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Dyslexia in Higher Education

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“To learn to read is to light a fire; every syllable that is spelled out is a spark.”

Victor Hugo

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Acknowledgements

How time flies, what a cliché…. But it does seem only yesterday I applied for a job as a PhD student at the Department of Experimental Psychology, a leap into the great unknown. And yet today, here it is: my PhD. Looking back over the past four years, I am convinced that this project would not have been successful without the help of many others. Some words of gratitude are definitely in place.

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Introduction

Chapter 1

Chapter 1: Introduction

Setting

In 2008 an Odysseus grant was awarded to Prof. Dr. Marc Brysbaert. Having spent 7 years at Royal Holloway University in London, he returned to Ghent University, Faculty for Psychology and Pedagogical Sciences. Using this grant, a Centre for Reading Research (CRR) was established at the Department of Experimental Psychology. The CRR focused on three lines of research: word recognition, language dominance and reading, and last but not least dyslexia in higher education. Within this research group I started a PhD on this topic, shortly afterwards joined by colleague Wim Tops.

Research goals

Dyslexia is at present a widely known disorder which has received a lot of attention from researchers all over the world. Initially, the scientific community focused on dyslexia in primary school children, as this is the time the literacy problems first present themselves. Subsequently, researchers expanded their area of interest to the identification of precursors of dyslexia in toddlers and the implications of being dyslexic in secondary school. Thanks to the extensive research performed on these populations, early detection, diagnosis, and remediation and guidance programs have improved enormously in the last decennia. It is partly due to this increase in knowledge on the appearance of dyslexia and in the effectiveness of treatment protocols that adolescents perform better in secondary school. As a result the transition to higher education (HE) has been facilitated. The numbers speak for themselves. Studies from all over the world report an increase in the number of students with dyslexia, registering for a program in higher education. Not because more students are diagnosed with dyslexia each year, but due to a larger inflow of high school graduates in bachelor programs. Numbers from the international literature (Hadjikakou & Hartas, 2008; Hatcher, Snowling, & Griffiths, 2002; Madriaga et al., 2010) and more locally from Cursief[1] demonstrate this trend. Table 1 shows the number of applications for compensatory means and the number of confirmed diagnoses of learning disabilities (about 80% of these numbers are related to dyslexia) within the Association Ghent. For example, in 2010-2011 an increase of 31% in the applications can be noted compared to 2009-2010.

[1] Within the Association of Ghent (Ghent University together with 4 Colleges of higher non-academic education) the non-profit organization Cursief was responsible for attestations, the granting of facilities and support of students with functional impairments.

Table 1
Number of applications and assessments for facilities related to learning disabilities for students in higher education during the past three academic years within the Association of Ghent (data from Cursief).

		Number	Increase compared to previous year	Diagnosis confirmed by assessment
2009-2010	applications	426		
	assessments	170 (39%)		153
2010-2011	applications	559	31%	
	assessments	248 (44%)	46%	220
2011-2012	applications	615	10%	
	assessments	264 (43%)	6.5%	242

Note: the number between brackets represents the percentage of students applying for compensatory means in need of a valid attestation.

In all likelihood, the early detection and diagnosis, the increase in the efficiency of remediation programs, and the implementation of more extensive support measures in HE have led to a decrease in the impact of dyslexia on academic performance. According to Vogel et al. (1998) dyslexic students now nurse higher aspirations and expectations that go beyond secondary school. Also, their self-advocacy and self-knowledge has increased, leading to more effective planning.

Making precise estimates of prevalence of dyslexia in higher education is not easy. Even for the prevalence of dyslexia in the general population, numbers vary substantially. This is to a large extent caused by the fact that language proficiency is a continuous variable and that definitions used to describe the impairment are based on different cut-off scores (Ghesquiere, Boets, Gadeyne, & Vandewalle, 2012; Ziegler & Goswami, 2005). A prevalence up to 20% has been reported. However, prevalence rates of 5 to 10% are more commonly accepted (Jimenez, Guzman, Rodriguez, & Artiles, 2009; Lewis, Hitch, & Walker, 1994; Plume & Warnke, 2007; Snowling, 2000). As for the presence of dyslexia in higher education, numbers are even less straightforward. Few accurate and reliable data are at hand to describe the proportion of dyslexic students within the general bachelor population. The Flemish Educational Council published a report in 2006 with the following rough numbers. They cited a Dutch study by Broeninck and Gorter (2001) in which 2 to 3% of all students in a sample of 478,000 appear to be dyslexic. Numbers from the UK were also added. These numbers are somewhat more precise because in the UK the number of students applying for a Disabled Student Allowance is registered. In the academic year 2003-2004, 5.39% of the students had a functional impairment, of which 2.22% reported a learning disability (dyslexia and others). In the academic year 2009-2010, this proportion of 2.22% would result in a total number of 4356 learning disabled students[2] in Flanders alone. However, not only are these numbers outdated, they are mere estimates of the exact proportions.

A reason not to adopt these proportions without reserve is related to the risk involved in a generalization of prevalence rates to a specific student population. First, the rates are likely to differ between fields of study. Experience tells us that because of the language relatedness of their disability, dyslexic students are more inclined to register for more technical programs and are therefore more represented in some institutions than in others (Kleijnen & Loerts, 2006). Second, the criteria for entering higher education are likely to have an effect as well. A system with high entrance criteria results in a strong selection of individuals possibly leading to smaller proportions of students with dyslexia in higher educational programs (as may be the case in the UK and the US, where such models are at work). Accurate prevalence rates of dyslexia in specific segments of HE will only become available when institutions for higher education will be obliged to keep track of the number of applications for compensatory means. Because there are no regulations stating that students have to report their disability, part of the population may remain undetected nonetheless. There are some new initiatives within institutions in Flanders to register the number of students with dyslexia, but for now, there remains some uncertainty on the exact number of students with dyslexia in higher education. One certainty is that this number increases each year.

As a reaction to this trend, researchers started addressing the topic and studies were set up to explore the phenomenon. At first, information on the cognitive profile and the needs of these students within an academic context was limited but soon researchers started to realize that scientific frameworks were necessary to help these students succeed in higher education. So today, the literature contains an substantial amount of information on students with dyslexia in higher education, specifically on students who have English as their mother tongue (mostly from the US and the UK).

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[2] Based on the total number of students registered in an institution for higher education in Flanders on October 31st, 2009 (*Hoger onderwijs in Cijfers* [*Higher education in numbers]*, Flemish Government)

In the early 1990s the first studies on dyslexia in adulthood were conducted with a main focus on reading and writing. A first question that had to be answered was whether individuals diagnosed with dyslexia in childhood could compensate for their reading and/or writing deficits in adulthood. This was clearly not the case (Elbro, Nielsen, & Petersen, 1994; Lefly & Pennington, 1991; Pennington, Vanorden, Smith, Green, & Haith, 1990). However, in these early studies cognitive skills such as memory or attention were left out of the picture. The focus also shifted towards a specific subgroup of adults namely students in higher education. A pioneer study on dyslexia in higher education that was a great inspiration for this project was the one by Hatcher et al. (2002). This is one of the first studies to investigate more than only reading and writing skills. This paper clearly demonstrated that literacy skills, processing skills, phonological skills, verbal fluency, and certain aspects of memory were also affected in students with dyslexia compared to their peers. Several other studies focusing on the same population followed this study. However, these studies often reported assessments on rather small sample sizes and included only a minimum of tasks. The meta-analysis performed by Swanson and Hsieh (2009) that was published while the project was already in motion, also drew our attention. Their study summarized the results of 52 papers (or 776 effect sizes) on reading disabilities in adults. This paper also demonstrated that dyslexia is persistent across age. Here, measures of cognition, phonological processing, verbal memory and achievement, math, vocabulary, spelling and writing resulted in moderate to high effect sizes in favor of adults without reading disabilities. The downside of the above studies that were a great source of inspiration in the set-up of this project is that they all reported research results performed in English speaking countries within an Anglo-Saxon educational model.

A generalization of English findings to other languages and educational settings is not without risk. There is the language difference in the transcriptions from phonology to orthography and vice versa. For example, English is said to be a very opaque language while Dutch is much more transparent. This difference in the one-to-one relationship between letters and sound (and the inverse) has been related to the rate at which children acquire reading and writing skills and also to the prevalence of reading and writing disorders (Ziegler & Goswami, 2005). Secondly, there is still no uniformity in defining dyslexia (for example in the US a discrepancy definition is still frequently applied) and cut-off scores vary greatly – going from percentile 25 to percentile 10. Obviously this implies a large difference in variability between the dyslexic populations within the different settings. Finally, educational settings are very different in Europe from the ones in the UK and the US. In the latter countries, in addition to demanding selection procedures access to higher education is granted based on academic achievement in secondary school. Also, tuition fees are quite high in these countries. In Belgium on the other hand -as in many other European countries- anyone with a secondary school diploma can enter higher education and tuition fees are lower due to government subsidies. As a result, the student populations in these educational settings may be different.

