with very few spelling errors, the "...longest written work he had ever produced..." (p.473). Another student was previously extremely reluctant to engage in self-expression but after using the programme, she "...became increasing willing to talk to her mentor as a method of identifying exposition topics, *(thus improving)* socialization..." (p.473). This indicated that technology could also improve aspects other than just learning *per se* and indeed could be used as a tool to draw out shy and withdrawn students.

Hetzroni and Shrieber (2004) used a single-subject ABAB research design with three participants aged 12-13 years old with diagnosed learning disabilities and average IQ to examine the effectiveness of using a word processor (Microsoft Word 2000) to aid writing, spelling, and reading. The results showed that all three participants achieved fewer spelling mistakes (from baselines of 11-17% spelling mistakes to final results of 1-3%) and fewer reading errors (from baselines of 5-12% reading errors to final results of 0-1%). In addition, teachers assessing the written quality of the work produced indicated that the essays produced were organised better than before. This study shows that a simple use of a widely available software package can improve writing, reading, and spelling ability.

Cullen, Richards, and Lawless-Frank (2008) used a case study approach with a modified multiple baseline with seven participants aged 10-11 years old with diagnosed learning disabilities to examine the effectiveness of a talking word processor (Write: Outloud) and word prediction program (Co: Writer) on their writing. There were three phases in the study - baseline, Write: Outloud intervention alone (Phase 2), and Write: Outloud intervention with Co: Writer

(Phase 3). Results indicated that mean spelling accuracy increased from baseline of 87% to 95% (phase 2) to 96% (phase 3). Using a standard marking rubric (maximum mark of 20), participants average rubric score also increased from a baseline of 9.4 to 9.9 (phase 2) (both failing scores) to a score of 11.3 (a passing mark). Each of the participants essays were marked by three teachers and averaged to produce a final mean score. This study shows evidence for the effectiveness of technology in improving spelling and writing skills.

All the three studies reviewed (Cullen et al., 2008; Hetzroni & Shrieber, 2004; Zhang, 2000) used non-experimental research methods. Thus, even though the results point to the effectiveness of using technology-based interventions with children with special needs, these results are difficult to generalise. There is thus a need for more experimental research into this area so as to properly inform intervention methods for children with special needs and generalise the results. Several experimental studies have already been conducted, however, these studies were often conducted with participants diagnosed with dyslexia in languages other than English. Although it is known that dyslexia in different languages can manifest in different ways and hence differ in their responsiveness to phonological remediation (Rose, 2009), it is still useful to review if technology-based interventions helped these groups of participants.

Ecalle, Magnan, Bouchafa, and Gombert (2008) investigated whether computer based training in phonemic awareness can improve reading in children with dyslexia in French. A total of 26 children diagnosed with dyslexia and with IQ higher than 70 participated in the study. A pre-test, intervention, post-test design was used. The participants were randomly assigned into an experimental group (n=13) who underwent ortho-phonological phonemic audio-visual computer-based training or a control group (n=13) who underwent a computer-based training that only showed text on screen for the participants to read. At post-test, the experimental group was significantly better in pseudo word reading, regular word reading, and irregular word reading, indicating an increased ortho-phonological ability. This showed that computer based training using ortho-phonological units can improve reading ability, showing the effectiveness of assistive technology.

Kast, Meyer, Vogeli, Gross, and Jancke (2007) investigated the effectiveness of a multisensory training software programme (Dybuster) on 43 children with dyslexia in German and 37 age-matched controls using an experimental pre-post design. The group of dyslexia children was further divided into two groups (those with intervention in the first three months and those without intervention in the first three months). Children with dyslexia without software intervention in the first three months as well as the control group showed reading improvements of only 0 to 9%. Children with dyslexia with software intervention in the first three months had reading improvement of 19 to 35%. Due to obvious ethical issues, the Children with dyslexia without software intervention during the first three months underwent the intervention and subsequently showed a improvement of 27 to 35%. Although one problem with the research was that the experimental and control groups differed significantly on baseline measures of IQ, the results do indicate that the reading software improved reading of people with dyslexia in German.

A meta-analysis of current experimental research with people with dyslexia in English would provide an amalgamation of available information and provide a review of the impact of using technology-based interventions and thus inform practitioners in this area. The purpose of this meta-analysis is thus to synthesise findings from experimental research studies gathered by a systematic review of the literature on the effectiveness of technology-based interventions on the phonological skills of children diagnosed with dyslexia in English.

Method

Procedure

The meta-analysis employed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart for search strategy (see Figure 1) and adhered to the APA Meta-Analysis Reporting Standards (MARS) (APA, 2011).

Search Strategy for Study Identification

A computer literature search up to December 2013 was performed in the following electronic databases: Academic Search Premier, Education Research Complete, ERIC, PsycARTICLES, & PsycINFO. The following key words were used:

- technology, computer, elearning, mobile learning, ICT
- intervention, instruction, remediation, therapy
- phonology, phonological skills, spelling
- dyslexia

No other sources for records were searched. The inclusion criteria were that the studies must involve a technology-based intervention, participants of the studies must be formally diagnosed with dyslexia or at risk for reading difficulties in English, outcome measures used must include at least one measure of phonological skills, and studies must utilise a pre-test-post-test experimental design and include means, standard deviations, and sample sizes.

Effect Size Analyses

An effect size is a measure of the strength of a phenomenon (Kelley & Preacher, 2012). The larger the effect size of an intervention, the more effective that intervention. Individual effect sizes for each eligible study with reported means and standard deviations were calculated based on Cohen's *d*, defined as the difference between two means (mean change) divided by the standard deviation for the control group. A Cohen's *d* score from 0.2 to 0.49 is considered a small effect, a score from 0.5 to 0.79 is considered a medium effect, and a score of 0.8 and above is considered a large effect.

The weighted mean differences method was chosen to obtain the pooled estimates of overall effect sizes for common outcome measures (Wolf, 1986).

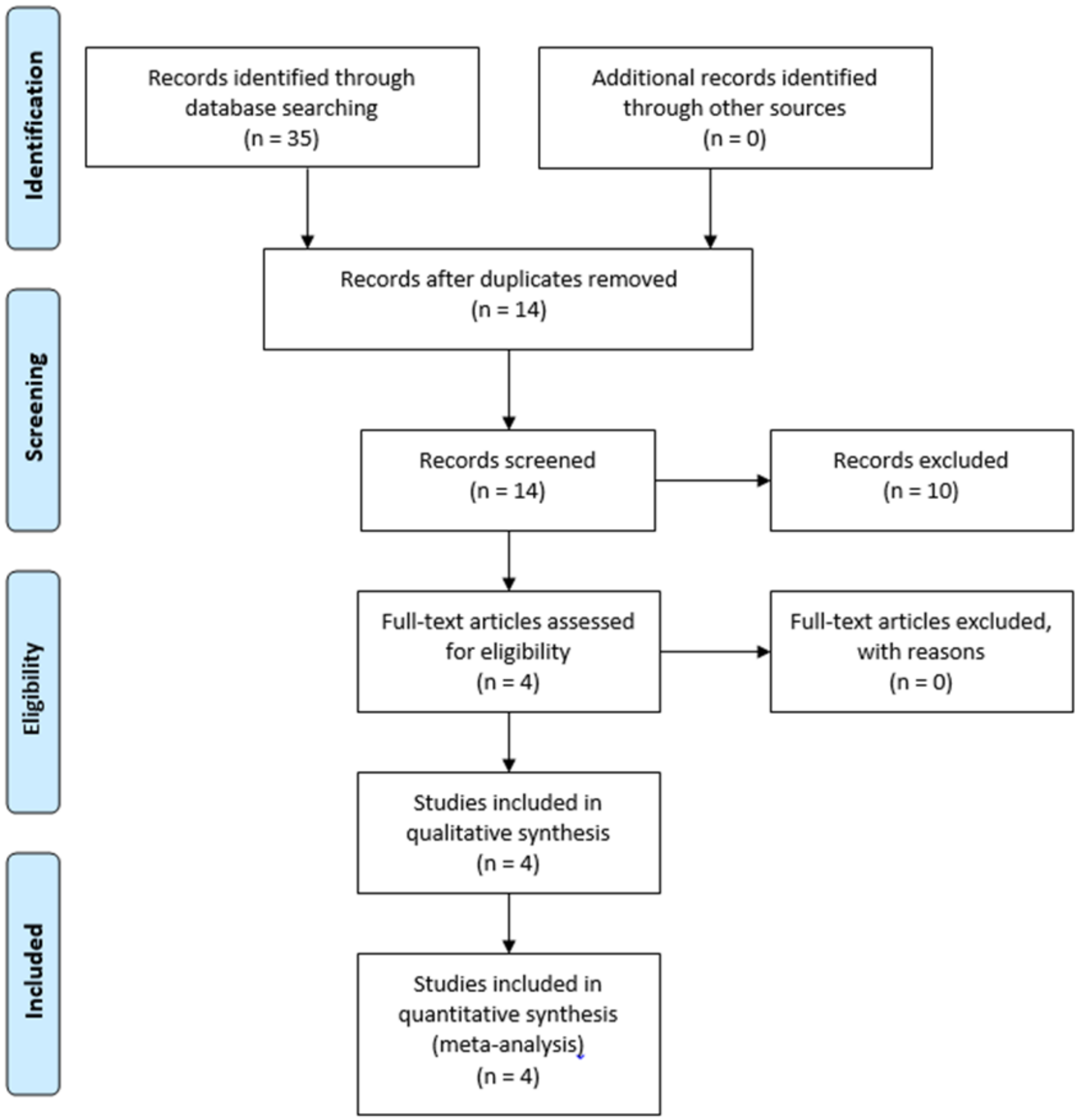

Figure 1. PRISMA Flowchart for this Study.

Weights were based proportionately on the number of participants in each study (Hedges & Olkin, 1985).

Results

Thirty five articles were initially identified via database searching. There were 14 articles after removing duplicates. A total of 10 articles were excluded, one as it did not have pre-test post-test measures, another as it used morphological outcome measures, and eight others conducted in languages other than English. Thus, a total of four articles were included in the qualitative synthesis (see summary of studies in Table 1).

Table 1 Summary of Study Details

Author(s)	N	Technology Used	Intervention Length	Grades /Ages	Outcome Measures (refer to qualitative synthesis for more information)	Effect Sizes
Blythe (2006)	10	Phonics Alive2: The Sound Blender	10 weeks (≈11.5 hours)	Grades 1 to 6	1. Reading Composite Index (2+3+4) 2. Word Reading 3. Reading Comprehension 4. Pseudoword Decoding	1. 0.62 2. 0.27 3. 0.40 4. 0.58
Gaab et al. (2007)	22	Fast ForWord	20 minutes 5 times a day over 8 weeks (≈13.3 hours)	10:5	1. Word Reading 2. Non-Word decoding 3. Passage Comprehension 4. Listening Comprehension 5. Phonological Awareness 6. Phonological Memory 7. Rapid Naming	1. 1.14 2. 1.38 3. 0.44 4. 0.58 5. 0.63 6. 0.53 7. 0.46
Higgins & Raskind (2004)	28	Speech Recognition Programme	25 minutes 2 times a week over 17 weeks (≈14.2 hours)	8 to 18	1. Word Recognition 2. Comprehension 3. Phonological elision 4. Non-word Reading	1. 0.18 2. 0.17 3. 0.25 4. 0.35
	28	Automaticity Programme	50 minutes, 3 times a week over 17 weeks (≈42.5 hours)		1. Word Recognition 2. Spelling 3. Comprehension 4. Phonological elision 5. Rapid letter naming 6. Non-word reading 7 Sight word reading	1. 0.10 2. 0.09 3. 0.24 4. 0.26 5. 0.19 6. 0.17 7. 0.18
Torgesen et al. (2010)	34	Read Write and Type program (RWT)	4 50-minute sessions per week over a school year (≈80.4 hours, with 44.6 hours on computers)	Grade 1	1. Word Identification 2. Word Efficiency 3. Word attack 4. Non-word efficiency 5. Blending Words 6. Phonological elision 7. Segmenting Words 8. Rapid Naming Digits 9. Rapid Naming Letters	1. 0.41 2. 0.22 3. 0.59 4. 0.26 5. 0.70 6. 0.28 7. 0.64 8. 0.67 9. 0.33
	35	Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech (LIPS)	4 50-minute sessions per week over a school year (≈84.3 hours, with 35.6 hours on computers)		1. Word Identification 2. Word Efficiency 3. Word attack 4. Non-word efficiency 5. Blending Words 6. Phonological elision 7. Segmenting Words 8. Rapid Naming Digits 9. Rapid Naming Letters	1. 0.64 2. 0.52 3. 0.95 4. 0.81 5. 0.44 6. 0.61 7. 0.87 8. 0.33 9. 0.00

Qualitative Synthesis

Blythe's (2006) pilot study on the effectiveness of computer-based phonological skills training was conducted with 20 primary school students diagnosed with dyslexia using a pre-test post-test control group research design. The study involved using a commercial off-the-shelf computer software called "Phonics Alive 2: The Sound Blender". This programme consists of 12 modules which build phoneme awareness skills, phoneme-grapheme correspondence, sound and letter blending, and processing speed. Each module takes an average of 15 minutes to complete. The 10 participants in the computer intervention group were instructed to repeat each module until a mastery level of 90% correct responses was achieved. Parent reports indicated that all children were compliant throughout the 10-week training period. Eight out of ten children completed all twelve modules, with the two youngest completing through to module 10. The other 10 participants were in the control group. The outcome measures were items from the Wechsler Individual Achievement Test, second edition (WIAT-II) (Wechsler, 2002). The Reading Comprehension Index provided a measure of general reading ability. It is produced by combining the standardised scores of each of the following reading subtests: The Word Reading subtest that provided a measure of sight word reading, with participants reading aloud from a graded word-list; the Reading Comprehension subtest that provided a measure of textual comprehension by reading narrative passages (either aloud or silently) then answering comprehension questions; and the Pseudoword Decoding subtest that provided a measure of the student's ability to apply phonetic decoding skills by having the students read aloud from a list of graded nonsense words designed to mimic the phonetic structure of words in the English language. There were significant interactions between treatment group and time for the overall Reading Composite Index (RCI) [$F(1,18) = 29.08$, $p < .001$] with the treatment group showing a greater increase in RCI and all subjects, effects sizes ranged from small to medium, $d = 0.27$ to 0.62 (for specific effect sizes, see Table 1). Although the study only had 20 participants: 10 in the treatment group and 10 in the control group, participants were randomly assigned and compliance to the intervention programme was monitored. In spite of the small number of participants, results were still significant. The results show that computer-based training was effective in improving phonological skills of children with dyslexia even with only approximately 11.5 hours of training over 10 weeks.