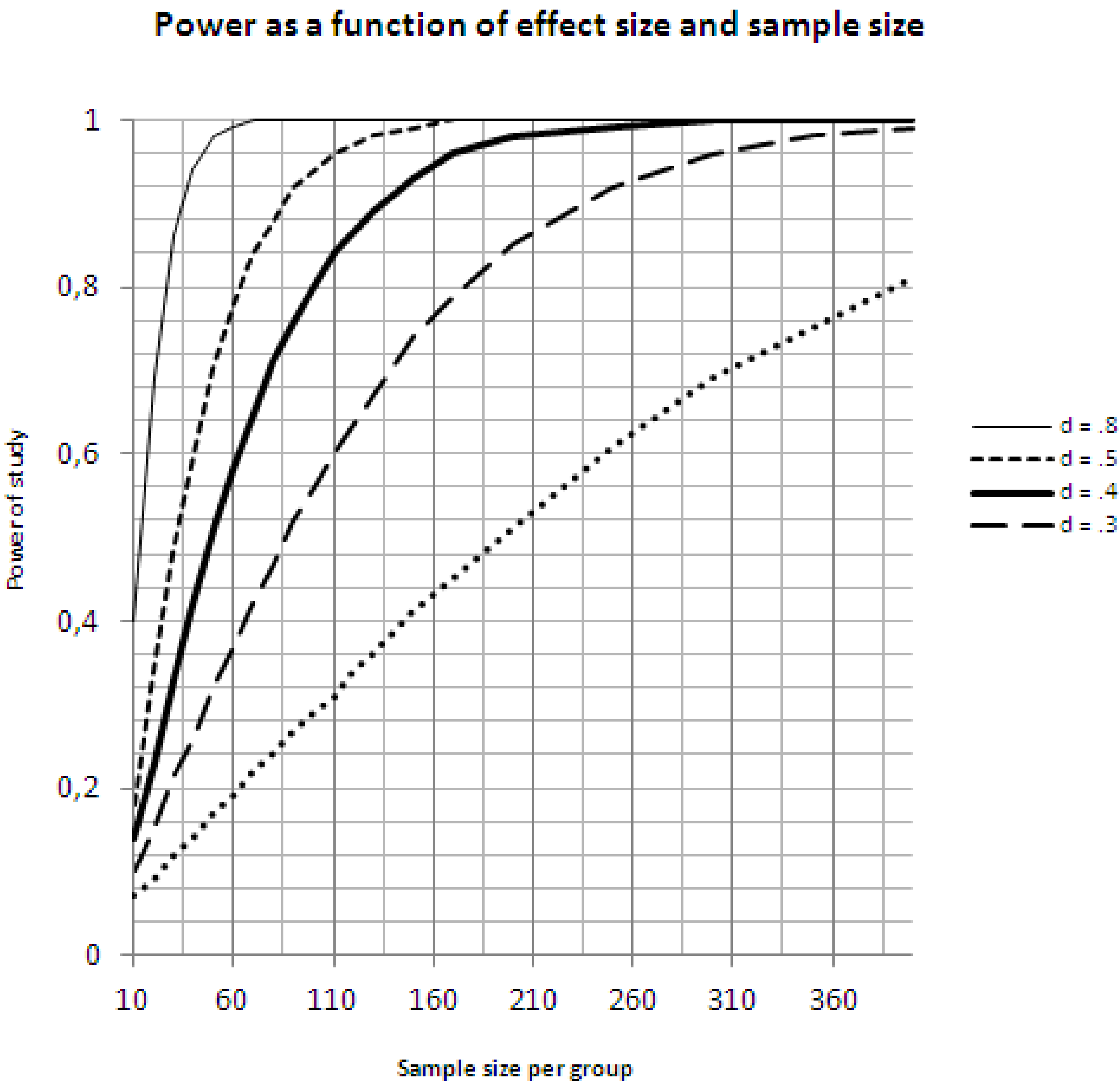

Figure 1. This figure shows the power of a study with two independent groups as a function of sample size for different levels of effect size (assuming that alpha, 2-tailed, is set at .05). For a small effect size (d = .2) we would need two samples of 393 participants to yield a power of 80%. This means there is 80 % chance of finding a significant difference between the groups, given that an effect of this size exists at the population level.

So in the startup phase of this project, limited information was available on dyslexia in higher education for languages other than English (Reid, Szczerbinski, Iskierka-Kasperek, & Hansen, 2007; Szenkovits & Ramus, 2005; Wolff, 2009). These few studies in non-English languages are characterized by small sample sizes and mainly focus on reading and writing. The main disadvantage of small sample sizes in applied research, are the large confidence intervals around the statistical quantities, specifically in a between group design. The smaller the sample, the larger the difference between groups within a population has to be, to remain detectable and reliable. This can be referred to as a problem of statistical power. As a rule of thumb, to assess effect sizes as small as $d = .4$, one requires two groups of 100 participants (see Figure 1). For this reason, new studies with large sample sizes are vital in languages other than English.

As such, up until then (2009) there was little to go on in Flanders to optimize existing guidance protocols for dyslexic students in higher education. To our knowledge, little specific research had been done on this topic within the Dutch language. Of course, professionals were not completely in the dark, as they could rely on years of experience and practical knowledge on the theme. As for the available literature on the topic, we saw that it was mainly practice driven. Examples are the manual *Studying with Dyslexia* [*Studeren met dyslexie*] by Hofmeester (2002) and the *Protocol Dyslexia Higher Education [Protocol Dyslexie Hoger Onderwijs]* (Kleijnen & Loerts, 2006) where relevant knowledge, information and guidelines are formulated on the diagnostic procedures and the support measures for dyslexic students in higher education.

An important disadvantage of the existing initiatives that were based on practical experience was the absence of a reference point to evaluate their abilities. One of the goals of the present research project is to create a general cognitive profile of students with dyslexia compared to normal functioning students. The construction of a theoretical framework based on research results will assist professionals to validate and optimize existing support and diagnostic protocols for students with this learning disorder. Additionally, dyslexic students also have a right to be informed about the challenges they are facing in HE and what their chances are of succeeding.

For learning disabled students in higher education having a valid diagnosis is crucial. Although manifestations of their learning disability may be subtle and manageable in secondary education, in higher education the increased work load puts extra strain on these students. To compensate for their difficulties, institutions of higher education grant specific facilities such as extended time for exams, the use of spelling software, and the use of private testing rooms (Sullivan, May, & Galbally, 2007; Vogel,

Vogel, Sharoni, & Dahan, 2003). As said before, an increasing number of students apply for these facilities. The increase would not be problematic if all students had a valid diagnosis and/or attestation when they enter higher education. Unfortunately, this is not the case (Gilroy & Miles, 2001; Parrila, Georgiou, & Corkett, 2007). In a Report of the National Working Party on Dyslexia in Higher Education, Singleton (1999) noticed that only half of the undergraduates in the UK have been diagnosed with dyslexia prior to their entry in higher education. Estimates in Canada indicate that up to 85% of the individuals do not receive their first formal diagnosis until they reach university/college (Harrison & Nichols, 2005). As for Flanders, Table 1 illustrates that just over half of the students with an indication of dyslexia have a valid attestation in their possession. Often students have been diagnosed but no longer possess of the attestation. Or the attestation that is provided does not contain enough information to be considered valid. In these cases, Cursief briefly retests the individuals to confirm the diagnosis before granting compensatory means. This still means that at the beginning of an academic year, services responsible for these assessments are overwhelmed with applications from students in need of an attestation before their first exam begins -only three months later. This puts considerable pressure on these services. They would profit from clear-cut guidelines for a time-efficient diagnosis. Besides two recent initiatives for diagnostic protocols for dyslexia in adolescents, in Flanders not many materials are available. These two initiatives are the GL&SCHR (De Pessemier & Andries, 2009) and the IDAA [Interactive Dyslexia Test Amsterdam-Antwerp] (Van der Leij et al., 2012). The GL&SCHR is a large test battery for advanced reading and writing containing three main tests that focus on reading and spelling and seven additional subscales evaluating associated problems such as rapid automatized naming, phonological awareness, short term memory and vocabulary. The IDAA is a fully computer based assessment tool using brief presentations of items that must be identified or copied.

In a recent paper by Tops, Callens, Lammertyn, and Brysbaert (2012) the question for a short and effective diagnostic tool was addressed. When the confirmation or rejection of a diagnosis is the primary goal, Tops et al. (2012) showed that a test protocol with 3 predictors is sufficient. This is comparable to the test protocol set up by Hatcher et al. (2002) where four tests lead to a 95% diagnostic accuracy. However, an attestation is not the only reason why students ask for an assessment. Often they wonder about their individual strengths and weaknesses in order to be as efficient as possible in a context where the stakes are high. So, an interesting question is how one can obtain as much information as possible on a person's abilities in the most time-efficient way. For researchers it is also important to know how the various skills are interrelated and affected in students with dyslexia.