Gaab, Gabrieli, Deutsch, Tallal, and Temple (2007) conducted an fMRI study investigating neural correlates of rapid auditory processing in children diagnosed with dyslexia but also included behavioural measures suitable for this analysis. Twenty-two children with dyslexia participated in a pre-test post-test control group research design with 23 matched controls. The technology-based intervention used was the Fast ForWord Language programme. The remediation consists of five 20-minute training sessions per day, five days a week over a period of eight weeks for a total of approximately 13.3 hours. The outcome measures included Word, Non-Word decoding, and Passage Comprehension (subtests from the Woodcock-Johnson Reading Mastery Test Revised (WJRMT-R)); Listening Comprehension (subtest from the Woodcock-Johnson-Revised (WJ-R) Test of Achievement); Phonological Awareness, Phonological Memory, and Rapid Naming (subtests from the Comprehensive Test of Phonological Processing (CTOPP)). Results showed significant improvements in all these seven measures with effect sizes from medium to large, *d* = 0.44 to 1.38 (for specific effect sizes, see Table 1). Of particular interest is the result that the effect sizes for the improvement in word reading and non-word decoding was over 1.0, which is a huge effect. This research was very controlled, had good participant numbers, and add to the evidence that computer based training is effective in improving phonological skills of children with dyslexia.

Higgins and Raskind (2004) investigated the effectiveness of Speech Recognition Based Programmes (SRBP) (auditory and visual representations of words) and Automaticity Programmes (AP) (Multisensory with more interactivity) on a total of 42 children with learning disabilities. The 42 children were divided into two groups, 28 children on assistive technology and 16 children on classroom teaching and the research design was an experimental pre-post control group intervention design. To control order effects, part of the 28 students did the AP intervention then SRBP, and part did SRBP then AP. The outcome measures were: Word Recognition, Spelling (subtests from the Wide Range Achievement Test-3); Comprehension (subtest from the Formal Reading Inventory); Phonological elision. Rapid letter naming (subtests from CTOPP); Non-word reading, and Sight word reading (subtests from the Test of Word Reading Efficiency (TOWRE). The SRBP group improved significantly more on word recognition, comprehension, phonological elision, and non-word reading, with effect sizes ranging from small to medium, *d* = 0.17 to 0.35 (for specific effect sizes, see Table 1). The AP group improved significantly more on all the above measures and spelling, rapid letter naming, and sight word reading, however, effect sizes were small, *d* = 0.09 to 0.26 (for specific effect sizes, see Table 1). This is despite the fact that the intervention for SRBP was for only 14.2 hours, far lesser than on AP that was for 42.5 hours. The small effect sizes for the AP intervention show that more hours of training does not necessary translate to a greater effect. The researchers also noted that one major limitation of their study was that their participants ranged in ages from 8 to 18, this wide range could have affected the results as a number of reading intervention studies report different treatment effects across ages (e.g. Wise, Ring, & Olson, 1999, 2000 cited in Higgins & Raskind, 2004).

Torgesen, Wagner, Rashotte, Herron, and Lindamood (2010) investigated the effectiveness of two computer-assisted instructional programmes on children at risk for dyslexia (but too young for formal diagnosis of dyslexia). The study employed a pre-test post-test experimental control group research design. Thirty four children went through the Read Write Type (RWT) programme (based on the premise of directly teaching students the spellings of phonemes) for 80.4 hours that had a computer-based training component of 44.6 hours. Thirty five children went through the Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech (LIPS) programme (based on the idea of early knowledge of the oral motor awareness of phonemes for decoding and encoding) for 84.3 hours with a computer-based training component of 35.6 hours. As noted, both programmes were not fully computer based programmes and were blended programmes that included one-to-one teacher instruction. The outcome measures were Phonological elision, Blending Words, Segmenting Words, Rapid Naming (subtests from CTOPP); Word Identification, Word Efficiency, Word attack (subtests from WJRMT-R); and Non-word efficiency (subtest from TOWRE). The effect sizes of the RWT intervention ranged from d = 0.28 to 0.70 (for specific effect sizes, see Table 1). The effect sizes of the LIPS programme ranged from no effect to large effects with effect sizes ranging from d = 0.00 to 0.95 (for specific effect sizes, see Table 1). However, these results must be qualified, the researchers noted that the computer based instruction in this study was a supplement rather than a replacement for teacher-led instruction. There should have been an additional intervention group with just computer based intervention without any teacher-led instruction. In spite of this, the results do show that computer based interventions (whether solely or as a supplement) positively impacts the phonological skills of children with dyslexia. These results are to be interpreted in line with follow up tests after two years that indicated that although results were still significant, effects sizes for outcome measures have dropped to d = 0.33 to 0.43, which were still medium effect sizes even after two years. This suggested that intervention outcomes could fade out over time.

The four studies used a variety of computer-based interventions. The computer programmes used by Higgins and Raskind (2004) were fairly primitive. The SRBP programme was based on a Microsoft PowerPoint 1997 platform with recorded speech and suffered from recognition errors common in all speech recognition type software. The AP programme employed a speech synthesiser (a 1998 model) that had a fairly artificial robotic speech. On the other hand, the other three studies used commercial off-the-shelf computer programmes that had high levels of interactivity and good graphics. It was thus not surprising that the Higgins and Raskind (2004) study had the lowest effect sizes among the four studies.

Quantitative Analysis

There was only one common outcome measure among the four studies, Non-word Decoding (called Pseudoword Decoding in Blythe (2006), Non-word reading in Higgins & Raskind (2004), and Non-Word efficiency in Torgesen et al. (2009)). Using this common outcome measure as a basis of comparison among the four studies, all four studies showed significant results for the technology-based interventions on the outcome measure of Non-word decoding. A grand total of 157 participants with dyslexia had significant improvements in phonological skills after some form of technology-based intervention with effect sizes for non-word decoding ranging from d = 0.17 to d = 1.38 (see Table 2). Using the weighted mean differences method proportionately based on sample sizes, the pooled estimate of overall effect size for non-word decoding is d = 0.56, which is a medium effect size.

This provides evidence for the positive impact of technology-based interventions on the phonological skills of children with dyslexia. If we remove the Torgesen et al. (2010) study from the pooled estimate of overall effect size and account for technology-based intervention without the confounded issue of blended instruction, the results still showed that a total of 88 participants with dyslexia had significant improvements in phonological skills after technology-based intervention alone with a pooled estimate of overall effect size of d = 0.58, which is similar to the overall effect size of d = 0.56. This gives strong evidence for inclusion of technology-based intervention in dyslexia remediation.

Discussion and Conclusion

Four studies were selected in this meta-analysis. All four studies employed a pre-test post-test experimental research design with control groups. Under both qualitative synthesis and quantitative analysis, all four studies showed significant positive results in using technology-based interventions to improve the phonological skills of children with dyslexia. There were no

Table 2 Effect Sizes for Non-Word Decoding (Ranked from Largest to Smallest)

Author(s)	N	Technology Used	Outcome Measures	Effect Sizes
Gaab et al. (2007)	22	Fast ForWord	Non-Word decoding	1.38
Torgesen et al. (2010)	35	LIPS	Non-word efficiency	0.81
Blythe (2006)	10	Phonics Alive2: The Sound Blender	Pseudoword Decoding	0.58
Higgins & Raskind (2004)	28	Speech Recognition Programme	Non-word Reading	0.35
Torgesen et al. (2010)	34	RWT	Non-word efficiency	0.26
Higgins & Raskind (2004)	28	Automaticity Programme	Non-word reading	0.17

major methodological concerns with any of the four studies. However, Torgensen et al. (2010) study used a blended technology-based approach that included a teacher-led component, an example of good practice that may nevertheless have confounded the effects of a purely technology-based intervention.

The technology-based intervention that had the greatest effect was Fast ForWord (Gaab et al., 2007). It is worth noting that this intervention only occurred over five 20-minute training sessions per day, five days a week over a period of eight weeks for a total of approximately 13.3 hours. This seems to support the conclusion that repeated practice is one of the most useful approaches. The two interventions that had the smallest effect was Higgins & Raskind (2004) use of the Automaticity Programme (Cohen's *d* = 0.17) that had an intervention period of 42.5 hours and Torgesen et al. (2010) use of RWT (Cohen's *d* = 0.26) that had an intervention period of 80.4 hours (44.6 hours on computers). Thus, the amount of time spent on the intervention was not directly related to how effective it was. This conclusion is limited by the small number of studies that was examined, more research would have to be conducted to determine if the length of intervention was correlated to outcome.

All four studies used a measure of Non-word decoding as one of the outcome measures. It is thus suggested that Non-word decoding can be seen as a *de facto* standard for measuring phonological skills, especially for dyslexia remediation. Also, the presence of this common outcome measure allowed for the amalgamation of the results and a combined weighted overall effect size.

Based on consolidation of the evidence from these four studies that include the use of six different technology-based interventions, there is evidence to support the use of such interventions. However, this conclusion should be taken with caution as only four articles up to December 2013 met the criteria for inclusion (which also shows the lack of research in this area). Overall, more research with larger sample sizes should be conducted to better understand the effect of technology-based intervention and future research should include an outcome measure of non-word decoding to allow for continued future consolidation of research knowledge. Technology-based intervention should be considered an important element in dyslexia remediation of phonological skills.

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The importance of Rapid Automatized Naming Skills as a Predictor of Reading Acquisition: A Theoretical Overview

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This article presents a theoretical overview of the concept of rapid naming skills as one of the critical sub-skills of reading acquisition. Rapid automatized naming is recognized as a relevant marker in early reading in addition to phonological awareness and verbal working memory. This paper describes how the relationship between rapid automatized naming and reading skills affects specific reading difficulties within the framework of existing developmental and cognitive research. Finally, future implications for research and applications in the educational field are provided.

Keywords: naming skills, rapid automatized naming skills, reading acquisition, specific reading difficulties

Introduction

The purpose of the current paper is to give a theoretical overview on the concepts of naming and rapid automatized naming (RAN). It is also important to show the connections between naming skills, reading skills and reading difficulties (RD). The aim is to emphasise the value of knowledge about the concept and development of naming skills, and possible developmental difficulties as crucial factors from both a scientific and practical perspectives.

These are important for the identification and assessment of reading progress and to potentially identify RD in children. It is proposed that rapid automatized naming is a useful method to include in both cognitive reading research and diagnostic tests. This overview is based on the neuro-cognitive, psycholinguistic and developmental research in the field.

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Reading is a fundamental skill for successful performance in modern society and it is therefore hard to over emphasize its value. Considerable emphasis and efforts are focused on teaching and learning to read in educational institutions and society in general. Developed reading skills are the basis of further learning skills and academic success.

Reading includes the functions of both decoding and comprehension. For the purposes of this paper, the reading process is defined as decoding and RD as difficulties in decoding and does not consider the highly significant element of reading comprehension.

RD caused by biological, psychological and cognitive factors, despite adequate pedagogical environment, are considered as specific reading difficulties (SRD) / dyslexia. Cognitive and linguistic processes and reading predictors can be noticed in the pre-reading period and have significant predictive value in later reading performance. Reading ability, risks and difficulties are visible in the pre-reading period and can be efficiently predicted by the level of language skills (naming, rapid naming, phonological processing and awareness), working memory, visual and auditory perception, kinaesthetic perception and rhythm (Georgiou, Parrila, Manolitsis & Kirby, 2011; Furnes & Samuelsson, 2011; Holopainen, Ahonen, Lyytinen, 2001; Lervåg & Hulme, 2009; Norton & Wolf, 2012; Nation, 2005; Pastarus, 1999; Shaywitz, 2003; Van der Leij, Lyytinen & Zwarts, 2001; Wolf, 1999).

Naming

Naming, which is one of the basic linguistic processes, is defined as the attribution of a linguistic equivalent (symbol) to an object, characteristic, action, and the use of it (Luria, 1962). Different terms express various aspects of the Naming skill concept. *Word finding* and *word retrieval* refer to the ability to retrieve the word from memory capacity and to use it properly. *Lexical retrieval* and *lexical access* refer to lexical and semantic aspects, i.e. aspects of meaning (Salmi, 2008; Tuovinen, 2003).

From the neuropsychological point of view, naming ability, including rapid naming, is a multiple-phased cognitive phenomenon guaranteed by the human neurobiological structure. The Naming process is provided by cooperation between different areas of the brain. Readiness of the visual area of both hemispheres is crucial for the perception of objects. Subsequently, the language areas of the posterior part of the frontal and temporal lobes of the left hemisphere are activated. In these areas of the brain phonemes and the meanings of words are analysed. The motor areas of the frontal lobe guarantee the activation, i.e. they generate the motor program for oral performing (Laine, 1995; Lehtonen, 1993; Luria, 1962; Wolf, 1982, 2008; Wolf & Bowers, 1999). Automatization of cognitive processes, including speech and language processes is provided by the function of the cerebellum (Nicolson & Fawcett, 1999, 2008).

Several researchers have demonstrated that word finding is guaranteed by different neurological structures within the brain and activation of the specific brain areas depends on the type of stimuli presented (serial or discrete presentation). These researchers have ascertained that naming discrete stimuli is related to occipital and frontal lobes and naming serially presented stimulus is linked to the pre- and anterior parts of the frontal lobe (Messer & Dockrell, 2006; Wiig, Zureich & Chan, 2000).

It has been established that naming different stimuli activates brain regions at different levels of activation. Naming letters has been observed to cause more activation in the angular gyrus, parietal and occipital lobe than naming pictures. Naming pictures activates the frontal lobe more strongly. This pattern of activation pattern suggests that there are stronger links between reading and letter naming than between reading and picture naming (Misra, Katzir, Wolf & Poldrack, 2004). Wolf (1986, 2008) has explained the phenomenon in terms of the automatization processes. Wolf`s research shows that naming pictures can be automatized less than naming letters (alphanumerical stimuli generally), and the latter requires greater activation of brain.

According to Luria (1962), the difficulties in naming are caused by damage or dysfunction of different parts of the brain: pre-motor area of the frontal lobe (efferent motor aphasia), superior and medium part of the temporal lobe (acoustic-amnestic aphasia) and posterior part of the temporal lobe (semantic aphasia).

Damasio and her teams (Damasio, Grabowski, Tranel, Hichwa & Damasio, 1996; Damasio, Tranel, Grabowski, Adolphs & Damasio, 2004) have extended knowledge about the neuropsychological basis for the Naming process. They have proven that word retrieval in naming faces, animals and tools is correlated with separable neural sites within different higher-cortices of the temporal regions in left hemisphere outside classic language areas and are correlated with noting objects. Additionally, strong activation was found to be visible in other parts of the brain: motor region, orbital frontal lobe, occipital lobe, anterior temporal lobe and supra marginal gyrus. These researchers showed that recognition of the naming task was evenly distributed across the two hemispheres. The researchers' claim is that impaired retrieval of words denoting actions is related to damage of the left prefrontal and/or premotor regions. This confirmed the partial segregation of naming for different word categories. The usage of these brain parts depends on the task performed (to name or to recognize) and the conceptual category of the item (unique, common or familiar). Impaired word retrieval was not visible in the right hemisphere.

All naming tasks investigated related to temporal regions showed significant blood increase for naming tasks relative to the control no-naming tasks. They summarised that for optimal retrieval of words from different categories, different anatomically separable regions are involved and there are dissociations relative to the type of words and anatomical locus. In short, as language is both a left and right hemisphere function, this assumption should be extended to the rapid naming concept as well, and regarded as underpinned by the cooperation of both hemispheres.

Adult brain imaging studies show that the relevant regions of the brain, that underpin reading and naming, involve very closely related neural circuits. It is logical to assume then that (especially single word) reading and naming processes are performed in the same way. Common neural mechanisms and the integrity of left hemisphere circuits sub-serve the development of rapid automatized naming and reading thereby underpinning the relationship between early rapid naming skills and reading skills. However, the relationship between rapid automatized naming and reading seems to be unidirectional in its development. Difficulties in efficiency with the naming circuits constrain development of reading skills, but increased reading skills do not correlate as increased naming skills per se. Development of naming skills is mainly considered as a function of age and cognitive ability (Karlep, 2003; Laine, 1995; Lervåg & Hulme, 2009; Luria, 1962; Messer & Dockrell, 2006).

Rapid automatized naming could be affected by the magnocellular system. Clarke et al. (2005) demonstrated that good readers paused less than poor readers in rapid naming tasks and that their pauses resembled strategic pauses specific to reading. The authors associated the phenomenon to eye fixations, that occur in the reading process. The magnocellular deficit hypothesis states that SRD readers present difficulties with precision of visual perception and eye moving control (Misra et al., 2004). This is questioned by Hutzler, Kronbichler, Jacobs and Wimmer (2006) who did not notice any differences in eye movements between SRD and normal readers in letter perception and therefore did not associate difficulties in reading with magnocellular deficit.

Moreover, RAN difficulties could be partially caused by inherited genes. Berninger, Abbott, Billingsley and Nagy (2001) found in their study (n > 100 SRD students and their parents) that 83.3% of children and 56% of parents presented rapid naming difficulties. Two longitudinal researches (Jyvaskyla Longitudinal Study and Dutch Study) have shown that children with RD and/or familial dyslexia risk lower achievement in naming tasks than children without any dyslexia risk (van Bergen, de Jong, Regtvoort, Oort, van Otterloo & van der Leij, 2011; Lyytinen, Ahonen, Eklund, Guttorm, Laakso, Leinonen, Leppänen, Lyytinen, Richardson & Viholainen, 2001; Torppa, Lyytinen, Erskine, Eklund & Lyytinen, 2010). Many researchers have evaluated the relationship between RAN and heredity and have found it to be medium to strong (r = 0.40...0.60). These findings suggest that because reading ability in the primary school is affected by genes that rapid naming may also be affected by genes (Byrne, Olson, Samuelsson, Wadsworth, Corely, DeFries & Willcut, 2006; Deutsch & Davis, 2010; König, Schumacher, Hoffmann, Kleensang, Ludwig, Grimm, Neuhoff, Preis, Roeske, Warnke, Propping, Remschidt, Nöthen, Ziegler, Müller-Myhsok & Schulte-Körne, 2010; Grigorenko, 2004; Samuelsson, Byrne, Quain, Wadsworth, Corley, DeFries, Willcutt & Olson, 2005).

Various sets of instruments have been developed in order to explore naming skills. Naming tests are designed to assess the time taken, based on age-related norms, for word finding, semantic and phonological precision and articulation of the named words, assuming the child does not have any speech or language pathology or mental retardation. There are two basic types of naming tests: tests with serially presented stimuli and discrete stimuli.

As mentioned above, naming and reading are underpinned by the same psychological basis. By exploring a person's naming skills one can easily then draw conclusions about his or her reading skills, therefore naming tasks are often included in reading tests.

1. Rapid Automatized Naming (RAN)

Rapid Automatized Naming occurs in everyday life when reading where the correspondence between phonemes and graphemes is a form of rapid naming. During the reading process the rapidly changing grapheme sequence (visual stimuli, letters) has to be decoded into the form of phoneme sequence (sounds).

At the cognitive level, RAN assumes cooperation between many processes: perceptual, attention, memory, reasoning, lexical-semantic and articulatory. Visual, auditory and verbal processes are involved in RAN skills in the context of timing and sequencing. Difficulties in one or more of the aforementioned aspects could cause rapid automatized naming difficulties (RND). RAN and reading skills are found to be correlated at the medium level (n = 1550, r = .45) and Rapid naming deficits are associated with Specific Reading Difficulties (Ahonen, Tuovinen & Leppäsaari, 2003; Denckla & Rudel, 1976a, 1976b; Swanson, Trainin, Necochea & Hammill, 2003; Norton & Wolf, 2012; Waber, Wolff, Forbes & Weiler, 2000; Wolf, 1982, 1991, 1999; Wolf, Bally & Morris, 1986). Research has shown that RAN has an especially high predictive value for reading results of marginal readers, i.e. those readers who remain under the 10th percentile for reading and above the 90th percentile for slowness of naming (Araujo, Pacheco, Faisca, Petersson & Reis, 2010; Frijters, Lovett, Steinbach, Wolf, Sevcik & Morris 2011; Lervåg, Bråten, & Hulme, 2009; Meyer, Wood, Hart & Felton 1998). According to numerous studies, Rapid Naming predicts reading results up to Grade 4 (Badian, Duffy, Als & McAnulty 1991; Frijters et al., 2011) or even to Grade 6 (Vaessen & Blomert, 2010).

When measuring RAN, the most relevant criteria are naming speed and accuracy/precision. Research suggests that slow naming speed and/or the amount of mistakes in naming tasks predict RD in both regular and irregular orthographies. However, the relation between RAN and reading is considered stronger in regular orthographies than irregular ones (Araujo et al., 2010; Badian et al., 1991; Denckla & Rudel, 1974; Furnes & Samuelsson, 2011; Korhonen, 1995; Salmi, 2008; Wolf, 1986). This is because it is easier to learn to read in a language which is transparent, and therefore speed of reading is the key to diagnosis, by contrast with accuracy in irregular languages. RAN speed has more diagnostic value than accuracy in regular orthographies (Aro, 2004, Holopainen et al., 2001; Lervåg, Bråten, & Hulme, 2009; Misra et al., 2004; Wolf, 1986; Wolf & Bowers, 1999). Studies on Chinese language have shown a strong correlation between RAN and reading in Chinese, i.e. in uniquely different logographic systems of reading. RAN is identified as a significant and stable predictor of reading in Chinese up to Grade 5 and presents the most dominant type of cognitive deficit in Chinese-speaking children with dyslexia (Ho, Chan, Lee, Tsang & Luan, 2004; Kang, 2004; Yeung, Ho, Chik, Lo, Chan & Chung, 2011). A few studies have examined the predictive power of RAN in Arab and Persian languages. These studies found, that despite having different orthographies in comparison with English, RAN could predict reading skills in these languages as well (Sadeghi, Everatt, McNeill & Elbeheri, 2009; Taibah & Haynes, 2011). Although the lowest in range, RAN increased steadily and was strongly fixed by Grade 3 (when basic decoding skills become automated) and even exceeded the predictive power of phonological awareness in Arabic (Taibah & Haynes, 2011). A Malay language screening test has also identified RAN as a contributory predictor to reading, in addition to phonological deficits (Lee, 2008).

The most well known RAN tests are the *Rapid Automatized Naming Test*, (Denckla & Rudel, 1974; Wolf & Denckla, 2005), *Rapid Serial Naming Test* (Wolf and Denckla, 1986) and *Rapid Automatized Naming Subtest* (Wiig et al., 2000). Speed, as the most valuable and distinctive characteristic of the process, is assured by changing the stimuli in a RAS serial presentation to make the task more challenging. The number of errors are a secondary consideration in RAN tasks. The aim of naming tasks is to name presented stimulus (alphanumerical, non-alphanumerical or mixed versions) as fast as possible and move ahead to the next stimulus. The most widely used stimuli are numbers, letters (alphanumerical), pictures, colours, geometrical shapes (non-alphanumerical) and mixed versions. The traditional naming test consists of 4-8 subtests, each subtest contains 5 and 10 randomly presented stimuli repeated over the page (Ahonen et al., 2003; Clarke, Hulme & Snowling, 2005; Denckla & Rudel, 1974, 1976a, 1976b; Wolf, 1982, 1991, 1999; Wolf, Bowers & Biddle, 2000).

A list and summary of selected research using RAN/RAS tests is presented by Wolf and Denckla (2005). This summary, intended for researchers, highlights samples, ages/grades and results gathered between 1972–1995. Most of these investigations have involved children (primary school) and teenagers (basic school); a few studies engaged pre-schoolers or adults. Two studies explored RAN skills in kindergarten children. Regular readers completed samples as controls, and the experimental groups were described as dyslexic readers, slow learners, ADD students and impaired readers. Two of the studies listed were conducted in German. These studies elaborated on normative data for RAN measurement, investigated RAN and reading relationship and compared RAN results in controls with experimental groups.

The normative data findings from these studies have allowed subsequent years of RAN investigations to delve more deeply into this field of study. The most challenging research questions concerned the neuro-cognitive and genetic relationship between RAN and reading, the role of RAN in the reading process and the connection between Rapid Naming Deficits and Specific Reading Difficulties. Educational and practical implications are very relevant issues in the context of assessment and remedial instruction for struggling readers.

Most of the researchers suggest that there is a stronger and more specific correlation between alphanumerical stimuli and reading than non-alphanumerical stimuli and reading (Misra et al., 2004; Pham, Fine & Semrud-Clikeman, 2011; Wolf, 1991; Wolf, 1999, 2008; Wolf et al., 1986). Savage and Fredricson (2005) and Compton (2003) discovered that the naming of alphanumerical stimuli has predictive value in relation to decoding, reading precision and speed. In accordance with this body of research, picture naming does not present a predictive value to reading. Savage and Fredricson (2005) have discussed the following: picture naming requires semantic access, which is not inevitable for the naming of non-alphanumerical stimuli. The automatization process in naming alphanumerical stimuli depends on age, cognitive capacity and reading instructions. The decrease in predictive value of picture naming, as an age-related function, is explained by the non-automatization processes of picture naming (Arnell, Joanisse, Klein, Busseri & Tannock 2009; Luria, 1962; Misra et al., 2004; Wolf, 2008; Wolf et al., 1986). Contrary to these notions, some research has demonstrated that picture and colour naming are stronger and more persistent (up to age 18), in relation to reading speed and comprehension, than naming alphanumerical stimuli (Arnell et al., 2009; Cronin, 2011; Denckla & Rudel, 1974; Lervåg & Hulme 2009).

The results of numerous studies have shown that RAN contributes substantially to reading fluency across all six primary school grades. Indeed, the relationship between RAN and word reading fluency increases gradually as a function of reading experience (Breznitz, 2006; Vaessen & Blomert, 2010).

The relationship between RAN and reading comprehension has not been explained unambiguously and the need for further research is articulated (Arnell et al., 2009; Compton, 2003; Denckla & Rudel, 1974; Li, Kirby & Georgiou, 2011). Some research confirms that RAN also predicts reading comprehension. It has been claimed that reading comprehension and number and letter naming might be related to the articulation pause time rather than pure articulation time. The latter relationship is found in Grade 6, but not in Grades 2 or 4 (Li, Cutting, Ryan, Zilioli, Dencla & Mahone 2009; Li, Kirby & Georgiou 2011). Chinese reading comprehension has been found to show a statistically significant (albeit small) contribution from RAN (letters and numbers) (Leong, Tse, Loh & Hau, 2008).

Briefly, research has confirmed that RAN predicts reading performance. The speed of alphanumerical RAN performs as an especially strong predictor in transparent orthographies.

There are clear developmental changes in the speed of RAN, based on the mean and standard deviations for the RAN/RAS Tests at 14. Age intervals and correlations with age are represented in the RAN/RAS Examiner Manual (Wolf & Denckla, 2005). The data presented show evenly decreasing testing time from age 5 to 18. The mean time recorded at age 18 is two to three times less than the mean time at age 5, accordingly: objects 74 sec and 35 sec, colors 73 sec and 34 sec, numbers 74 sec and 27 sec, letters 83 sec and 28, 2-set letters and numbers 97 sec and 31 sec, 3-set letters, numbers and colors 94 sec and 32 sec. Variability, as expressed in Standard deviations decreased between age 5 to 12 (mean variability 30.5 and 10.6), but persisted to age 15 and increased somewhat between age 16–17 (mean 9.1) and showed the smallest deviations by age 18 (mean 8.8). RAN mean times were moderately correlated with age, with correlation coefficients between .48 and .64, significant at $p < .0001$ level. Similar developmentally determined findings were reported by Li et al. (2011) who measured RAN articulation and pause times in both English and Chinese and noticed both decreased by age, but the pause time decreased faster than articulation time. These developmental changes in articulation and pause times show that pause time is the more sensitive indicator of language proficiency.

These results confirm that RAN time decreases as function of age. These results are in line with theoretical knowledge about improving reading acquisition in preschool and primary school and stating that reading acquisition to be mainly completed by ages 12-13.

2. Naming Difficulties

Several terms are used to refer to naming difficulties: naming deficit, word finding disorder, lexical look-up problems, dysnomia and anomia.

It is justified to consider Naming Difficulties as a persistent problem (reflecting low- or non-automated processes) in word selection, retrieving and producing processes. Naming Difficulties reflect the inability to name a real or imagined object or to find the word necessary to continue a conversation as well as incorrect or improper usage of a word, slow retrieval of words from memory or emerging secondary markers (e.g., extra words, gestures etc.). Naming Difficulty does not implicitly include word comprehension difficulties But rather retrieval diffculties (Constable, 2007; German & Newman, 2007; Luria, 1962; Tuovinen, 2003; Messer & Dockrell, 2006).

Naming Difficulties can be combined with other developmental disabilities. Children with Naming Difficulties are noticably linked with specific language impairment, dysphasia, dyslexia, learning difficulties (LD) and stuttering (Araujo, Pacheco, Faisca, Petersson & Reis, 2010; German & Newman, 2007; Tuovinen, 2003; Messer & Dockrell, 2006; Rapin & Allen, 1983). There is adult Naming Difficulties have been related to aphasia, dementia, Alzheimer syndrome and Parkinson disease (Luria, 1962; Taler & Phillips, 2008), but these are usually acquired rather than developmental. Naming

Difficulties have been observed to be very persistent and can be transmitted from childhood to early adulthood (Ahonen et al., 2003; Arnell et al., 2009; Constable, 2007; Holopainen et al., 2001; Korhonen, 1995; Meyer et al., 1998; Salmi, 2008; Wolf, 1999). The type of Naming difficulty most frequently observed in children with Specific learning difficulties includes word retrieval problems coupled with circumlocution.

2.1. Rapid Naming Difficulties

Rapid Naming Difficulties, described as inconsistent and slow or delayed development and abundance of mistakes, are characteristic of specific language impairment (SLI) and other developmental disorders. Rapid Naming Difficulties are usually assessed based on the standard deviation 1, 5 or 2 depending on the naming speed and amount of mistakes (Ahonen et al., 2003; Denckla & Rudel, 1976a; Wolf et al., 1986).

Rapid Naming Difficulties can be observed at both developmental and behavioural levels. At the developmental level, difficulties appear as inconsistencies, i.e. noticeable relapses and nonlinear growth curves. Difficulties at the behavioural level are demonstrated by slow naming speed and an abundance of mistakes. In the following section, the problems with RAN will be explored in greater depth, presenting a range of comparative data.