The Law for Equal Opportunities of July 2008 and the UN Convention on the Rights of Persons with Disabilities have created a legal context for the creation of compensatory means for students with dyslexia who enter higher education. However, even with these adjustments it is not unlikely that students with dyslexia are more at risk for failure and drop-out than normal functioning students. Due to the importance of reading and writing in higher education, dyslexia is likely to have an impact on academic functioning and indirectly influence other important academic skills. In comparison with the literature available on general academic performance in higher education, far less has been written on the success rates of learning disabled students and the factors affecting academic success. Some studies have shown that students with learning disabilities can attain normal levels of academic performance with the assistance of adequate academic support. Within the Anglo-Saxon educational context outcomes seem quite positive for students with learning disabilities. However, this system is based on the master-apprentice model (once you get in, you are expected to succeed), which prevents the generalization of the findings within such an academic context to other educational settings. But little to no information is available in other contexts. Additionally, considering the enormous amount of research on academic achievement in normal functioning students and the factors that predict success, it is remarkable that there is no such information available for this specific subgroup. In normal functioning students a large number of factors have been found to influence academic performance such as familial and background related factors, preschool experience, personality, intelligence and metacognitive study skills. The only two studies I could find that focus on factors that potentially influence academic growth in learning disabilities is the one by Patrikakou (1996) and the one by Murray and Wren (2003). In the first study parental expectations and perceptions of parental expectations were found to be crucial for raising the academic expectations and the achievement of adolescents with and without LD. Also, the most important predictors of success were the same for students with and without LD, suggesting the model worked in the same way for both populations. In the second study, FIQ and procrastination accounted for a small amount of variance in this subgroup. The lack of information on factors affecting academic performance in students with dyslexia is unfortunate because it is highly relevant for students support centers with respect to study choices and career decisions.

In the middle of the PhD project a collaboration was set up with Carol Whitney, Dr. in Neuroscience and Cognitive Science at the University of Maryland. Together with Cornelissen, P. she had worked out a theory on the possible contribution of a deficit in letter position encoding in dyslexia. The underlying cause of dyslexia remains the subject of intensive debate. The most influential theory is the phonological deficit hypothesis. This theory is motivated by the fact that problems with phonological awareness are very prominent in individuals with dyslexia across ages and languages (Ziegler & Goswami, 2005). These problems with phonology are also supported by neuro-imaging studies (Goswami, 2008). The phonological deficit theory states that individuals with dyslexia have specific problems in representing or recalling phonemes and as a result experience difficulties in mapping the orthographic form of words to representations of the corresponding auditory speech sounds and in recalling those representations from memory (Snowling, 2000; Stanovich, 1988). Although these phonological deficits are apparent in children as well as in adults, there is far less agreement on the origin of these phonological problems and its relation to reading. Some authors see the phonological deficit as the primary cause of dyslexia while others see it as secondary to other low-level cognitive, sensory or motor deficits (Bishop, 2006). It has been postulated that problems in phonological awareness might be a symptom, rather than a cause of reading difficulties. In an fMRI study Dehaene et al. (2010) found that adult illiterates showed reduced activity in the auditory cortex when confronted with oral speech, just like individuals with developmental dyslexia. Blomert and Willems (2010) also failed to find evidence for the claim that phonological deficits cause reading deficits. Also, in a study by Castles and Coltheart (2004) the authors state that so far no study has provided straightforward evidence that there is a causal link between competence in phonological awareness and success in the process of learning to read and spell.

Because of the uncertainty surrounding this phonological impairment hypothesis, other interpretations of dyslexia have been proposed. According to the magnocellular deficit hypothesis abnormalities in the processing of rapidly changing temporal information are the main cause of dyslexia (Stein & Walsh, 1997). Others proposed disorders in the development of the cerebellum as the origin of dyslexia (Nicolson et al., 1999). More recently, the anchoring deficit hypothesis (Ahissar, 2007) has gained influence. Szmalec, Loncke, Page, and Duyck (2011) view dyslexia as a result of impaired language learning and processing caused by an underlying deficit in the long-term learning of serial-order. These are all unitary accounts of dyslexia, which have difficulty accounting for the heterogeneity of the disorder (Heim et al., 2008). A more multifactorial view of dyslexia was proposed by Bishop (2006) according to which several perceptual and cognitive impairments interact and lead to complex reading profiles. Menghini et al. (2010) conducted a study to verify this multifactorial hypothesis and argued that dyslexia is indeed a complex disorder caused by heterogeneous neuropsychological deficits. Their findings support a multiple deficits model stating that in different individuals different cognitive impairments can lead to reading problems.

As for the contribution of a visual deficit in this multifactorial approach of dyslexia, using MEG technology Helenius, Tarkiainen, Cornelissen, Hansen and Salmelin (1999) showed that the first divergence between normal and dyslexic readers occurs at a visual level. 80% of the dyslexic readers did not show the typical left hemisphere infero-temporal activation 150 ms post-stimulus when confronted with letter strings (as opposed to symbols and faces). This area is often referred to as the visual word form area (Warrington & Shallice, 1980; Cohen et al, 2000; Dehaene,Cohen, Sigman & Vinckier, 2005). Taroyan and Nicolson (2009) also found indications for deviations in early electrical brain activation in the visual word form area when confronted with words and pseudowords. Seemingly, dyslexic readers have not learned the string-specific visual processing that normal readers do exhibit (Whitney & Cornelissen, 2005). Therefore, the question has been raised whether a deficit in visual word recognition can account for any variance in the appearance of dyslexia. Based on the SERIOL model of visual word recognition, Whitney and Cornelissen (2005) formulated why early visual processes could contribute to dyslexia. As a detailed model of word processing, this SERIOL (Sequential Encoding Regulated by Inputs to Oscillations within Letter Units) model describes how the visual signals from the retinas are converted into abstract representations ready for the activation of lexical representations (Whitney, 2001; Whitney & Cornelissen, 2008). The SERIOL model postulates a left-to-right word recognition process at the highest, lexical level. The letters of the words are encoded in such a way that the signal of the first letter fires before those of the second letter, which in turn fire before those related to the third letter, and so on. This left-to-right firing of the letters in the model is called the location gradient. The activation gradient is in line with the transmission time of the retinal signals if the word is fixated on the first letter. It is, however, in contradiction with the retinal signal when the word is fixated on the last letter. Therefore, the signals of the various letters must be inhibited for various delays, a process called the location gradient. A further factor involved is that the retinal signals of the first and the last letter are stronger/faster because these letters are not fully surrounded by other letters. Because the location gradient is a process very specific to reading, Whitney and Cornelissen (2005) hypothesized that problems with its acquisition (as a result of learning to read) would lead to deficits very similar to those observed in dyslexia. Carol Whitney suggested testing her hypothesis on our population providing us with the perfect tool to do so. When briefly presenting trigrams at different locations in the right and left visual field, the predictions are the following. Given that the location gradient is not operative in RVF, normal readers and dyslexic readers should perform very much the same, with better performance for the last and the first letter than for the middle letter. In contrast, given the importance of the location gradient in LVF the performance of the dyslexics should be very different from that of the controls. Chances of identifying a letter would be fully described by the distance from the fixation location and lateral inhibition. As a result, the last letter in LVF would be identified more often than the other two letters.

To conclude, the main incentives to set up this large study on dyslexia in students entering higher education were the following. A substantial rise in the number of students with dyslexia is observed. Within the Anglo-Saxon model of education much information is already available on these students but for several reasons it cannot be generalized to other settings. This creates a need for more detailed information on the cognitive profile of these students in Flanders. Second, some students with dyslexia are still in need of a valid attestation for their disability; some seek knowledge on their strengths and weaknesses. This is why support centers need cost-efficient diagnostic protocols for dyslexia in higher education. Finally, there is little information on how these students perform in HE and which factors contribute to their success/failure.

Project in motion

Timeline

Before going into detail on the different phases of the project, a general timeline is presented (see Figure 2). The first thing that had to be done before the actual testing of subjects, was setting up a theoretical framework to work in. From February 2009 to August 2009, information was gathered from the international and national literature on abilities that differentiate normal readers from adult readers with dyslexia and more specifically on dyslexia in higher education. A selection on which cognitive skills to include in the project was made. This selection was mainly based on their relevance within an academic context and their potential contribution to the construction of a general cognitive profile and a diagnostic protocol for students with dyslexia. These skills needed to be operationalized in some way. The next step was to search for Dutch -preferably validated- instruments that tested the envisioned skills. Additionally, contact was made with Cursief for the recruitment of participants. In August 2009, the first students presented themselves and the collection of data began. Students with dyslexia and control students were recruited and tested throughout the academic year 2009-2010. In a next phase, the data were entered and some preliminary data mining was done to start getting a grip on the data (September 2010-December 2010). During this time, the experiment on visual word recognition in dyslexics was also conducted. From January 2011 and onwards, data was analyzed in relation to specific research questions focusing mainly on the dissemination of the findings in international journals. In

October 2012 data for the longitudinal aspect of the project was collected. This all resulted in two PhD Projects: Dyslexia in higher education: Research in Assessment, Writing skills, and Metacognition by Wim Tops and the present one.