Ahonen et al. (2003) have explored and described the characteristics of Rapid Naming Difficulties in three independent groups of children aged 6-12. The research included a control group (normal development, no special teaching), part-time special teaching of students in mainstream schools (mild reading difficulties, n = 235) and full-time special teaching of students (severe speech and reading difficulties, n = 85). RAN development in both of the special groups is characterised as inconsistent and dependent on specialist support in the learning process.

Students in special groups showed delay, achieving approximately similar results to the control group in naming speed (especially with colours and objects) one to three years later. For example, the colors-letters-numbers subtest naming speed in the age 8 control group (51,0 sec) was obtained by students in the part-time special teaching group at 9 years (46,7 sec) and by students in the full-time special teaching group at 10-11 years (48,2 sec).

Moreover instability and relapses were noticed in the development of naming skills for the students in special groups. For example, the special group students' numbers-letters and colors-numbers-letters RAS naming speeds at 10 years were measured respectively at 41,8 sec and 44,6 sec, while at 11 years they were respectively 44,2 sec and 51,7 sec. This seems to indicate that they were becoming slower and more variable with age.

One noteworthy finding is described by Ahonen et al. (2003), namely that special group students passed the objects subtest faster at 8 years than normal development students. These results confirm those previous results demonstrating RAN development peculiarities in children with aberrational speech development.

The amount of mistakes in RAN tests are connected to age and cognitive development. A decreasing number of mistakes and an increasing number of self-corrected mistakes are considered age-related functions, as with naming speed. The aforementioned research by Ahonen et al. (2003) revealed nonlinearity between age and correction of mistakes and dependence on special teaching. The authors found that special group students tended to self-correct their naming mistakes less often than normal group students. Both part-time special group students and control group students tended to correct their mistakes, approximately 60-87%. The range of corrected mistakes of full-time special teaching group students stayed at 44-82, 1%.

Similarly, in a comparative study by Araujo et al. (2010) about dyslexic and normal readers, RAN tests with different results were found. They measured significant differences between dyslexic and normal readers in RAN speed, accordingly – 1.2 ± 1.3 and 0.7 ± 0.87, $p < 0,001$.

A Dutch investigation by van Bergen et al (2011) reported additional different results in RAN tests comparing at-risk dyslexics, at-risk non-dyslexics and controls. Comparisons revealed that in Grade 1, the at-risk non-dyslexics were significantly slower than the controls, but surprisingly, significantly faster than the at-risk dyslexics. The phenomenon is worth further exploration. After half a year of reading instruction, at-risk dyslexics were slower in the naming of letters compared with the at-risk non-dyslexics, who were slower than the controls, and scored accordingly, 0.82, 0.96 and 1.18, $p < 0.001$. By the end of the first school year, at-risk non-dyslexics had reached the same level as the controls, scores for at-risk dyslexics were 1.24, at-risk non-dyslexics and controls 1.01, $p < 0.001$.

Ho, Chan, Tsang & Lee (2002), research showed that 50% of dyslexic Chinese children had difficulties in rapid naming, which is a major problem for orthographic and visual processing (36,7%) (cited by Kang, 2004).

In conclusion, the features of Rapid Naming Deficit are inconsistent development; slow naming speed and large amount of mistakes. Rapid Naming Difficulty is a characteristic problem for SRD/dyslexia and those at risk for it.

2.2. Double Deficit Hypothesis (DDH)

Based on findings drawn from connections between RAN skills, phonological awareness and reading skills, Wolf, (1986) developed the Double Deficit Hypothesis (DDH) which combines a single or combined RAN speed deficit and a phonological deficit in children with SRD. According to this theory readers may be divided into four subgroups. The first subgroup is composed of children with a naming speed deficit but intact phonological awareness. They read slowly but without phonological mistakes. The second group has a phonological awareness deficit but intact naming speed. These children read fast but with many phonological mistakes. Both groups show mild to moderately impaired reading skills and comprehension which is not persistent, especially where they are supported by relevant treatment and special reading instructions. The third group of readers has both naming speed and phonological awareness deficits, i.e. double deficit. These children have severely impaired reading skills and a reading comprehension deficit in combination with a slow verbal ability and they would be classified as classic dyslexics. The fourth group has no problems in naming speed, phonological awareness and reading or reading comprehension. Single deficit occurs among ~ 15-20% and double deficit for ~ 60% of children with SRD. Wolf and Bowers have suggested that RAN difficulties are characteristic of children with SRD but not children with mental retardation (Wolf, 1986; Wolf, 1999; Wolf & Bowers, 1999; Wolf et al., 2000). Consistent with the aforementioned double-deficit hypothesis, similar subtypes of dyslexic readers were found in Araujo et al. (2010) research in a Portuguese sample: 18.2% showed a single deficit in either RAN or phonological tasks and 50% co-occurrence of both. Based on their research results Araujo and colleagues stated that a RAN deficit seems to be more persistent in impaired readers with intact phonological skills. Papadopoulos, Georgiou and Kendeou (2009) have noted that the single phonological-deficit subtype, showed reading results consistent with their age group by Grade 2, but not the single naming-deficit group. Inter alia, these findings seem to confirm the role of RAN to be more important in regular orthographies (Araujo et al., 2010).

This double-deficit theory was replicated in Cronin's (2011) longitudinal study from preschool up to Grade 5 in order to verify the hypothesis and RAN (besides PA) as a reading predictor. The results showed that the RAN object scores of preschool and kindergarten children predicted reading at every age level and offered support for the double-deficit hypothesis and Lervåg's and Hulme's (2009) neuro-developmental theory. It was concluded that both RAN and PA predict reading disabilities in English, throughout the elementary school years, and that the early assessments of these variables were more diagnostic than measures used at later ages. Kang's (2004) study in Chinese proved that RAN speed was the most significant predictor of good readers for Grade 1 and Grade 3. Additionally, RAN speed was the most significant predictor for reading failure for Grade 5.

Contrary to Double Deficit Theory, some critics have controlled for the double deficit statistically. They have argued that RAN and phonological awareness are sequenced sub processes from a larger phonological representation and cannot be observed separately (Ramus, 2003).

3. Rapid Automatized Naming, Cognitive Processes and Reading

The naming process is a verbal-cognitive complex consisting of cognitive, perceptual and linguistic sub processes all underpinning the reading process. The research stresses that these common processes characterize both naming and reading: retrieving and utilising a linguistic equivalent in accordance to presented stimuli as quickly and precisely as possible. Naming skills are considered important in reading acquisition, especially in alphabetic-phonetic orthographies (Denckla & Rudel, 1976a; Furnes & Samuelsson, 2011; Goswami, 2000; Georgiou et al., 2011; Wolf, 1991, 1999). Incorrectness and slow naming speed refer to SRD, and are characteristics of both SRD and general learning difficulties (Messer & Dockrell, 2006; Heikkilä, Närhi, Aro & Ahonen, 2008; Waber et al., 2000).

The following overview of the cognitive processes, underpinning naming and reading processes, is based on Salmi (2008) and supplemented by the author of this paper. This review reflects published concepts and discussions on this field.

Although the relationship between RAN and phonological skills has been researched and explored, there is no consensus on explanations of the precise mechanism behind it. Some researchers claim that RAN and phonological skills are independent processes measuring different aspects of reading (Närhi, Ahonen, Aro, Leppäsaari, Korhonen, Tolvanen & Lyytinen, 2005; Savage & Fredricson, 2005; Wolf, 1999; Wolf & Bowers, 1999; Wolf et al., 2000). These views were confirmed by Araujo et al. (2010) who identified a group of dyslexic children with intact phonological processing but poor in RAN skills. Other researchers have defined RAN as efficiency of phonological code retrieval and a component in large-scale phonological and memory processing. These researchers e.g. Ramus claim that slow naming speed is related to slow phonological processing and they consider the decreased naming speed to be a part of the phonological representation (Ramus, 2003; Vellutino, Fletcher, Snowling & Scanlon, 2004; Swanson et al., 2003; Vukovic & Siegel, 2006; Wagner & Torgesen, 1987).

Naming skills are based on speed of information processing. However, it is still not clear whether naming skills are related only to verbal information processing speed or could be related to general information processing speed. According to the verbal information processing theory, naming speed is related only to language processing speed. A connection has been found between slow naming speed and unusual language processing deficiency, associated especially with decreased timing and orthography (Li, Kirby & Georgiou, 2011; Lervåg & Hulme, 2009; Messer & Dockrell, 2006; Neuhaus, Foorman, Francis & Carlsson, 2001; Wimmer, Mayringer & Landerl, 1998).

According to general information processing theory, decreased naming speed reflects general information processing deviation independently of age and reading experience. The special difficulties of dyslexic readers in managing rapidly changing or presented stimuli, in both visual and auditory tasks, have supported this theory (Catts, Gillespie, Leonard, Kail & Miller, 2002; Denckla & Rudel, 1976b; Kail, Hall & Caskey, 1999; Kleine & Verwey, 2009; Nicolson & Fawcett, 2008; Wolf, 1991; Wolf & Bowers, 1999; Wolf et al., 2000). In 1976, Denckla and Rudel had already described the difficulties experienced by dyslexic readers in timing when performing both linguistic and non-linguistic tasks. Some authors presume that there is a strong correlation between general information processing speed and RAN (Logan, Schnatschneider & Wagner, 2009).

Automatization theory stresses that learned skills accumulate through the process of repeated practice and become more and more fluent until intentional thinking about skill performance is no longer needed. Both naming and reading automatization are defined by fast and short reaction times. Automatization of naming skills is considered to be a fast and effortless level of processing, that provides access into phonological, semantic, lexical and syntactical components and requires some or no awareness at all (Catts et al., 2002; Logan, 1997; Logan et al., 2009; Meyer et al., 1998; Nicolson & Fawcett, 2008; Neuhaus & Swank, 2002; Norton & Wolf, 2012; Wolf et al., 1986; Wolf et al., 2000). Tests consisting of serially presented pictures are treated as a relevant tool for measuring the automatization aspect of RAN skills (Meyer et al., 1998).

It has been claimed that automatization deficits affect skills more widely than just those involved in language and literacy, and that all skills that demand expert performance will be compromised (Nicolson and Fawcett, 2008). Children with RD have been found to present automatization difficulties in timing and sequencing tasks, gross motor and balance tasks (Kleine & Verwey, 2009; Nicolson & Fawcett, 2008).

Contrary to the automatization theory, some studies have shown that general automatization difficulties do not cause SRD. The results that dyslexic children achieved in motor and balance tasks and other non-verbal tasks differed very little from the results of control children of appropriate age (Wimmer et al., 1998; Kasselimis, Margarity & Vlachos, 2007; Ramus, 2003).

There are also contradictory results and explanations about RAN and working memory: some authors confirm the connection between RAN and working memory, others show the instability and/or weakness of the connection, while a third contingent relates a connection with orthography. The need for further research is widely expressed by all (Ackerman, Dykman & Gardener, 1990; Georgiou, Das & Hayward, 2008; Närhi et al., 2005; Salmi, 2008).

There is now a limited number of recent studies that have investigated articulation as an underlying factor for RAN. The research evaluated explicit articulation time and pausing between two stimuli as two distinct processes. The process more relevant to RAN and the reading relationship is pausing time as it refers to language-specific associations between visual and verbal codes, speed of lexical access and progress forward speed (Araujo, Inacio, Francisc, Faisca, Petersson & Reis, 2011; Georgiou, Parrila & Kirby, 2006; Lervåg & Hulme, 2009; Li, Cutting, Ryan, Zilioli, Dencla & Mahone 2009; Li, Kirby & Georgiou, 2011; Salmi, 2008, Wolf, 1999 Wolf & Bowers 1999). Li et al., (2009, 2011) has figured out that colour and letter naming pause time and number naming articulation time were significant predictors of reading fluency. In contrast, the same investigation showed that number and letter pause variability were predictors of reading comprehension. In summary, RAN pause time and total naming time were related to reading comprehension by Grade 6, but not in earlier grades.

Naming skills are related to lexical-semantic processes (Salmi, 2008). However, researchers have found that naming skills and semantic skills are weakly connected statistically and that semantic problems do not include naming difficulties implicitly (Constable, 2007; Swanson et al., 2003). Serially presented stimuli tests investigate RAN sub-skills and discretely presented stimuli tests measure lexical-semantic aspects. Children with SRD tend to have difficulties in RAN tasks rather than unusual deficiencies in vocabulary skills. Consequently, serial RAN could be more strongly related to reading than discrete RAN (de Jong, 2011; Meyer et al., 1998). Wolf (1991) has pointed out that children with SRD have shown difficulties in naming discretely presented stimuli, that relates to the weakness in reading acquisition and in access to the lexical-semantic features.

The differential value of RAN tasks is noteworthy when viewed in the context of developmental disorders. RAN and diverse learning difficulties are probably related in several various ways. The differences in rapid naming RAN, especially in picture naming, have been noticed to discriminate between children with RD and attention deficit hyperactivity disorder (ADHD) (Savage & Fredricson, 2005) and also children with SRD and general learning difficulties (Denckla & Rudel, 1976a, 1976b; Heikkilä et al., 2008; Torppa et al., 2010). Conversely, Waber et al. (2000) found that RAN made a more visible difference in LD, but was inefficient in separating SRD children from LD children. The discussion on RAN as general or language specific phenomena is still an open one, and more research is needed.

Educational and Future Implications

In summarising materials referenced and analysed on the role of RAN in the reading process, it is possible to propose some implications for future scientific research and educational practice.

By necessity, future research into RAN needs to be accompanied by heterogeneous and relevant knowledge about reading complexity, the underlying processes of reading and reading difficulties. Increased depth of understanding about RAN's role in the reading process assumes the continued incorporation of information from brain imaging and/or genetics. More in depth understanding of the role of RAN in reading processes assumes that the incorporation brain imaging and/or genetics should be continued.

Understanding the relationships and the sequence of cause and result sequences is crucial for effective early identification and remediation arrangements. In the reading research conducted so far, there have been various sets of instruments and variables used. Educators need reliable, easy-to-use and time-efficient approaches and methods to detect reading status, reading difficulties and the risk for it in children at pre-school and school age. RAN tests administered in the early years of reading (from preschool up to Grade 3) have been shown to have high diagnostic value and so, the inclusion of RAN tasks into reading assessment instruments is justified by these numerous investigations.

By detecting potential difficulties in reading acquisition, as early as possible, we can prevent further academic, behavioural, emotional and social problems (Byrne et al., 2006; Katzir, 2008; Kim, 2004; Norton & Wolf, 2012; Wolf, 2003).

Struggling readers need access to effective and science-based educational remediation programs. Understanding the different types of challenges children face in learning to read is important in developing and delivering accommodated instruction practices to children. Children with reading problems benefit from specified remediation programs directed toward their cognitive and language abilities, including naming and fluency problems that underlie reading disabilities. Children with special naming and fluency deficits may not benefit from traditional intervention programs (Byrne et al., 2006; Katzir, 2008; Norton & Wolf, 2012; Wolf, 1999).