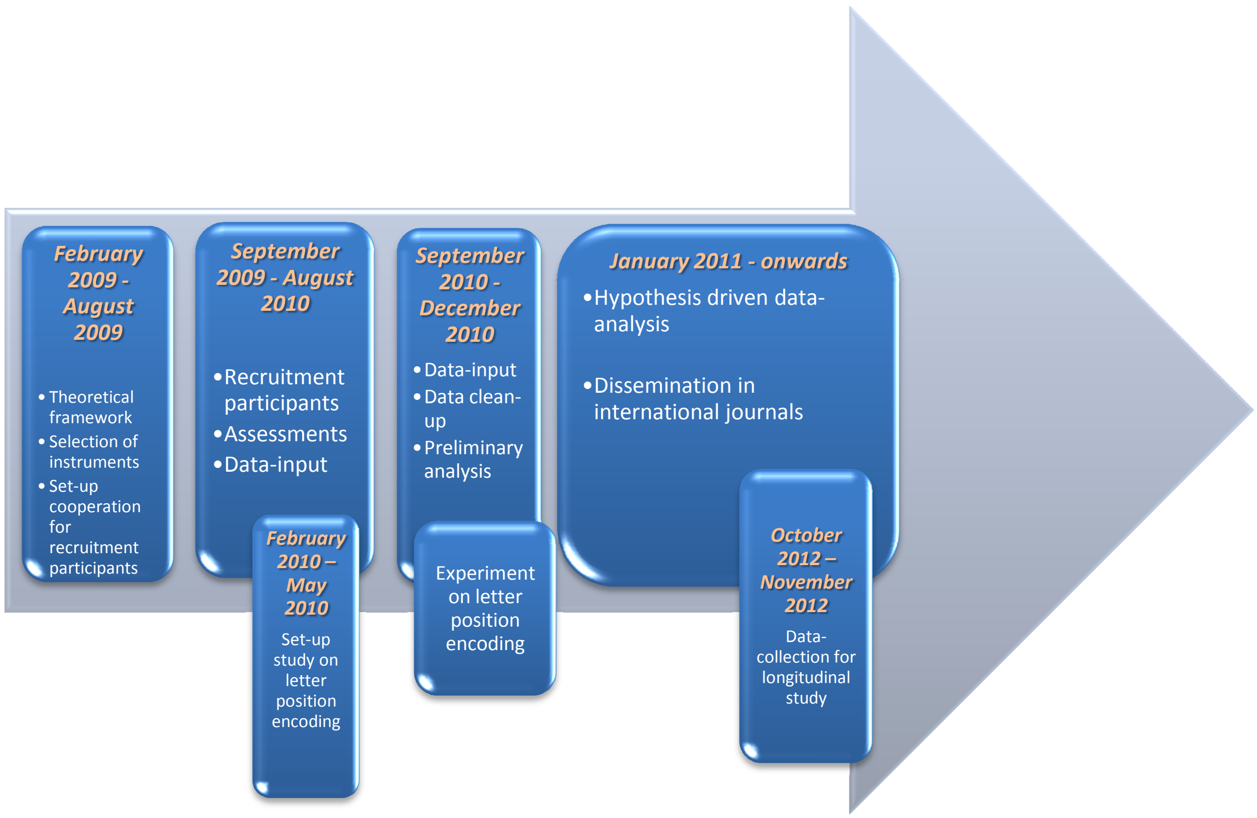

Figure 2. Timeline of the PhD project

A definition of dyslexia

The research project concerns students who enter higher education with dyslexia. Leaving the normal population holds some risks, however. On more than one occasion differences in research results have been attributed to differences in the definition of the impairment. To avoid possible problems in this respect and to make comparisons between studies more straightforward, the following paragraph describes the view on dyslexia that has been applied throughout the study.

Dyslexia is a developmental disorder mostly diagnosed at some point during primary school and secondary school. However, as reading and writing are such important everyday skills, dyslexia has a lasting impact throughout the entire lifespan (Callens, Tops, & Brysbaert, 2012; Hatcher et al., 2002; Swanson & Hsieh, 2009). The core of dyslexia is the presence of a permanent reading and/or spelling deficit. Definitions of dyslexia vary greatly and are either of an explanatory, descriptive or comprehensive nature. An example of an explanatory definition is the one by the International Dyslexia Association (Lyon, Shaywitz, & Shaywitz, 2003) which refers to the phonological deficit theory as the cause of dyslexia. Although there is a lot of evidence supporting a phonological component in dyslexia, other causal theories are gaining support and there is something to say for a more multifactorial causal model of dyslexia. As long as the exact causes of dyslexia are not known, an application of this type of definition is risky. Definitions of a comprehensive nature combine the descriptive and explanatory approach. They both provide indications for the specific needs of dyslexics in relation to reading and writing. The individual educational and/or professional restrictions due to the impairment are inventoried and specific guidelines are formulated. However, the expression of these impairment-related restrictions is largely influenced by individual traits and social circumstances. Inspired by the lack of uniformity in the definition of dyslexia the Network Learning Disabilities Flanders [Netwerk Leerproblemen Vlaanderen] published a vision text in which they declared to firmly believe in the usefulness of the descriptive definition of dyslexia by the Foundation Dyslexia Netherlands [Stichting Dyslexie Nederland, SDN]). As a result, this definition is applied throughout the whole of Flanders and its institutions for higher education. Because of the risks involved in using an explanatory or comprehensive type of definition, this Foundation Dyslexia Netherlands is more inclined to adapt a pure descriptive definition that has as sole purpose the classification of individuals based on objective criteria and symptoms. They formulate the following definition: *"Dyslexia is an impairment characterized by a pervasive problem in the automation of reading and/or writing on a word level"*. To make this definition less prone to differences in interpretation, they elaborate on the term pervasive. On the one hand, pervasive means that the reading and/or writing skills on word level should be significantly lower than expected, given one's age and circumstances. A cut-off score of percentile 10 has been set. This means that compared to a relevant reference group the individual should score amongst the weakest 10 percent on validated and reliable instruments for reading and/or spelling. In addition, a resistance to instruction should be demonstrated meaning that the low scores remain present despite adequate remedial teaching and instruction. According to the "response to instruction" model (Vaughn & Fuchs, 2003) adequate instruction should be defined at three levels. The first refers to the classroom setting.

Teachers should provide classroom instructions with enough expertise and effort while applying the most effective methods. When this first level instruction is considered insufficient, a process of detection, problem analysis and adjusted didactics should be put in motion. Finally, when both levels do not lead to a satisfactory improvement, individual remedial teaching should be provided. When remediation covers all three levels, it can be considered adequate. A last criterion used by SDN is that the impairment should not result from external factors (such as educational deprivation) or individuals factors (such as sensory deficits). This does not exclude the possibility of a comorbid disorder but should not be able to explain the difficulties in reading and/or spelling.

The cognitive profile and an assessment protocol for students with dyslexia

a. Participants

All individuals participating in the study were first year bachelor students (professional or academic) within the Association Ghent. They all had Dutch as their mother tongue and had normal or corrected-to-normal vision. At the beginning of the first of two test sessions, participants filled in an intake form to gather some personal information. Participants were asked to report the type of diploma obtained in secondary school (General SE, Technical SE, Art SE, and Professional SE), the type of bachelor program (field of study) they were following and the institution for HE they were registered in. The highest obtained educational level of both parents was also asked. The study followed the ethical protocol of Ghent University, meaning that students gave informed consent and were informed that they could stop at any time if they felt they were treated incorrectly. All participants received a financial contribution for their participation.

i. Dyslexia group

The group of 100 students with dyslexia was recruited with the assistance of Cursief. Every first year bachelor student applying for special educational measures related to dyslexia at this organization was asked to participate until a total of 100 was reached. To find a group of 100 participants with dyslexia who completed the full study, we had to approach an initial cohort of some 120 students. Of these 120 students a small number of students chose not to cooperate once the study was explained to them. A few more students failed to show up at appointments.

Of the 100 students with dyslexia, 96 reported **a history of reading and/or spelling problems** starting in primary school. Three students reported problems only from secondary school onwards. From one student we did not get a clear answer on this matter. Ninety-eight students reported having been

diagnosed prior to the study by trained diagnosticians. From two participants these data are unavailable. From the 98 students with a previous assessment, 61 had been diagnosed in primary school, and 37 of them in secondary school. These diagnosis were made by Centers for Student Counseling (CLB; *N*=24), by speech and language pathologists or neurolinguists (*N*=42), by specialized doctors such as child psychiatrists or developmental neurologists (*N*=6), in rehabilitation centers (*N*=14), and by psychologists or pedagogues (*N*=4). In 8 cases the students could not recall the exact function of the diagnostician. From two participants this information is unavailable. Of the 98 students we have additional information from, 87 reported having received **individual remediation** by a speech language pathologist. In 67 cases this remediation took place in primary school, in 11 cases in secondary school, for 9 students remediation started in primary school but continued in secondary school. One participant started his first year in primary school in an institution for special education. Eight students received individual tutoring at school (which can be considered as remediation). Only two participants had not received any specific aid for their reading/spelling problems. Individual remediation (by a speech language pathologist) typically lasted 3 years and 11 months, with a range of 6 months to 10 years and a standard deviation of 2 years and 2 months. It can be noted that for 20 students that had received remediation in primary school, the actual diagnosis was only made in secondary school. For the two students who did not receive any specific individual remediation the following can be said. Both experienced problems from primary school onwards. The first student obtained scores below percentile 1 on word spelling and word reading and percentile 3 for pseudoword reading, indicating the severity of the disorder. She also reported having received a lot of individual help from her mother, who was a teacher. The second student also scored below percentile 10 for both nonword reading (pc 9) and word spelling (pc 7). In primary school and secondary school suggestions from teachers to engage in individual remediation were ignored but the mother assisted daily in homework and studies. Strictly speaking, for these two students the resistance to instruction has not been proven on all three levels but we believe that the 6 years in primary school and 6 years in general secondary education -in combination with the clinical scores on reading and/or spelling- are sufficient to prove the resistance to instruction and as such include them in the clinical group.

So, most students had received a formal diagnosis before entering higher education. However, for a student entering higher education to be given access to compensatory means, confirmation of a diagnosis is necessary when the criteria on the attestation do not meet the ones stated by the SDN. Cursief had to retest 46 students and confirmed the diagnosis in all cases[3].

In an interview taken during the test protocol, the presence of any **comborbid disorders** was questioned. In the Figure below (Figure 3), only the comorbid disorders that were formally diagnosed were included. Several other students reported problems with attention, concentration and math without ever having received a formal diagnosis. One student reported having Chronic Fatigue Syndrome (CVS) and two students an eating disorder. These were not included in the table as relevant comorbid disorders.

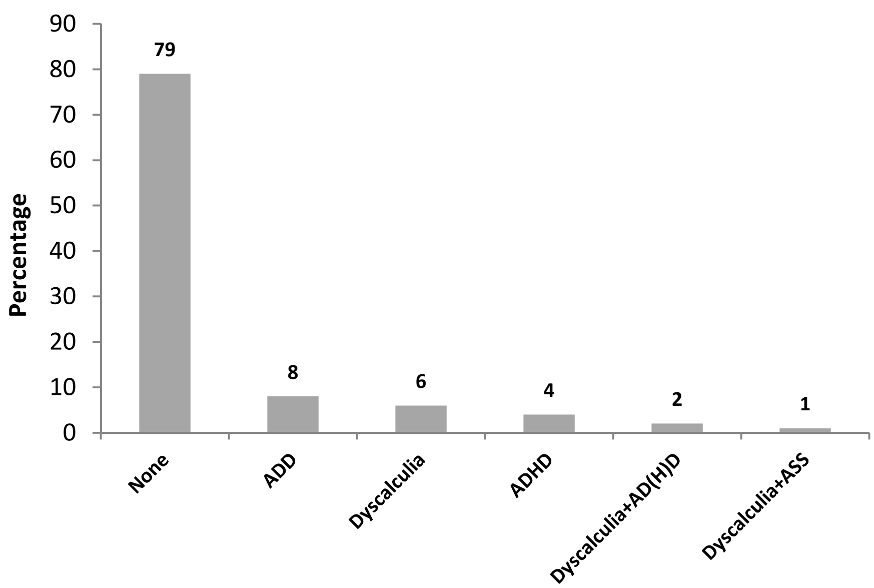

Figure 3. Percentages of the different types of comorbid disorders in the dyslexia sample. ADD= Attention deficit disorder; ADHD= Attention deficit hyperactivity disorder; ASS= Autism spectrum disorder.

The mean **age** of the group with dyslexia was 19 years and 4 months. The mean **Fluid IQ** as measured with the Kaufmann Adolescent and Adult Intelligence Test (Dekker, Dekker, & Mulder, 2004) was 105 [SD = 11.04].

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[3] In Table 1 only 80% of the diagnoses are confirmed. Possibly the selection procedure had an influence on the confirmation rates in the sample. In the study the first applicants of the academic year were recruited. Students who do not succeed in the first semester might also question their reading and writing skills, asking for an assessment.

To evaluate if the **male: female ratio** in the dyslexia group was representative for the general student population; this was compared to the number of students inscribed in one of these 5 institutions for HE in the academic year 2009-2010 (see Table 2). The male: female ratio in the sample was representative for the general population as described above [χ^2 *(1)* =0.646; *p*= .42].

Table 2
Number and proportions of males and females in the sample and the general population

Gender	**number in sample**	**percentage in sample**	**number in population**	**percentage in population**
Female	59	59%	24617	55%
Male	41	41%	20233	45%
Total	100	100%	44850	100%

Note: Based on data published by the Flemish government on October 31st, 2009 (Hoger onderwijs in Cijfers [Higher education in numbers], Flemish Government).

The 100 students were inscribed in an **institution for HE** within the Association Ghent. The 5 institutions were represented as follows (Figure 4).

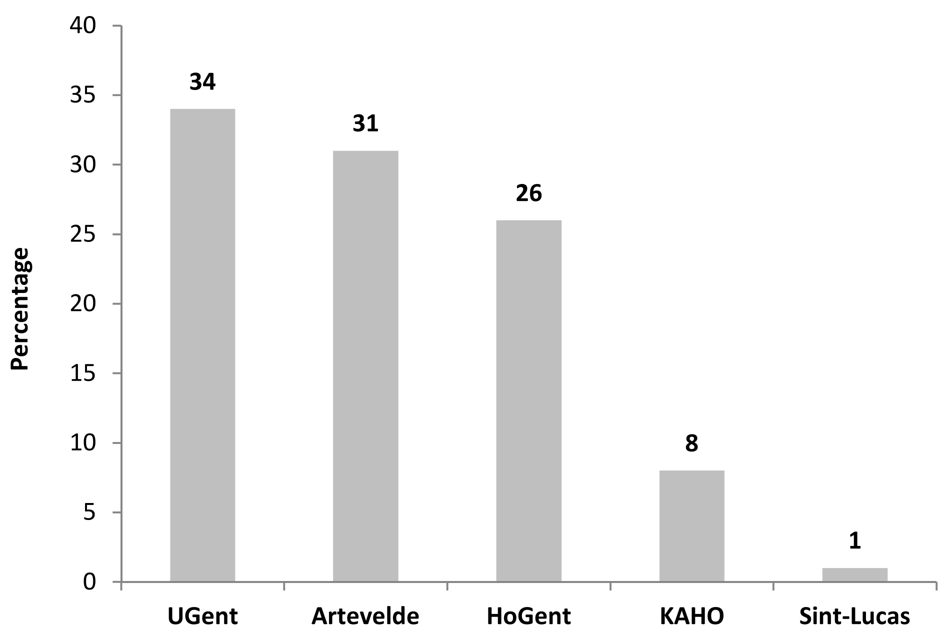

Figure 4. Percentage of inscriptions per institution in the sample of students with dyslexia.

Of the 100 students, 63 were inscribed in a **professional bachelor program** and 37 in an **academic bachelor program**. A comparison of this sample proportion to the general student population tells us that students with dyslexia are more inclined to inscribe in a professional bachelor [χ^2 *(1)* = 1.28; *p*=.001] than an academic bachelor (see Table 3).

Table 3
Number and proportions of students inscribed in an academic or professional bachelor in the sample and the general population

Gender	**number in sample**	**percentage in sample**	**number in population**	**percentage in population**
Professional	63	63%	89263	47%
Academic	37	37%	101590	53%
Total	100	100%	190853	100%

Note: Based on data published by the Flemish government on October 31st, 2009 (Hoger onderwijs in Cijfers [Higher education in numbers], Flemish Government).