It is debated whether RAN presents limited implications in practice to improve reading skills and it has been noted that training for RAN (letter) has little effect on either RAN or reading training. This evidence suggests that RAN taps into a more basic index of cognitive and language processing (Lervåg & Hulme, 2009; Norton & Wolf, 2012).

Wolf (1999), and colleagues have investigated using reading sub-skills to demonstrate methods for improving reading fluency. The essential consequences and implications of the Double Deficit Theory can be demonstrated using the RAVE-O program (retrieval, automaticity, vocabulary-elaboration, and orthography). RAVE-O meets the needs for reading fluency and automaticity at two levels: in reading behaviors (word identification, word attack, and comprehension) and in the underlying component processes, including visual and auditory recognition, orthographic pattern recognition, lexical-retrieval and semantic processes. Tasks in this program have been used to address the need to increase visual scanning speed, orthographic pattern recognition, auditory discrimination and word identification, which share the same cognitive processes with RAN.

The principle concept of the practice is that one retrieves fastest what one knows best. Norton and Wolf (2012), stated that differential treatment studies are critical in determining whether subtypes of children with processing-speed difficulties are benefited by the targeting of specific word recognition skills or by placing more comprehensive emphases on fluency across all the underlying components.

The results of existing studies indicate that remedial training programs need to be specific to a reader's subgroups (by DDT) and the language in which reading improvements are sought (Li et al., 2011; Wolf, 1999; Wolf & Bowers, 1999).

Recent developments in visual media have inspired researchers to consider how reading using new and electronic media affects early reading instructions and reading automaticity and fluency comprehension (Norton & Wolf, 2012).

Summary

Previous research has shown that naming skills provide two basic functions of language – naming and generalisation. It is essential for everyday living to be able to retrieve necessary words from memory and to present them as fast and correctly as possible. Disturbances (slow speed and crucial amounts of mistakes) in these processes suggest Naming Difficulties and are related to SRD (Denckla & Rudel, 1976a, 1976b; German & Newman, 2007; Luria, 1962; Messer & Dockrell, 2006; Tuovinen, 2003; Wolf & Bowers, 1999).

Valuable knowledge has been obtained about RAN, one of the naming sub-skills. RAN is considered a verbal-cognitive skill that is comprised of visual and auditory perception, articulation and lexical processes of language, as well as, sequencing and timing processes. RAN tasks simulate the reading process and they have the same origins. Therefore, results from RAN tests are able to predict later reading performance including both as SRD and the risk of SRD. Researchers have shown that Naming Difficulties have persistent connections to SRD. Naming Difficulties observed before the beginning of formal reading instruction (age 6-9) persisted through adolescence, so that reading was performed more slowly and more mistakes were made in both naming and reading tasks, than by their peers.

Despite the progress that has been made in understanding the phenomenon of RAN and connections to the reading process, future investigations are required. More research is needed to elaborate on causal mechanisms between RAN and reading involving cognitive and executive processes. Furthermore, the relationship between RAN and phonological processing needs further investigation. We look forward to the continued analyses of the two concurrent approaches still under discussion in the field: whether the issue is language specific or a more general deficit. The double deficit hypothesis and the three proposed groups of RD are not clearly established yet. There is a lack of investigations about double deficit hypothesis in different languages and orthographies. The stability of RD groups is still under question and requires more detailed research.

Practical experience in the use of RAN in the diagnostic process is still not fully reflected in published research. There must be lot of essential information for scientific approach and researches in generalisation of practice.

RAN as a treatment has value and merits more attention. Its widely known title of *'easy to measure, hard to improve'* makes it a worthy matter for both theoretical and practical application.

In conclusion, contemporary research into the area of RAN skills are essential for different languages and cultures in focusing on the nature of RAN and its casual relationship to different developmental difficulties regarding further theoretical and practical statements.

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Could pre-school eye movements contribute to diagnosis of reading and/or dyslexia? A longitudinal case study

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The author studied the relationship between eye movements of a preschool child (boy) and his subsequent development as a reader. The aim was to contribute to findings about whether there is information within eye movements about future reading development and its anomalies. The case report showed that long-term, partial weakening of eye movements correlated with long-term, partial weakening of reading development. With caution it can be stated that examinations of eye movements may contribute to prognostic considerations in the field of reading development and may become part of preschool screening.

Keywords: dyslexia, reading, eye movements

Diagnosis code 315.0 in DSM-IV-TR specifies the following criteria for dyslexia: A. Reading performance is significantly lower than expected for that particular chronological age, IQ and education; B. The reading disorder interferes with school performance or general activities which require reading skills; C. In differential diagnostics, it is necessary to eliminate the following from the list of reading disorder causes: mental retardation, sensory disorders, neurological illness and other general health ailments, including emotional neglect.

The etiology of dyslexia is still unclear. The prevailing opinion is that the disorder is of neurobiological origin (e.g. Bakker, Van Strien, & Licht, 2007; Bucci, Brémon-Gignac, & Kapoula, 2008; Galaburda, 2005; Wiseheart, Altmann, Park, & Lombardino, 2009).

According to phonological theory, the essential problem is so-called phoneme

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awareness (Liberman, 1984). This is the ability to identify parts of a word, phonemes, in the word as a phonetic whole. Each phoneme has a particular grapheme (i.e. letter) assigned to it. While reading, a child must identify a specific grapheme from others and add sound to it (known as grapheme – phoneme correspondence). Dyslexics have difficulty identifying phonemes and are therefore unable to orientate themselves with respects to grapheme – phoneme correspondence, and with their deformed phonological key they are not able to access meaning which is coded within the graphic representation of words.

Eye movements of the so-called phonological dyslexics (see Rayner, 1998, 2009) are highly erratic but only while reading a text adequate to their chronological age. When reading a much easier text, their eye movements become renormalised. In non-reading tasks, i.e. those not requiring linguistic processing, their eye movements do not significantly differ from the controls. The cause for the failure among linguistically oriented dyslexics to read correctly then does not originate from incorrect eye movements but from imperfect linguistic or phonological processing instead.

Visual dyslexics are quite different to phonological dyslexics. Visual dyslexia is associated with the theory of visual deficit or magnocellular theory (Eden, Stein, Wood, & Wood, 1994; Eden, Van Meter, Rumsey, & Zeffiro, 1996; Galaburda, Menard, & Rosen, 1994; Livingstone, Rosen, Drislane, & Galaburda, 1991; Ray, Fowler, & Stein, 2005; Stein, 1991, 2001; Stein & Fowler, 1984; Stein, Richardson, & Fowler, 2000; Stein & Talcott, 1999; Wilmer, Richardson, Chen, & Stein, 2004). Advocates of the theory of visual deficit argue that the nature of the problems dyslexics have need not necessarily be of linguistic origin, as problems may also occur in a non-verbal situation.

Presumably, the problems are accountable to changes in the magnocellular system. Proponents of the visual and magnocellular theory ascribe significance to differences in eye movements between dyslexics and control groups while performing non-verbal tasks. They claim that the eye movements of dyslexics are normal but they are unable to process visual images and spatial information as such. Supposedly, eye movements are not the cause of poor reading. The theory of visual deficit does not deny the validity of phonological problems. The above mentioned authors (e.g., Eden et al., 1994; Ray, Fowler, & Stein, 2005, etc.) merely try to demonstrate the fact that dyslexia is a far more diverse problem than generally believed and that the problems of dyslexics reach beyond the limits of traditionally-defined language deficits stemming from impaired phoneme awareness.

A specific approach to the eye movements of dyslexics is expressed in the cerebellar theory. Its proponents note that many dyslexics have, in addition to the reading and language problems described in the phonological theory, non-linguistic problems, such as imbalance or motor and sensorimotor discoordination (Brookes & Stirling, 2005; Finch, Nicolson, & Fawcett, 2002; Nicolson & Fawcett, 2011; Nicolson, Fawcett, & Dean, 2001;

Reynolds, Nicolson, & Hambly, 2003; Stoodley, Fawcett, Nicolson, & Stein, 2006). The cerebellum plays a significant role in controlling oculomotor behaviour – i.e., cerebellar dysfunction manifests itself through eye movements and affects a person's reading aptitude.

The share of visual-spatial problems among dyslexics remains an unanswered question. Under the strong influence of phonological theory, it was generally believed that the language-deficit type was more prevalent, whereby visual or visuo-spatial disorders were considered complementary. Researchers estimated that at least two thirds of dyslexics have had problems with the phonological conversion of orthographic symbols (Rayner & Pollatsek, 1989; Castles & Coltheart, 1993). However, this was conclusion was challenged by the visual theory followed by the magnocellular theory. Stein (2001) pointed out that in his studies only one third of dyslexics have mostly phonological problems, one third mostly visual-orthographic problems, and in the remaining third both types of problems are more or less equally prevalent.

Despite a great number of studies focusing on links between eye movements, reading and dyslexia, published in the last three decades, the role of eye movements is still unclear. The aim of this study, therefore, is to help clarify the role that eye movements play in reading and/or dyslexia.

In one of our studies (Jost, 1992), we came across the case of a boy who had above average phoneme awareness, yet below average reading development. This case is the subject of the following study.

Method

Participants

The boy was part of a sample group of cca 100 children which we observed from preschool age to the end of sixth grade. The aim of the study was to determine to what extent eye movements could be used to predict reading development. All the children had attended kindergarten from the age of 5 to 6 and had then started to attend primary school (children in the Czech Republic start school in September after they reach the age of six). All the children had an identical curriculum and were subjected to identical teaching methods. The children's native language was Czech. None of the children's families were registered with the social support system on suspicion of the child abuse and neglect syndrome (CAN), alcoholism, any form of addiction, criminal behaviour or financial poverty. During the five-year monitoring, none of the children underwent any neurological or psychiatric treatment. None were assessed as ill by a paediatrician. No sensory defects were detected from among the children, that is to say, visual defects had been amended.

Eye Movements

We used an infrared head mounted eye tracker developed by Pavlidis at the University of Thessalonike, Greece. Eye movements were measured with 100 Hz temporal and 0.2° spatial resolution. The recordings were monocular (taken from the left eye only). The reason for this was the need to simplify the apparatus. The device was not able to register vergence; nevertheless, the recordings of saccades were not affected in any significant way. Despite that the subjects perceived the tasks binocularly. The child was seated in a chair and his/her head was stabilised by a chin and/or head rest. The eye tracker was calibrated using a three-point routine. The output data were subjected to an online check that enabled the subject to be encouraged continuously to perform to the best of his oculomotor ability. Fixations and saccades interrupted by blinks were excluded from further analysis.

We used two non-reading tasks to examine eye movements: 1) In the so-called sequential task, the child watched a horizontal row of six lights which lit up gradually from left to right and back, right to left, etc. This task stimulated horizontal saccades. 2) The child fixed its vision on a target drawn on a piece of paper. This task tested fixation stability.

Measures

In the preschool period we gained information from parents about the personal and family history of their child, and from kindergarten teachers we gained information about the hyperactivity of the child using the shortened version of Connors' Rating Scale.

In the primary school period we recorded the child's successes, administered tests on reading, intelligence (WISC), graphomotorics, attention, sociometric position, self-concept and Connors' Rating Scale for hyperactivity and examined speech with regard to articulation dyspraxia.

Reading

This was measured by a standardised test and described by the amount of correctly read words within a time interval. Speed of reading in the Czech linguistic environment (i.e., in a phonetically highly consistent spelling system) correlates with comprehension (Matejcek, 1998a, 1998b). The reading test was administered at the end of the 1st, 2nd, 3rd and 5th grades. The purpose was to describe the development of the children's reading. What usually occurs (Bakker, 1990) is that within the first two years of school attendance (the phase of initial reading), children preferentially process text using the right cerebral hemisphere. Between second and third grade, they switch to the left hemisphere and begin to use this one preferentially. In fourth or fifth grade, reading development should be stabilised (the phase of advanced reading). Average pupils in Czech schools are able to read fluently and with comprehension any unknown text in their native language adequate to their age after the first term of school attendance.

Graphomotorics

This is measured using a standardised test (Matejcek & Strnadova, 1974). The child copies geometric shapes according to those supplied, e.g. circle, diamond, the intersection of a five-pointed star and a pentagon, etc.

Pupil's self-perception

Measured by SPAS (Student's Perception of Ability Scale) from Boersma and Chapman (Matejcek & Vagnerova, 1987). This test measures overall level of self-appraisal and enables the comparison of a pupil's self-appraisal in the subjects of Czech language (i.e. native language) vs. mathematics.

Visual concentration
This is measured using a standardised test (Jirasek, 1975) during which the child is presented with a table containing randomly arranged numbers from 1 to 25 and the child's task is to find the numbers in sequential order as quickly as possible. The task is repeated ten times and the time is measured each time.

Pupil's popularity
This is measured by the pupil's score on the sociometric test L-J from Long and Jones (Musil, 1977) using a like-dislike scale.

Results

Eye Movements

Figure 1 shows the characteristic course of the boy's eye movements at preschool age (6 years, 7 months).

It is evident from the report that the child fixates each light and adheres to the required sequence. With regards to this characteristic alone, the child's eye movements are within normal limits. A striking feature of eye movements which stand out from the norm is dysmetria, which means an imbalance between the size of an eye movement and the movement of its stimulus. Dysmetria takes the form of hypermetria or hypometria. During hypermetria, or 'overshooting', the

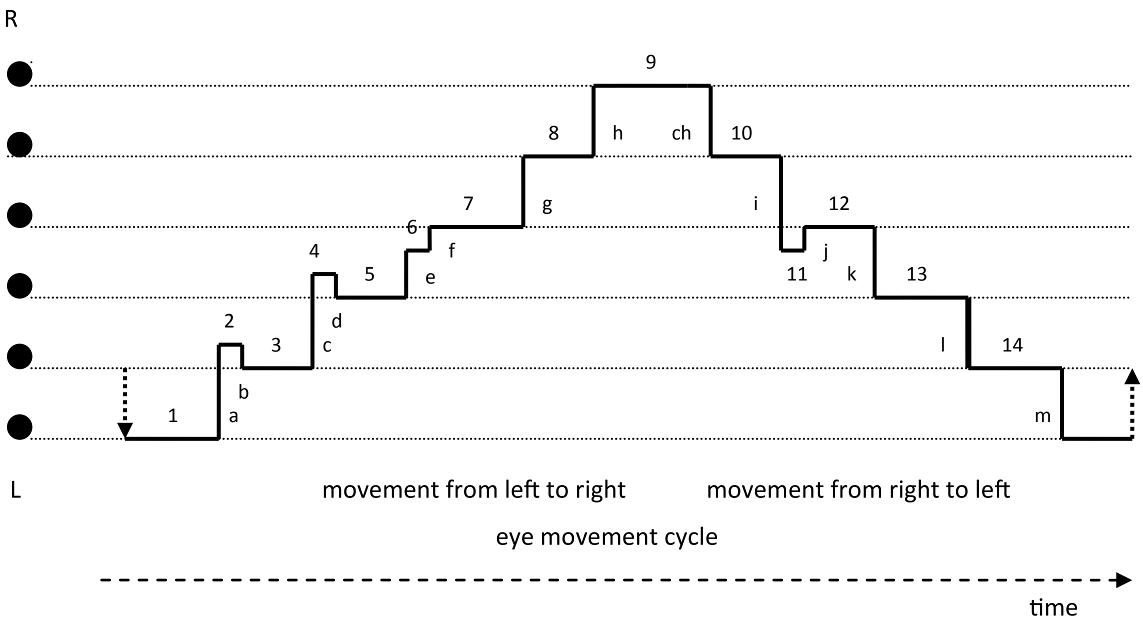

Figure 1. Eye movements of the observed child in the sequential task. Numerals signify fixations (horizontal lines), lower-case letters signify saccades (vertical lines). The capital letters 'L' and 'R' indicate left and right edges of the row. Lights were turned on and off gradually from left to right and back, from right to left, etc. As one light was turned on, the previous light was switched off. The light period was constant and lasted for 0.5 seconds. The distance between lights was an angle of approx. 3°.

eye movement is greater than the movement of the stimulus from one position to the other; the eye must return in order to reach the correct position – this is known as a corrective regressive saccade (Ciuffreda & Tannen, 1995; Leigh & Zee, 1987). In Figure 1 we can see hypermetric saccades *a, c*, and *i* (saccades *b, d*, and *j* are regressive corrections). During hypometria, or 'undershooting' (Ciuffreda & Tannen, 1995; Leigh & Zee, 1987), it is reversed; the saccadic movement is shorter and the subsequent correction is progressive. In Figure 1 we can see hypometric saccade *e* (*f* is a progressive correction). Dysmetria is a reflection of the precision of saccades. In a pathological context, dysmetria may signify a cerebellar disorder, possibly a disorder of the brain stem, or a sign of a visual disorder, e.g. hemianopia. Dysmetria is also studied in relation to reading disorders (Ciuffreda & Tannen, 1995; Leigh & Zee, 1987).