Concerning the **field of study** of the students, programs were grouped to avoid small numbers in certain groups. These fields of study were grouped in 8 categories namely Health care, Business sciences, Human sciences, Law and criminology, Education, Art and history, Politics and sociology and Industry and technology. Health care includes programs such as audiology, occupational therapy, nursing, midwife, physical education and pharmacy. Programs such as journalism, office management, corporate management, business engineer and IT were grouped in Business sciences. Human sciences programs include social work, pedagogy, psychology and special education. Law and criminology include only those exact two programs. Education includes kindergarten teacher, primary school teacher and secondary school teacher. The Art and history group include art sciences, history and interior design. The programs communication sciences and political and social sciences form the group Politics and sociology. Finally, Industry and technology include programs such as wood technology, chemistry, bio-engineer, industrial engineer, logistics, fashion technology, and electro mechanics. Figure 5 shows the proportions of students per field of study in the dyslexic sample.

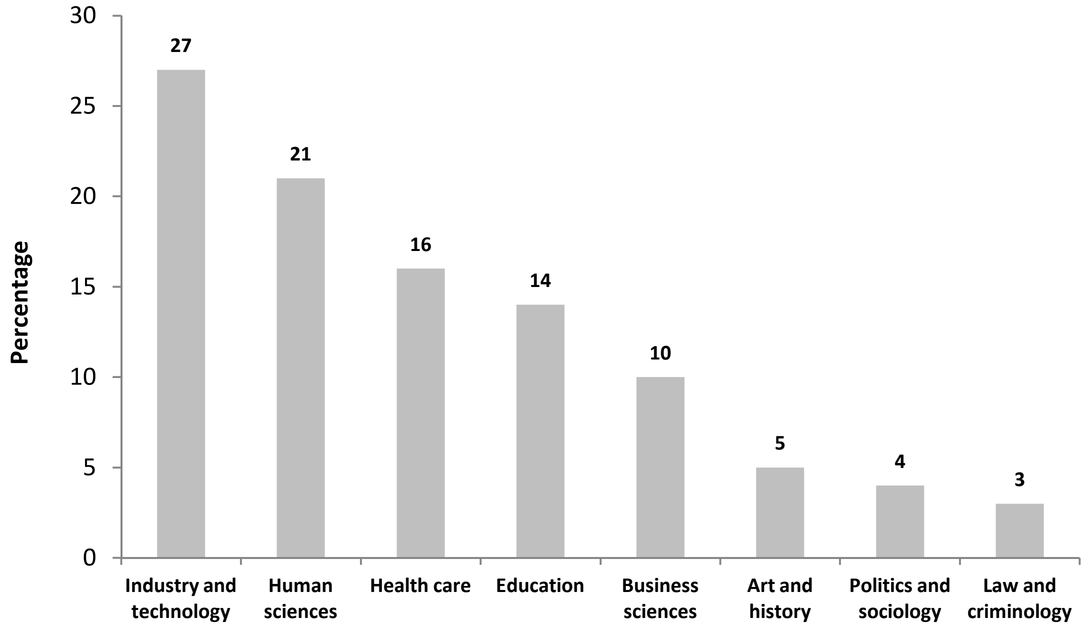

Figure 5. Percentage of inscriptions per field of study in the dyslexic sample.

To see if our sample was somewhat representative with respect to the general population regarding field of study, we compared inscription percentages of the general population with our sample distribution. Because field of study is influenced by gender, we did this separately for the male (see Figure 6) and female group (see Figure 7) in the study. Fields of study that were not represented in our sample were left out in these comparisons. Programs that were not represented in our sample were for example medicine, dentistry, music and stage arts, audiovisual and moving arts, bio-technique, nautical sciences, veterinary and languages.

In general these sample distributions were significantly different from the general bachelor population for the male [χ^2 *(7)* = 16.55; *p*=.021] as well as the female group [χ^2 *(7)* = 24.15; *p*=.001]. For the male group, less dyslexic students were inscribed in programs in Business sciences and Education and more in Industry and technology. Especially the wood technology program was well represented in our sample. For the females, Business sciences and Law and criminology were also less represented whereas more female students with dyslexia seemed to have chosen a program in Human sciences and Industry and technology.

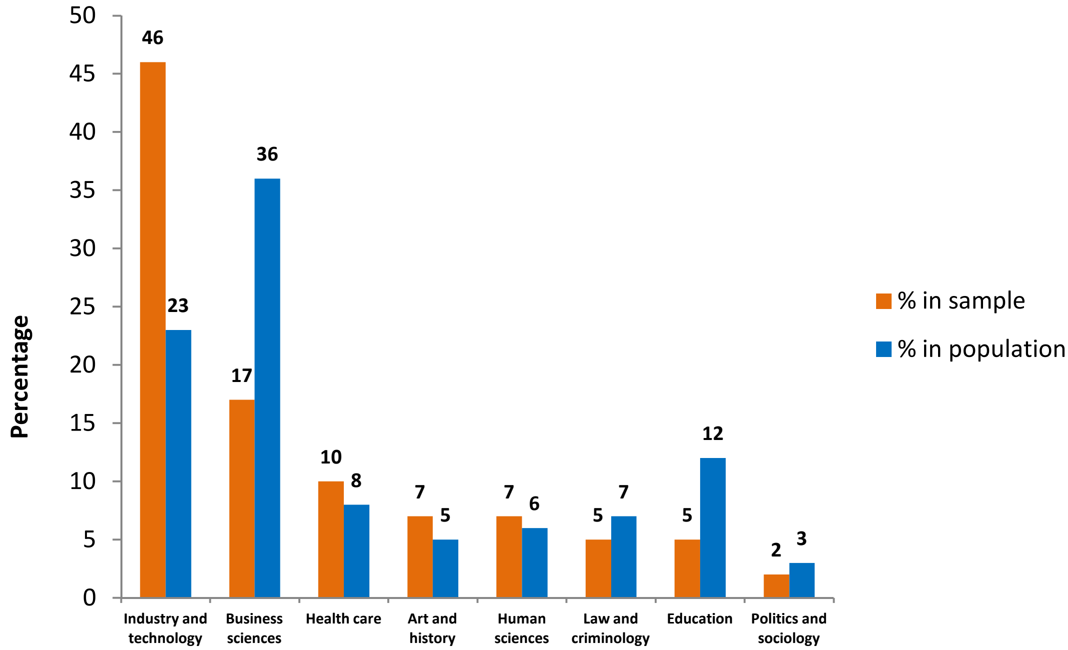

Figure 6. Comparison of the percentage of male students according to field of study in the sample and the general population.

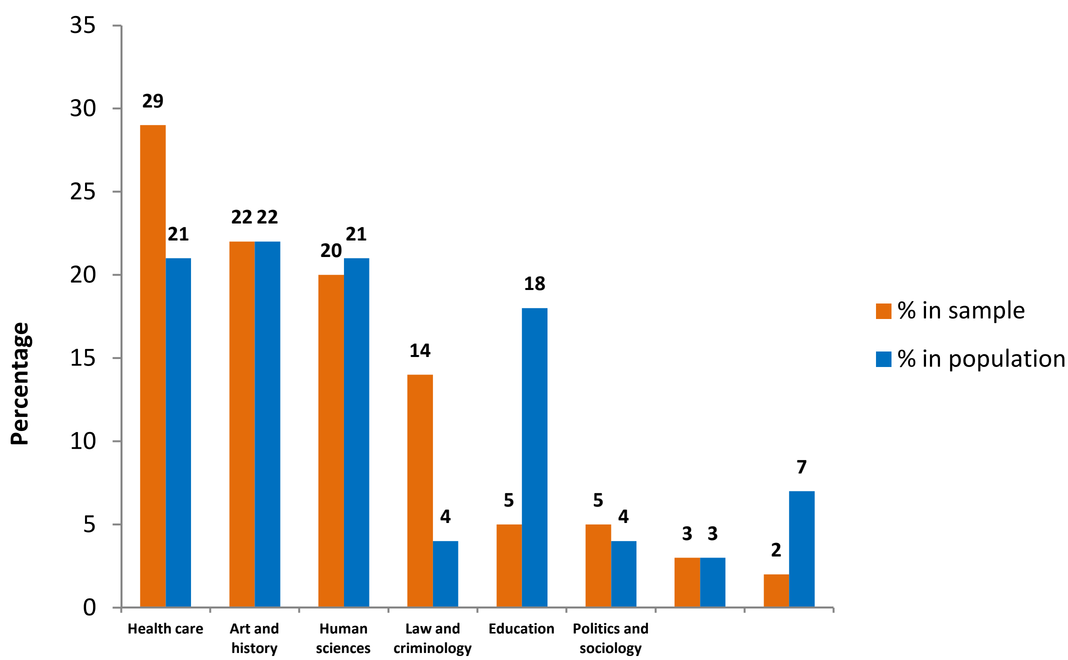

Figure 7. Comparison of the percentage of female students according to field of study in the sample and the general population.

ii. Control group

For every student with dyslexia that was recruited, a control participant was matched on gender and field of study (plus institution). To recruit these 100 control students, the social networks of the students were addressed, in addition to student coaches and electronic learning platforms. None of the members of the control group reported any known neurological or functional disorder such as a learning disability. The mean age of the control group was 19 years and 11 months. The mean Fluid IQ was 107 [*SD*= 10.83].

iii. Both groups

Groups did not differ in age [$t(198) = -0.91$; $p = .36$] or in Fluid IQ [$t(198) = 0.92$; $p = .36$]. The latter is interesting because it contradicts an assumption sometimes held that dyslexic students are less intelligent than their peers. In each group 41 males and 59 females participated. Per group 34 students were university students, 3 students followed an academic bachelor program at a college for higher education and 63 followed a professional bachelor program at a non-academic college for higher education.