In our boy's case, the overall percentage of dysmetric saccades was equal to 20.7% and the percentage of overshoots was 18.5% out of the overall number of saccades. In terms of z-score, this represents a value of 2.77 which is well above average. The boy´s eye movements were significantly hypermetric. The above average proportion of dysmetria induced an increased variability in eye movements during fixation which we expressed using a variation coefficient (V = standard deviation during fixation / average time of fixation). Its value was equal to 42%.

The boy's eye movements were characterised by *regular fixations* as well as *auxiliary fixa*tions which induce greater variability in fixation times (both terms, regular fixations and auxiliary fixations, are working terms). We identified auxiliary fixations as those which followed dysmetric saccades and then led to regular fixations. In Figure 1 auxiliary fixations are numbered 2, 4, 6 and 11. All other fixations in Figure 1 are regular. We did not observe any *chaotic fixations* (working term) during which one or more stimuli (lights) would have escaped the child's attention and seriously undermined the sequence of eye movements and introduced chaos.

To express the temporal stability of eye movements, we split each recording in half and compared the two halves. An entire recording lasted approximately 40 seconds so each half was 20 seconds long. Although at first glance this may seem like a short period of time, this approach has proved itself in preschool children. The boy's performance was characterised by a decrease in oculomotoric efficiency. If, in the first half of examinations, he overshot at a rate of 15% out of the overall number of saccades, which is typical for boys, then in the other half it was over 18%.

To express right-left orientation, we distinguished between the direction of left to right and right to left, see Figure 1. In the boy's case, dysmetric saccades were oriented unevenly from right-left: from left to right we observed about 16% dysmetria while in the opposite direction, from right to left, it was only 4.3%.

In the second oculomotoric task, the fixation of a stationary point, we observed a good performance. The boy managed to eliminate eye movements and kept his eyes in one position. Therefore, we were able to exclude fixation instability.

Psychological variables

Phonological awareness

At preschool age the child was able to break apart and assemble words according to individual speech sounds, even with respect to their correct order in words. He was also able to break apart and assemble words using syllables with respect to their order in words. He was able to correctly identify the initial, middle and end sounds in words including vowels. He was able to correctly identify words that rhyme and was able to actively construct a rhyme to a particular word. He was able to correctly identify alliteration which is the repetition of a particular sound at the beginning of a series of different words and/or phrases. According to such findings, uncomplicated reading development of the child was predicted.

Personal history

We found no significant factors. The mother's pregnancy was without complications, the baby was carried to full term, there were no perinatal incidents, the child's birth weight was 3,000g / 50cm, postnatal development was normal, the child was not examined neurologically, underwent common childhood illnesses, there was no serious illness. There were no sensory defects.

School history

The child began attending primary school on schedule and without delay (children begin school at the age of six in the Czech Republic). The child did not repeat any school year and did not change schools or attend specialised classes. The child was observed from the mid-80s – at that time there was a single kind of primary school with a single common programme for all children. Reading was taught via an analytic-synthetic method.

Family history

The family was complete, functional. The father was a university student, teacher; the mother was a high school student. The family spoke Czech, both parents had Czech nationality. The child had an older sister who flourished with excellent results in linguistic and non-linguistic subjects.

Success

An average grade was calculated from marks in a final report covering grades 1-6 inclusively. The average grade for both Czech (native) language and mathematics was 2.00. In the Czech Republic, a classification system of 1-5 is used where 1 represents the best performance and 5 the worst.

Intelligence

In the WISC test, the child's verbal performance outweighed non-verbal (verbal IQ = 113, performance IQ = 101).

Reading

At the end of first grade, the boy was able to read 20 words/min., i.e. the verbal IQ – reading discrepancy equalled 1.80 SD. The percentage of errors was 4.8%. At the end of second grade, the boy was able to read 33 words/min., i.e. the verbal IQ – reading discrepancy equalled 1.87 SD. The percentage of errors was 5.7% which is on the borderline of sten 4 and 5. At the end of third grade, the boy was able to read 47 words/min., i.e. the verbal IQ – reading discrepancy equalled 2.13 SD. The percentage of errors was 5.1%. At the end of fifth grade, the boy was able to read 67 words/min., i.e. his verbal IQ – reading discrepancy equalled 1.73 SD. The percentage of errors was 2.9%, i.e. on the borderline of sten 4 and 5. Reading comprehension was satisfactory, storyline context was clear to him, and he reproduced substantial parts of the plot. However, he needed lead-in questions. When reading he complained of visual wobble (letters blur, move and hurt his eyes).

Reading pace acceleration

Reading pace acceleration (*Ac*) was expressed by the formula *Ac* = the number of correctly read words in the second minute / the number of correctly read words in the first minute (%). Acceleration is a parameter with which we evaluate the uniformity of reading performance. A significant decrease in Ac can be ascribed to, e.g. increased fatigue which may in turn be caused by a weakened CNS. At the end of second grade (after two years of schooling), the result of the reading test was *Ac* = 83, i.e. a decrease in reading tempo which within the reference sample of children (N = 85) was average (z = 0.03). At the end of third grade (after three years of schooling), the value was Ac = 52 which corresponded to the value z = -2.23, i.e. well below average.

Concentration

The child's performance corresponded to sten 5 (weak average zone). Pace acceleration corresponded to sten 5 (weak average zone).

Graphomotorics

The child's performance was found to be in sten 5 (weak average zone).

Speech

The child's speech from preschool age was fluent and articulate with no lisp. The child expressed his ideas very well. During second grade, we examined the child's clumsy articulation / speech dyspraxia with negative findings. But even in this respect, his language developed very well.

Self-perception

We administered the SPAS test during fifth grade. The overall result corresponded to sten 5 (weak average zone). Following are the results of each subtest: general skills (sten 6), confidence (sten 6), mathematics (sten 5), reading (sten 5), spelling (sten 3-4), writing (sten 8).

Hyperactivity

Connors' Rating Scale of hyperactivity was administered to teachers during the child's preschool years and a second time during grade three. In both cases the child was assessed as being very calm and focused.

Sociometry

During third grade we gave the children the L-J questionnaire which measures social rank by popularity–unpopularity. The test showed a slightly increased popularity index and ruled out unpopularity.

Findings after 18 years. The same child's eye movements were examined after a period of 18 years, at the age of 23, using the same method as in his preschool years. At the time, the boy had graduated from secondary vocational school. After finishing primary school, he had initially enrolled at high school but had transferred to vocational school during his first year of study. He did not enjoy reading and tended to avoid reading. If he reached for a book, it was usually comics. When reading he complained of visual wobble (letters blur, move and hurt his eyes) and headache. He was able to read 70 – 80 words/min; his rate of reading was decelerated. Reading comprehension was satisfactory, he reproduced substantial parts of the text, however, without details.

A recording of eye movements showed similar characteristics as were present when he was of preschool age: extensive dysmetria and subsequent corrective saccades, without chaotic fixations.

Discussion

Eye movements in the monitored subject showed long-term stability, i.e. continuous dysmetric saccades with the exclusion of fixation instability.

This finding corresponded with the following psychological findings: the structure of intellectual performance was less uniform; verbal performance outweighed non-verbal performance in the child. This dominance could be interpreted as being due to an over-stimulating family environment (father: university student/ teacher, mother: high school student), but when taking into account eye movements, reading development and even some findings in attention tests and drawing tests, it is more probable that the cause was neurobiological.

The findings in attention tests and drawing tests were non-pathological and without defects, however, the child's performance was within the range of average, or rather, weaker average. In contrast, the child's potential level of development was higher as can be inferred by his performance in the verbal part of the intelligence test (above average).

Attention test and graphomotoric test performances both correspond to findings in the non-verbal part of the intelligence test which was also within the range of average. Reading development was generally slower in relation to the norm. Even after primary school, reading probably played a serious role in the further educational development of the child. The child had intellectual needs, applied to a high school which he left within the first year to attend a less challenging vocational school – the child should be seen as a 'less demanding reader'. We saw a noticeable decline in reading pace which, when taking into account the child's weak performance in the non-verbal part of the IQ test and the pace distribution in the attention test, supported the possibility that the child was easily fatigued.

The attention test indicated performance was in the lower part of the average range and acceleration rate was also reduced. In reading, in non-verbal subtests of the IQ test and even in the attention test, the child worked in a visual environment in which he had to orientate himself. Similar requirements were placed on him during the oculomotor task. The child had problems in all these tasks, his performance was delayed intraindividually – in relation to his developmental level as estimated by the IQ test, or interindividually in comparison with his peers.

These findings contrast strikingly with the high level of phonological skills observed in preschool age. It is precisely this above average level of phonological skills together with above average performance in verbal parts of the IQ test and a stimulating family environment that led us to believe that the reading development of the child would be smooth and at least average. This conclusion was fully consistent with the phonological theory of dyslexia.

However, reading development did not confirm this hypothesis. It was probably not a case of deep dyslexia. We may consider the child´s reading difficulties to have been objective, not caused by the child himself or his family or school. The most probable cause were CNS peculiarities of a prolonged nature, These peculiarities included the child's reduced ability to orientate himself in a visual environment in which a subject must process different visual forms and be able to manipulate them, putting them into sequences or syntaxes and finding relationships and regularities between them.

The boy's problems could have escalated if the boy had lived in a linguistic environment which was characterised by non-transparent orthography. Non-transparent orthography is particular to the English environment where spoken and written forms of language differ greatly. The Czech language, with its transparent orthography, probably offered the boy more favourable circumstances for reading development despite his deficit of non-phonological nature (see also analogous experiences from the field of the German language, Wimmer & Schurz, 2010).

The child is unlikely to have ADHD. The child was calm and focused throughout kindergarten and primary school. In oculomotor behaviour, we observed good fixation stability. Findings in personal history were negative. Motor coordination problems were not observed. Speech was pure and without clumsy articulation.

In our case study, long-term partial weakening of eye movements (dysmetria) coincided with long-term partial weakening of reading skills at decoding level. It was difficult to determine whether this was a case of comorbidity or a close relationship. If it was a close relationship, dysmetric eye movements were probably not induced by poor reading and poor linguistic processing of text. Eye movements of preschoolers were tested using non-reading tasks, where the influence of language was absent. Eye movements were also tested in the period before the commencement of reading education. It was possible to judge from the results that eye movements were not the only factor controlling reading ability and were probably not the dominant factor.

A causal relationship between eye movements and reading was found to be improbable. The findings in this study suggest there is a common factor affecting eye movements and reading ability. It could be an imbalance within the central nervous system, as referred to by Bakker (Bakker, 1990; Bakker, Van Strien, & Licht, 2007). This imbalance could be reflected in eye movements. Bakker's Balance Model is based on the specialised functions of each brain hemisphere: the visual processing of text is largely the function of the right hemisphere while the allocation of meaning to graphemes is largely the function of the left hemisphere.

The model assumes that the foundation of dyslexia is disrupted co-operation between the two brain hemispheres: the perceptual type is characterised by the tendency to process information in the right hemisphere. This type is able to decode graphemes quite well but has difficulty in assigning them meaning. Reading is slow with few mistakes. In contrast, the linguistic type is characterised by a disruption to the visuospatial factor.

Reading is characterised by substantive errors (the reordering of letters and syllables, omission of speech segments and syllables, the addition of words and their distortion) and in relation to decoding, this type has a greater ability to understand what is read. Both types of dyslexia were examined oculomotorically (Donders & Van der Vlugt, 1984). Eye movements of the perceptual type were characterised by a greater number of fixations, short saccades and a low number of regressions. In contrast, eye movements of the linguistic type were characterised by a large variation in fixation times and a large number of regressions. Our case study resembled the linguistic type from a reading and oculomotoric point of view.

Reading is a multifactor skill in which eye movements are one of many influences. Based on our case study it was not possible to compare the influence of eye movements of preschoolers on reading development with the influence of phonological awareness and family environment. If dysmetric eye movements had at least a hypothetically adverse effect on reading development in our case, then this effect was probably compensated in part by good phonological awareness and a linguistically stimulating and literacy-rich family environment.

Conclusion

The case report showed that long-term, partial weakening of eye movements correlated with long-term, partial weakening of reading development. With caution it can be stated that examinations of eye movements may contribute to prognostic considerations in the field of reading development and may become part of preschool screening.

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Dyslexia with Attention Deficit Hyperactivity Disorder: a case study

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This article is a case study of a child with dyslexia and ADHD who was provided with behavioural strategies to cope in class which proved to be effective. Children who have dyslexia and Attention Deficit Hyperactivity Disorder (ADHD) often face great challenges in school as their academic abilities are usually impeded by these two learning disorders. While dyslexia affects their literacy abilities, ADHD often affects their ability to pay attention and exercise executive functions. Children with ADHD are often found to be hyperactive, inattentive or a combination of both. On the other hand, these children often have normal to above average intelligence and can do very well academically if they are equipped with coping mechanisms. Physicians may suggest that children with ADHD be medically treated in order to curb their behaviour and perform better in school. However, these medications may contribute to undesirable side effects and this is the reason why many parents may disagree with having their children with ADHD under any form of medication.

Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental disorder which falls under the umbrella of Disruptive Behavioural Disorder (DBD) (Chia, Ng & Kuan, 2010). Chia et al. (2010) classified this disorder as relating to behaviour difficulties that are referred to as disciplinary challenges of neurobiogenic origin with a lack of and/ or inadequacy in self-regulation through manifestation of internalising (e.g. anxiety, depression, low mood) and/or externalising (e.g. conduct disorder, oppositional disorder, behavioural difficulties) socio-emotional traits. The defining characteristics or 'core symptoms' of ADHD as cited in the Diagnostic and Statistical Manual of Mental Disorders, 4th edition, Text Revision (DSM-IV-TR) (American Psychiatric Association, 2002), are difficulties with attention and

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concentration, hyperactivity and impulsivity. Simply, ADHD is diagnostically separated into three subtypes namely: Predominantly Inattentive (ADHD-I), Hyperactive/Impulsive (ADHD-HI), and Combined (ADHD-C) (Martin et al., 2006). These characteristics may stand alone, that is a child may display only inattention and low concentration span (ADHD-I), or they can exist in combination (ADHD-C) where the child is inattentive, hyperactive and impulsive. These key markers typically manifest as a loss of self-control, poor self-regulation and a deficit in inhibitory control (Taylor, O'Donoghue & Houghton, 2006). Such behaviours can be frustrating, not only for the child, but parents and teachers too. However the 'face' of ADHD is soon to change with the introduction of the DSM-5. The proposed changes to ADHD in the DSM-5 may reduce the stigmatization towards children with a learning disorder and/or ADHD. The DSM-5 suggested classifying ADHD as a neurodevelopmental disorder, separate from the disruptive behaviour disorder classification which it was conferred in the DSM-IV. This proposal may change pessimistic educational and parental attitudes, as well as restrict considering ADHD as a result of emotional and familial dysfunctional factors. This change may enable more children to receive the necessary therapy (see Al-Yagon et al., 2013 for a review of the expected impact).

Cook (2005) argued that through genetic and brain imaging studies, it had been found that ADHD is a brain disorder, not a disorder caused by parenting or other environmental factors. ADHD clearly runs in families, with heritability estimates ranging from 0.55 to 0.92. On average, 25% of immediate family members of children with ADHD are likely to have the disorder. Additionally, twin studies have been crucial in identifying ADHD within familial ties as well as causes of co-morbidity (Martin et al., 2006). It was also identified in this research that there is a strong association of genetic heritability between reading disability and the inattentive subtype (ADHD-I), and between the hyperactive/impulsive subtype (ADHD-HI) and Conduct Disorder (CD) as well as Oppositional Defiant Disorder (ODD). ADHD may present as co-morbid with other DBD such as CD or ODD. Up to 65% of children with ADHD are likely to have ODD and children with CD may also exhibit traits of ADHD. Further, children with ADHD are at risk of developing co-morbid psychiatric disorders, such as anxiety and depression, substance abuse as well as learning disabilities (Cook, 2005).

Children with ADHD are at risk of learning disorders such as reading disability or dyslexia. Hence, they are likely to struggle in school, display poor or negative academic performance and have low academic self-esteem. However, ADHD is not a learning disability but an associated disorder as it does not impact on the brain's ability to learn although it can interfere with the child's availability for learning (Silver, 2001). Furthermore, children with ADHD may display difficulties controlling their emotions or anger as there are issues of anger management and social-emotional behaviour relating to ADHD. They may show social impairment due to their tendency for offensive impulsive remarks or misinterpreting social cues. For instance, children with ADHD with/without other DBD are more likely to assume hostile intent when bumped in line by a peer than children without ADHD. These children may then react aggressively towards peers which could get them into trouble with teachers. They may also exhibit bullying tendencies towards peers, can be rowdy, emotionally immature and lack insight regarding their behaviours and feelings. They tend to have an external locus of control, and can blame teachers, parents or peers for their misbehaviour or academic failure.

ADHD is a condition of early onset usually identified in children as young as preschool ages. It is believed that children with ADHD will outgrow their disorder. However, studies have revealed that although they seem to outgrow their hyperactivity and impulsivity symptoms, which begin to dissipate around the age of 11 and 13 respectively, a significant portion of these children continue to manifest clinically significant levels of inattention into adolescence and young adulthood. As ADHD seems to be a lifelong condition only appearing to be dissipated with maturity, self-regulation or behaviour modification, some clinicians have suggested medication for children with ADHD in order to curb their disruptive tendencies so as to function more acceptably in school.

In their study, Wegrzyn, Hearrington, Martin and Randolph (2012) stated that many of the medications available for the treatment of ADHD are of the stimulant variety. Brain research and theory indicated that ADHD is caused by a dysfunction in the prefrontal cortex (Barkley, 1997) where important neurotransmitters, dopamine and norepinephrine are typically in short supply in children with ADHD. As a result, children with ADHD do not perform as well as controls in tests of their executive functions, which are the mental processes that control thinking, emotions, and behaviour. Therefore, ADHD medication activates these neurotransmitters to stimulate the prefrontal cortex (Szegedy-Maszak, 2002). Not surprisingly, there have been positive reports from children who have been medicated who experience improved behaviour which consequently reduced 'trouble-making' incidents, and made them more able to concentrate on schoolwork (Travell & Visser, 2006). Unfortunately, 20% of childhood ADHD patients do not respond to stimulant medication (Fox, Tharp & Fox, 2005) and thus, may continue to display challenging behaviours in the classroom. Moreover, not all parents of children with ADHD are advocates of pharmacological medication for fear of side effects such as suppression of appetite and sleeplessness, depression and head or stomach aches. Most have opted for alternative treatment as a solution such as social skills training, behaviour modification, anger management training or problem-solving skills training. Indeed the process of diagnosing children with ADHD and treating them with medication such as methylphenidate hydrochloride (e.g. Ritalin) continues to be controversial (Travell & Visser, 2006).

The challenging behaviours exhibited by children with ADHD have often been misconstrued as bad attitudes and any behaviour deemed to have resulted from it may lead to punishment either by parents or teachers. However, it is important to distinguish between these two terms so that children with ADHD are not wrongfully judged for their actions or behaviour. According to Chia et al. (2010), "behaviour" refers to an act or function done by a person in a particular way while "attitude" refers to the way of thinking or perception which in turn, effects the way a person behaves. Hence, any bad attitude can result in bad behaviour which can become challenging for parents or teachers. However, not all bad behaviours stem from bad attitudes. Borba (2004) noted that behaviours are more reactive and impulsive but attitudes are longer term. Therefore, a child 'behaving badly' may not necessarily have the intention to do so.

Reid, Wagner and Marder (2006) stated that ADHD is a chronic condition that is thought to affect 3 - 5% of children. The clinical definition of ADHD in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) expects a general impairment in behaviour and academic performance in school and/or at home. It is the most common type of co-morbidity that occurs with dyslexia in schools. A student may not be diagnosed with ADHD but they may show symptoms or traits that are commonly associated with it. Hence, it is pertinent that teachers be aware of the symptoms and traits of ADHD and how this condition impacts on children's academic and social performance, peers' learning in the classroom as well as teachers delivery of lessons.

Children with ADHD have been found to perform below their academic ability. In their longitudinal study, Galéra et al. (2009) found that the results corroborated with previous research findings which presented a significant relationship between ADHD and poor academic achievement. This was identified by Loe and Feldman (2007) who stated that there is a significant link between ADHD and negative academic and educational outcomes. In particular, children with ADHD were found to display poor academic functioning with poor reading and mathematics test scores (Biederman et al., 1996; Barry et al., 2002), increased rates of being retained at grade level in school (Barkley et al., 1990), and low rates of secondary graduation as well as post-secondary education (Mannuza et al., 1993).

Besides being co-morbid with dyslexia, ADHD can sometimes co-exist with other DBD such as Oppositional defiant disorder (ODD). The high rate of association between ADHD and ODD, at 65%, is worth noting as children with ADHD may not only present with inattentive, hyperactive or impulsive symptoms but also those symptoms that are linked with ODD such as being naughty, playing tricks on others, flouting class rules or throwing temper tantrums (O'Regan, 2006). Hence, teachers must exercise acute awareness and care when dealing with such students in order to garner their cooperation in the classroom which will lead to effective learning for these children.

Characteristics of ADHD

As mentioned earlier, the core characteristics of ADHD can be categorised by three subtypes namely, Predominantly Inattentive (ADHD-I), Hyperactive/Impulsive (ADHD-HI), and

Combined (ADHD-C), which can be further identified according to specific traits manifested by the children's actions. Chia et al. (2010) listed these traits as commonly related to ADHD:

- failure to give close attention to details
- commit careless mistakes in written work or other activities
- has difficulty sustaining attention in tasks or play
- does not seem to listen when spoken to
- does not follow through instructions
- failure to complete school work or duties
- avoid or/and dislike or reluctant to engage in tasks that require sustained mental effort
- easily distracted
- display forgetfulness when performing daily activities
- fidget a lot with hands or feet, or squirm in seat
- often leave seat during lessons
- often run about or climb excessively
- talk excessively
- often blurt out answers before questions are complete
- failure to observe turn taking and often interrupt or intrude on others

Any child with ADHD will present some of these characteristics. Moreover, many children with dyslexia will also present with similar symptoms, mainly because they experience difficulty in completing their work satisfactorily. It will undoubtedly be challenging and frustrating for parents and teachers to work with children who constantly display such behaviours at home or in the classroom. However, support and understanding can transform interactions with the child.

Profile of the child

Edwin (not real name) was diagnosed with dyslexia at a very early age when his mother noticed that he was unable to read and spell despite repeated teaching of the words. At the age of six, Edwin was still unsure of the alphabet and struggled when learning phonics. He also found it difficult to learn Chinese as he was confused by the hanyu pinyin. Additionally, Edwin showed difficulty writing within given spaces or on lines, made letter reversal errors with his words unevenly spaced as well as confusion with the alphabet upper and lower case.

Edwin's childcare centre teachers also provided similar feedback to his parents and added that Edwin was not learning at the same pace as his peers. Moreover, there is a family history of reading and spelling difficulties with Edwin's cousins experiencing the same challenges. Due to parental concerns, Edwin was subsequently referred to the Dyslexia Association of Singapore (DAS) and was assessed by a DAS psychologist. The assessment found Edwin to have an uneven cognitive profile. He had an above average to high cognitive ability but relative weaknesses in reproducing visual-spatial details and expressive language. He exhibited average literacy skills but had exceptionally high listening comprehension skills. While he could use phonological rules to read unfamiliar words, he showed some difficulties in his phonological processing.

The discrepancy between Edwin's

cognitive ability and his reading skills, coupled with his difficulties in phonological processing, are suggestive of dyslexia. Edwin joined the DAS remediation programme when he was in Primary 1. He was observed by his teacher to need more help with reading and spelling, as well as presenting weak ability to grasp concepts and comprehend passages. His handwriting was also an issue and hence, Edwin was taught cursive handwriting to help him improve these skills.

Research indicated that children with dyslexia sometimes have problems with handwriting as decoding the patterns of letters in words on paper can be troubling for them (Berninger et al., 2008). As a result, they frequently fail to develop the automatic flow of writing which helps them to express themselves clearly and easily in writing. Therefore, the continuous cursive handwriting style is best recommended for these children as each letter is formed without taking the pencil off the paper and consequently, each word is formed in one, flowing movement.

At Primary 2, Edwin was observed to be extremely hyperactive and impulsive in class by his new teacher who found working with Edwin rather challenging. Edwin's impulsivity can sometimes disrupt the flow of lessons and distract his teacher from delivering a smooth lesson. Although he was able to pass his English tests in school, Edwin was struggling with Mathematics which he had been failing since Primary 1. He was not able to comprehend Chinese and kept failing this subject too - due to his constant failure, Edwin was granted exemption from Mother Tongue at Primary 5. Edwin loved Science but was only marginally passing this subject. Edwin's teacher wondered if his under-performance could be the result of his hyperactivity and lack of interest towards task completion as he frequently observed that Edwin's enthusiasm frittered away as the class progressed. It was suggested to Edwin's mother that he should be assessed for ADHD. By the end of Primary 2, Edwin was diagnosed with ADHD [Conners' Continuous Performance Test II (CPT II)]. His report concluded that Edwin had a significant attention problem coupled with impulsivity and low perseveration.

As a result, Edwin's teacher had to consult a DAS educational advisor for the most suitable form of support for Edwin so that his learning potential could be met in school. It was suggested that Edwin be placed in a small class in order for his teacher to provide more guided assistance to Edwin.

The author began working with Edwin when he was in Primary 5. As with most children with ADHD, Edwin was easily distracted, had a very short attention span on tasks, avoided and sometimes showed reluctance to engage in tasks that require sustained mental effort, was fond of fidgeting with his hands and rocked in his seat excessively, could hardly sit still while doing work in the classroom, enjoyed walking around the classroom while the lesson was going on, often blurted out answers and failed to take turns to speak or interrupted others.

Besides the behavioural challenges that Edwin displayed in class, his literacy development was a concern too. He tended to misread, omit words or skip a line when reading. He had difficulty understanding passages that he read and thus, questions had to be posted to establish meaning for him. Edwin disliked writing activities and he would find ways and means to avoid undertaking this task. His verbal ability was not commensurate with his written expression ability as his writing was brief though he had many ideas to share. The grammar and technicalities of sentence construction were usually ignored. He often showed reversals of 'b and 'd' and had a poor sense of capitalisation and punctuation in sentences. Edwin continued to produce messy handwriting, depicting poor spatial awareness, letter formation and an inability to write within the given line and space.

During this time, Edwin was also seeing an Occupational Therapist at a children's hospital to address his difficulty in visual-motor integration as well as consulting an optometrist who assessed Edwin as having Amblyopia (lazy eye), Meares-Irlen Syndrome (visual stress) and visual tracking issues. It was also suspected that Edwin was suffering from perceptual distortion when he read certain font types. Subsequently, Edwin was recommended to use a tinted overlay to aid him in reading as this would help him to focus better.

Interventions and Remediation

While stimulant medication can be one intervention technique used on children with ADHD, its effects are not similar for every child. Due to this, some parents may not advocate the use of medication on their child with ADHD. Moreover, pharmacological treatment is rarely sufficient in addressing the multitude of chronic difficulties faced by children with ADHD. Hence, alternative intervention techniques or strategies must be employed in order to help children with ADHD cope with their disorder.

Preference-based teaching is one approach that can be employed by educators when working with these children. The essence of preference-based teaching involves identifying student preferences and then designing teaching programs in consideration of those preferences. Items and activities students prefer are incorporated within the teaching process. In addition, activities or events that students dislike are removed from the process where possible (Reid & Green, 2006). This approach can be used with any typical teaching programme for students with disabilities and in the case of this student profile, a child with dyslexia and ADHD. According to Reid and Green (2006), preference-based teaching involves setting the occasion for an enjoyable teaching session, identifying students' preferences and using the preferred ABC model where *A* refers to *antecedent* which pertains to what is done to promote student performance of a skill being taught, typically through prompting, *B* refers to the *target behaviour* that the teacher desires the student to demonstrate and *C* refers to *consequences* of the student's target behaviour applied by the teacher to reinforce or correct performance.