Data on type of **secondary education** (SE) degree were available. Figure 8 shows the former educational levels for each group. GSE stands for general secondary education, TSE for technical secondary education, ASE for arts secondary education and finally PSE for professional secondary education.

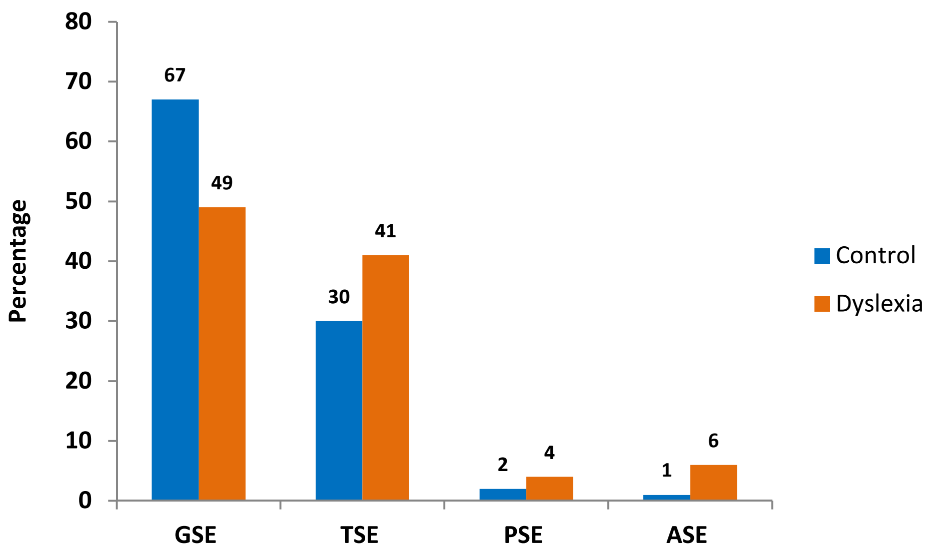

Figure 8. Former secondary educational level for the control group and the dyslexic group.

To see if there was difference in former education between groups, TSE (TSO), PSE (BSO) and ASE (KSO) were grouped because of small numbers in the ASE and PSE groups. Proportionally more students with dyslexia came from a non-general type of secondary education compared to the control groups [χ^2 (1) = 6.650; p=.015].

For all participants, the **attained educational level for both father** (see Figure 9) **and mother (**see Figure 10) was noted. These were categorized in four groups: lower secondary level (termination after the second year in secondary education), higher level secondary school (all 6 years), College and University. At the time of graduation of the parents the Ba-Ma structure was not yet institutionalized so higher education is split up in College and University. Colleges provided three or four year programs with a more applied nature, the standard university program at that time consisted of a minimal four year program, academic in nature.

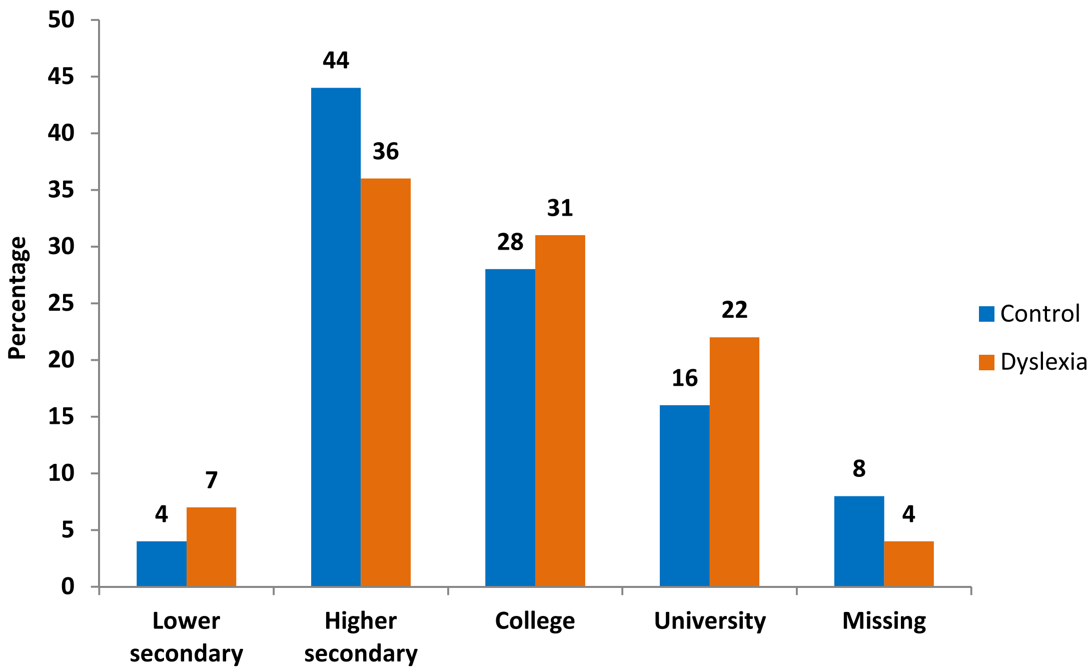

Figure 9. Educational attainment of the father for the control group and the dyslexic group.

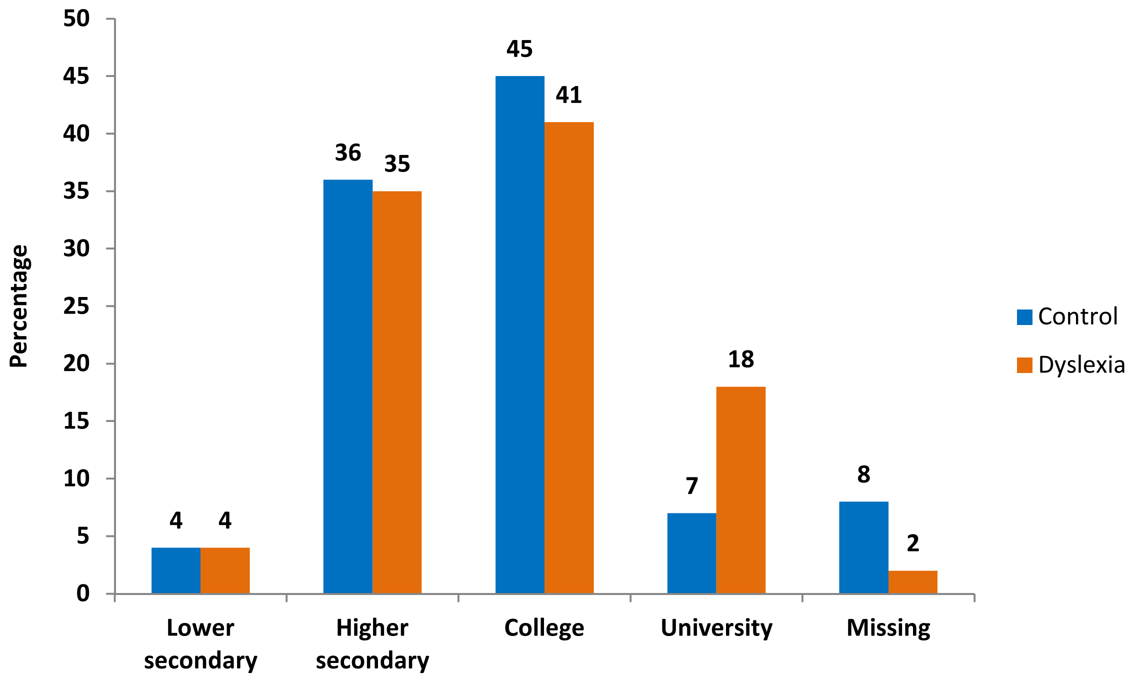

Figure 10. Educational attainment of the mother for the control group and the dyslexic group.