This approach requires the teacher to: build rapport with students by spending time to interact with them so that their enjoyment in participating in the teaching sessions are enhanced as they enjoy interacting with the teacher; identify which activities, items or environment the students like or dislike and to become familiar with them, thus incorporating those activities that the students like into the lesson and omitting those they dislike; and finally via the ABC model, establish what can be done to get students to demonstrate skills which they have been taught and what then are the consequences for their performance.

Besides preference-based teaching, other effective classroom intervention strategies for children with ADHD that have been researched consist of behaviour intervention, self-regulation intervention, academic intervention, home-school communication programmes, interventions addressing social relationship difficulties and collaborative consultation (DuPaul, Weyandt & Janusis, 2011). According to Barkley (2006), impaired delayed responding to the environment is the putative core deficit underlying ADHD. Hence, behavioural interventions that include antecedent and consequence-based strategies which may involve modifying the environment are used to directly address this impairment. Examples of antecedent-based strategies are classroom rules, task choices and task reduction. As antecedent-based strategies aim to trigger the occurrence of a specific behaviour, children with ADHD should be given structure so that the required behaviour can be obtained from them. Thus, they should be informed of classroom rules that they have to adhere to or be told of options and/or reduction in tasks that they have to complete before they get a reward. Reducing the length of an assignment to match students' attention spans, may reduce off-task, disruptive behaviour (DuPaul & Stoner, 2003) where as Dunlap et al. (1994) found that when students were provided with assignment choices, they showed higher rates of task engagement and lower frequency of disruptive behaviour relative to class sessions when teachers chose the specific assignments.

On the other hand, consequence-based strategies involve manipulating environmental events following a specific behaviour to alter the frequency of that behaviour. Examples of consequence-based strategies are contingent positive reinforcement, response cost and self-management interventions (DuPaul & Weyandt, 2006). The most popular among these are contingent positive reinforcement and response cost where a desired behaviour from the student would earn him a reward which can be in the form of praise, a token or point reinforcement, but misbehaviour may result in token or point reinforcements being removed contingent on disruptive, off-task behaviour. DuPaul et al. indicated that several studies (e.g., DuPaul, Guevremont, & Barkley, 1992) have presented significant improvements in task-related attention, as well as productivity and accuracy of class work, when the combination of token reinforcement and response cost is used.

As children with ADHD mature, they can be taught self-regulation strategies to monitor, evaluate and/or reinforce their own behaviour. This is usually achieved in conjunction with or following the successful application of teacher-mediated behavioural approaches.

Self-monitoring has been used successfully to promote on-task behaviours and class work completion. It has been widely established that children with ADHD usually face challenges in the academic front. Therefore, academic intervention is another strategy to help children with ADHD cope better in school. Sometimes students misbehave in the classroom because they are not able to grasp what is being taught due to a learning disability such as dyslexia. Academic interventions can be in the form of teacher-mediated direct instruction in relevant skills that require remediation such as note-taking which can improve their test performance, using computer technology and employing classroom peers to enhance task engagement and test performance. The combination of both academic and self-regulation interventions have shown to be beneficial for children with ADHD.

Home-school communication programmes are also pertinent since children with ADHD experience difficulties across settings. For example, a daily report card provides students and parents with feedback on class performance as well as target behaviours that need to be achieved or have been achieved by the student. Teacher ratings in the form of a Likert scale can be incorporated for ease of understanding. Based on this feedback, parents can employ home-based reinforcements so that the children will continue to work on target behaviours since children with ADHD have been known to improve in structured environments.

Besides parents and family members, peers also play a part in helping children with ADHD improve in their social skills as these children often experience difficulties making and keeping friends due to their inability to respond to situations in a non-aggressive manner. Hence, interventions that target social behaviours such as social skills training are designed to address peer relations and must be implemented for a sufficient duration to counteract the high risk for problematic outcome. Finally, collaborative consultation with school personnel can also improve the academic outcome of children with ADHD where these personnel will identify the areas needing improvement and work together to help the children with ADHD achieve this target.

In Edwin's case, most of the strategies mentioned above were employed. When preparing a lesson for Edwin, the author took his interests into consideration. For example, Edwin likes animals and technology and loves working with his hands. Therefore, the author would find passages on animals or technology for Comprehension or Cloze Passage exercises and based on the exercises, get him to form something using scrap material upon completion of the worksheets. Before the lesson began, Edwin got 5 minutes of 'chat time' where he would chat with the author, play a game on his phone or find scrap material to create something. Edwin was informed of what his 'reward' might be if he were to complete any tasks within the time given. He was also given 2 short breaks (5 and 7 minutes) in the 2-hour class. Besides this, the author would also bring Edwin out for a 10 minute exercise of walks or jogs around the school compound. Due to Edwin's difficulty with handwriting, he was allowed to use the iPad or Word Processor when doing Composition. This also encouraged him to attempt the activity which he liked the least. As Edwin was a young student, he needed to be constantly reminded to self-regulate his behaviour especially since he enjoyed walking around the classroom and attempting to create something with scrap materials. If he wished to do so, the ABC model was employed where he was expected to accomplish a required task before being allowed to have his way. Although the DAS did not have a daily report card programme, the author communicated with Edwin's mother via email to give her feedback on Edwin and how she could reinforce this approach with him at home. One particular collaboration between the author and Edwin's mother was the conversion of points to cash - points that Edwin earned in class were converted to cash by his mother. This spurred Edwin on to be more cooperative and accomplish more tasks when he attended lesson at the DAS. Additionally, Edwin's mother would share feedback given by his school special education teacher with the author so that she could also work on the same areas with Edwin. Indeed, the author found collaborating with Edwin's mother and his special education teacher beneficial in providing Edwin with structure that would assist him in doing better at school work and tests.

Educational Implications

Barkley (2006) stated that deficits in executive functions among children with ADHD have been well documented (Toplak et al., 2009). In their paper, Johnson and Reid (2011) indicated that executive functions refers to cognitive processes necessary for complex goal-directed behaviour (Loring, 1999) which include metacognitive knowledge regarding strategies and tasks, attention and memory systems that support these processes such as the working memory, and self-regulatory processes such as planning and self-monitoring (Meltzer, 2007). Executive functions involve planning, organizing, maintaining effort, and monitoring activities, all of which are necessary for academic success. Therefore, not surprisingly, executive functions deficit can negatively affect academic performance (Clark, Prior, & Kinsella, 2002).

Students with ADHD often experience serious academic difficulty (Johnson & Reid, 2011) and this is partly due to their poor executive functions. They often have school-related difficulties that affect learning, such as problems with organisation, attending class unprepared, writing down assignments, completing assignments at home, turning in class assignments on time (Gureasko-Moore, DuPaul, & White, 2007), and are inconsistent and careless in their schoolwork (Hinshaw, 2002). Students with ADHD are often referred to special education services and around 50% of them are deemed qualified for support (Barkley, 2006; Reid, Maag, Vasa, & Wright, 1994).

Typically, Edwin too experienced poor executive functions control, particularly in maintaining effort on tasks. He was also forgetful at times, leaving his possessions in the classroom when rushing off upon dismissal. At DAS, the author had employed the strategies mentioned above in order to get Edwin to be more task-focused so as to complete worksheets and exercises in good time. In a 2-hour class setting, Edwin was able to follow the structure that had been set for him rather successfully. In school, Edwin was coached not only by his teacher, but also the special education teacher to improve on his test performances. Needless to say, Edwin's parents played a vital role in providing him with the necessary support and guidance that he needed, such as coaching him on school subjects as well as allowing him to do activities that he liked as a form of reward.

Reflections

Children with ADHD can be a challenge. In the case of children with dyslexia and ADHD, what do we tackle first? Is it the behaviour that is impeding their progress in educational attainment or is it the difficulty that they face with academic demands that contributes to their negative behaviour? The situation is akin to that of the chicken and the egg. It is indeed problematic to determine which factor contributes more to a child's learning if an educational therapist does not know the child under his or her charge well.

Before Edwin came under the author's charge, she had the opportunity to read through his psychological reports as well as reports from his previous educational therapists. It was also fortunate that the author was acquainted with Edwin and had seen and interacted with him at the centre. Verbal feedback from his previous teachers prepared the author for what to expect from Edwin. Much has been said about working with children with ADHD or any form of DBD and how they can affect classroom teaching and teacher welfare such as affecting the learning of other students (Dodge & Pettit, 2003), exhibiting aggression (Frick et al., 1991), and their behaviour taking a toll on teachers as well as increasing teacher's level of frustrations and stress which may lead to burn out (Kokkinos, 2007). Therefore, it was fortunate that in this particular class, Edwin's class was kept small with no more than two students.

Edwin was a challenge but in a good way. The most critical factor for the author was to alter her expectations of him despite his high cognitive intelligence. The author's lesson objective had to be clear and thus, worksheet activities had to be minimised. Nevertheless, academic expectations were not reduced but it was important to keep expectations high whilst realising that these could be met in a different way. In this case, the amount of worksheets done did not equate to the amount of learning that took place in the classroom. Edwin's learning and behavioural difficulties allowed the author to explore various ways to engage him during lessons and to work with him through a different paradigm. Tapping into his interest, the author developed her lessons in ways that would encourage Edwin to attempt as well as sustain his interest in completing them. Although his handwriting continued to be an issue, Edwin was getting better at his spelling. He was also reading more carefully and accurately despite not using the tinted overlay or his spectacles (Edwin refused to use them after trying them a few times).

Edwin's ADHD behaviour was considered in his learning in many ways. For instance, even though the mainstream curriculum does not allow students to use a word processor in examinations, letting Edwin use his iPad for writing activities was a way to encourage him to embark on an activity that he would otherwise avoid. Moreover, the author's objective was to get Edwin to sustain his attention to attempt and complete the activity - a product focused approach - how it was done was of secondary importance. For someone like Edwin who could hardly be seated for 20 minutes, completing a piece of writing activity on his iPad was commendable. As writing activities are time consuming, Edwin was granted the occasional walk-about but he should immediately return to his seat to continue with task completion when specific instructions were given such as "Get back to your seat once you've done that" or "I give you 2 minutes to do it and then you've to continue your work". The timed break sessions as well as a short 'exercise' routine that were inserted in Edwin's two hour lesson helped him to focus better as the class progressed.

Another critical factor was the amount of parental support that Edwin received. Edwin's mother was tireless in her efforts to provide as much educational assistance to him as possible. She also encouraged him to explore his area of interests and supported them such as his interest in animals and keeping aquatic pets. Her spontaneous suggestion to convert the point system that the author implemented with Edwin into cash was a surprise but it was a positive motivating factor for Edwin to accomplish more tasks as well as behave better in the classroom. In this respect, he was more conscientious in his attempts and always tried his best.

Recently Edwin sat for the Primary School Leaving Examination (PSLE). This examination is important for all Primary 6 students as the result will determine if they could go to a secondary school and the level they would be eligible for. Edwin received his PSLE results with startling achievements - scoring a distinction for Mathematics, a subject he had been struggling with since Primary 1 and getting to the Express stream in secondary school. This would not have been possible if Edwin had lacked parental and school support as well as the protective factors that he possessed.

Edwin's difficulty with reading and spelling in his younger years as well as the academic demands when he began formal schooling, handwriting issues and dealing with ADHD could easily present him with many risk factors that were mentioned above. However, his determination, high-spirited personality and high cognitive ability were crucial protective factors that contribute to his success today.

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DYSLEXIA ASSOCIATION OF SINGAPORE (DAS)

Our Mission: Helping Dyslexic People Achieve

Our Goal: To build a world class organisation dedicated to helping dyslexic people and those with specific learning differences in Singapore.

Our Aims:

- To put quality first in delivering a comprehensive and effective professional service for dyslexic people and those with specific learning differences on a not-for profit basis.
- To provide an assessment service for individuals at risk of having dyslexia and/or specific learning differences.
- To provide educational programmes and other support services for individuals with dyslexia and/or specific learning differences.
- To raise public and professional awareness of the nature and incidence of dyslexia and specific learning differences.
- To enable others (teachers, parents and professionals) to help dyslexic individuals and those with specific learning differences.
- To assist and elicit financial and other support for people with dyslexia, those with specific learning differences and their families.
- To promote and carry out local research into dyslexia, specific learning differences and to disseminate results.
- To network with other organisations in Singapore and internationally to bring best practices to the DAS and Singapore.

DAS as a Social Enterprise

- We provide high-quality, professional, innovative and client-focused solutions to create and sustain services for the dyslexic community in Singapore and the region.
- We operate as a financially viable and cost-effective business which at the same time ensures that no dyslexic person is unable to access our services because they cannot afford it.
- We generate social returns on our investments through the development of a dynamic, motivated team of highly qualified and experienced professionals.
- We have a heightened sense of accountability to stakeholders through our professional management team.

Registered in 1991, the Dyslexia Association of Singapore (DAS) is today a vibrant voluntary welfare organisation with over 225 full-time staff who provide a wide array of services for dyslexics not only in Singapore but in the region. DAS Specialist Psychologists conduct assessment and diagnosis for preschool students to adults. DAS Educational Therapists, Speech and Language Therapists and an Occupational Therapist provide support for over 2,600 preschool, primary and secondary school students in 11 venues all over Singapore. Increasingly, DAS provides support for dyslexics who also suffer from other Specific Learning Differences such as ADHD, Dyspraxia, Dyscalculia and Non-verbal Learning Differences.

The DAS Academy is a Private Education Institution (PEI) registered with the Council for Private Education (CPE). It is a wholly-owned subsidiary of the Dyslexia Association of Singapore (DAS). Like DAS, the Academy is also a registered charity with the Commissioner of Charities. DAS Academy delivers a wide range of workshops and courses including a Master of Arts in Special Educational Needs. DAS Academy provides the bridge that links professionals, caregivers and people with special needs.

Asia Pacific Journal of Developmental Differences

Guidelines for Contributors

Overview

The Asia Pacific Journal of Developmental Differences (APJDD) will be unique in addressing a range of special educational needs including dyslexia, autism, dyspraxia, dyscalculia, ADHD in the Asian context. The journal will cover theory into practice and will provide a showcase for research in the Asian context as well as highlighting research areas which have implications for further research within Asia and beyond.

Frequency of Journal

The Journal will be published twice a year in January and July.

Contributions Considered for the Journal

Primary consideration for publications will be given to manuscripts that are focused on developmental differences within the Asia Pacific region. Manuscripts will be peer reviewed and included in the journal on the following criteria:

- They contribute to the further understanding of developmental differences as well as the applications and implications in the educational, social and cultural environments.
- They include sound research methods, interpretation and validity of results
- They contain organised and clarity of writing
- They contribute to the local Asian context
- They should original papers that have not been submitted to other journals or publications.

Submission of Manuscripts

All manuscripts are to be sent in electronic copy (MS WORD) as well as a PDF copy of the final edited document. PDF copy is required to verify the word copy and for publishing purposes. There is no need to submit hard copies of manuscripts.

Submissions are to be emailed to the editor at both email addresses below:

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Preparation of Manuscripts

It is expected that all manuscripts be submitted using the American Psychological Association (APA) standard of referencing and publication. APA style is detailed in the Publication Manual of the American Psychological Association (6th ed), which offers sound guidance for writing with clarity, conciseness and simplicity. Authors should follow the APA style in preparation of their manuscripts.

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