To see if there was a difference in parental educational attainment between groups, lower and secondary level were grouped because of small numbers in the lower secondary group. Using a multinomial regression with University level as a reference group, no difference in paternal educational attainment between groups [χ^2 *(2)* =1.29; *p*= .52] was found. As for the maternal educational attainment level, on group level there was a noticeable trend but the difference is not statistically significant [χ^2 *(2)* = 5.02; *p*= .08]. When looking at the pair wise comparisons, more mothers from dyslexic students had a university diploma than a college degree [*Wald*= -2.096; *p*=.02] and more had university degree than a secondary education diploma [*Wald*= -1.94; *p*=.03] (The Wald value can be interpreted as a z-score). When taking College level as reference group, we see that there was no difference between groups on secondary education versus college level [*Wald*=0.22; *p*=.41].

b. Test battery

While trying to find a maximum overlap between abilities that are important in dyslexia research in higher education and the available materials in Dutch, the following selection of test was made (see Table 4 below). In this table each test or subtest is categorized according to the cognitive skill it measures.

To measure intelligence and cognitive subskills seen as subcategories of the g-factor, the full KAIT battery (Kaufman Adolescent and Adult Intelligence Test) was administered. There were two reasons for chosing the KAIT instead of the WAIS. First of all, retest effects had to be avoided for those who had been tested in the past. Secondly, the KAIT has less rigorous time constraints which can be considered an advantage for students with learning disabilities. Next, we wanted to test the usefulness of two new instruments in higher education namely the GL&SCHR (see above) and the IDAA (see above) and some classical measures of reading and writing that are often used in diagnostic procedures for dyslexia namely the EMT (Dutch One-Minute-Test), the Klepel (a pseudoword reading test) and the AT-GSN dictation (a test for advanced spelling in Dutch). An additional advantage of the GL&SCHR is that it includes subtests that measure several functions which have been associated with dyslexia such as rapid naming, short term memory and vocabulary. Due to the importance of English as an academic language in higher education, English reading and writing skills were also evaluated, using the OMT (English One-Minute-Test) and the WRAT (Wide Range Achievement Test). Finally, a measure of mental calculations (TTR; speeded mental calculations) was added and a measure for speed of processing and attention (CDT; digit crossing test). For the longitudinal study, tests for personality (NEO-PI-R) and study skills (LASSI) were also inserted.

Table 4
Administered subtests according to the different cognitive skills

Cognitive skill / Subskill	**Test**	**Reference**
Reading		
Word reading	One-Minute-Test [Een-Minuut-Test]	Brus and Voeten (1991)
English word reading	One-Minute-Test	Kleijnen and Loerts (2006)
Text reading	Read aloud text “Fear of Failure” [Voorleestekst Faalangst]	De Pessemier and Andries (2009)
Silent reading	“How dangerous can a tick be?” [Hoe gevaarlijk is een tekenbeet?]	Henneman, Kleijnen, and Smits (2004)
Pseudoword reading	Klepel [De Klepel]	van den Bos, Spelberg, Scheepsma, and de Vries (1999)

Cognitive skill Subskill	Test	Reference
Automation	Automation [Automatisering en Uitspraaksnelheid]	De Pessemier and Andries (2009)
Text comprehension	Read Aloud-Listening Text Irstels [Leesluistertekst: "Irstels"]	De Pessemier and Andries (2009)
Spelling		
Word spelling	Word spelling [Woordspelling]	De Pessemier and Andries (2009)
English word spelling	WRAT-III English Word Dictation [WRAT Engels Woorddictee]	Wilkinson (1993)
Sentence dictation	General Test for Advanced Spelling in Dutch [AT-GSN]	Ghesquière (1998)
Proofreading	Other Spelling Rules [Overige spellingsregels]	De Pessemier and Andries (2009)
Writing speed	Writing speed [Schrijfsnelheid]	De Pessemier and Andries (2009)
Lexical decision	Flash Reading Words [Flitslezen Woorden]	Van der Leij et al. (2012)
Decoding	Flash Typing words [Flitstypen Woorden]	Van der Leij et al. (2012)
	Flash Typing pseudowords [Flitstypen Pseudowoorden]	Van der Leij et al. (2012)
	Flash Typing English words [Flitstypen Engelse Woorden]	Van der Leij et al. (2012)
Phonological awareness	Spoonerisms [Spoonerisms]	De Pessemier and Andries (2009)
	Reversals [Omkeringen]	De Pessemier and Andries (2009)
	Reversals [Omkeringen]	Van der Leij et al. (2012)
Rapid naming	Letters [Letters]	De Pessemier and Andries (2009)
	Digits [Cijfers]	De Pessemier and Andries (2009)
	Colors [Kleuren]	De Pessemier and Andries (2009)
	Objects [Objecten]	De Pessemier and Andries (2009)
General intelligence		
General information	Personalities [Persoonlijkheden]	Dekker et al. (2004)
Problem solving-reasoning	Symbol Learning [Symbool Leren]	Dekker et al. (2004)
	Logical Reasoning [Logisch Redeneren]	Dekker et al. (2004)

Cognitive skill / Subskill	Test	Reference
	Secret Codes [Geheime Codes]	Dekker et al. (2004)
Auditory comprehension	Auditory comprehension [Auditief Begrip]	Dekker et al. (2004)
Vocabulary	Vocabulary [Woordenschat]	De Pessemier and Andries (2009)
	Definitions [Definities]	Dekker et al. (2004)
	Double Meanings [Dubbele Betekenissen]	Dekker et al. (2004)
Memory		
Verbal memory	Phonological STM [Fonologisch KTG]	De Pessemier and Andries (2009)
	Verbal STM [Semantisch KTG]	De Pessemier and Andries (2009)
	Delayed Auditory Comprehension [Auditief Begrip: Uitgestelde Reproductie]	Dekker et al. (2004)
Working memory	Working Memory [Werkgeheugen]	De Pessemier and Andries (2009)
Visuo-spatial memory	Visuo-Spatial STM [Visuospatieel KTG]	De Pessemier and Andries (2009)
	Delayed Symbol Learning [Uitgestelde Reproductie]	Dekker et al. (2004)
Morphology and syntax	Morphology and Syntax [Morfologie en Syntax]	De Pessemier and Andries (2009)
Mental calculations	Speed Test Mental Calculation [Tempo Test Rekenen]	de Vos (1992)
Speed of processing/attention	Digit Crossing Test [Cijfer Doorstreep Test]	Dekker, Dekker, and Mulder (2007)
Personality	NEO-PI-R	Hoekstra, Ormel, and de Fruyt (2007)
Learning and study skills	LASSI	Lacante and Lens (2005)

c. Procedure

The complete protocol (see Table 5) was administered in two sessions of about three hours each. The protocol was divided into two counterbalanced parts with a break in between and halfway each session. If necessary, students could take additional breaks. The order of tests in part one and two was fixed and chosen to avoid succession of similar tests. Students with dyslexia started with part one or two according to an AB-design. The corresponding control student always started with the same part. All tests were administered individually by three test administrators according to the manuals guidelines. Test administrators were Wim Tops and I with the assistance of a test psychologist, Joke Lauwers, during a three month period[4]. To standardize administration they all read the test manuals, had a practice session, and followed some sessions of the starting administrator (Maaike Callens). Testing occurred individually in a quiet room. For most subtests, the participant was seated in front of the test leader. For the parts that were computer based, the participant was seated in front of a computer screen while the test administrator remained in the room. In addition to the test battery as described above, a semi-structured interview was taken from every student with dyslexia. During this interview information was gathered on their predisposition for dyslexia, language development, primary school and secondary school, self-perception, diagnosis of dyslexia, study skills and the frequency and ability of using a computer.

Table 5
Test Protocol

Part 1

1.	KAIT	1 h 30
2.	OMT	5 min
3.	IDAA	30 min
4.	Silent reading test	15 min
5.	NEO-PI-R	30 min

Part 2

1.	Interview	30 min
2.	CDT	5 min
3.	GL&TSCHR (+ EMT,KLEPEL)	1 h
4.	LASSI	20 min
5.	WRAT	10 min
6.	TTR	5 min
7.	AT-GSN	30 min

The experiment on letter position encoding in dyslexia

a. Participants

Participants were recruited out of the 200 students from the initial study. So, cognitive data (reading and writing skills, IQ) was already available. A request for participation was send to all 200 participants

[4] In the initial phase Eline Liekens, Master in speech and language pathology, did the assessments together with Maaike Callens. Wim Tops replaced her soon after the assessments started.

by email. Participants could register for the experiment until a total of 20 control students and 20 dyslexic students were inscribed. They received a small financial compensation for their participation in the experiment. Detailed information on the characteristics of these groups can be viewed in Chapter 5, Table 1.

b. Design

Whitney and Cornelissen (2005) suspect that the reading problems of individuals with dyslexia are caused by a problem in the left-to-right processing of words (or more specifically by a deficiency in the formation of the locational gradient). The paradigm of Legge, Mansfield, and Chung (2001) was used to test this hypothesis. Here, trigrams of consonants were presented tachistoscopically at 11 horizontal retinal locations (going from 5 letter positions or -2.5° to the left of fixation to 5 letter positions or 2.5° to the right of fixation) and participants had to type in the letters they managed to perceive. Speed and letter order were not included as variables in the analysis and are therefore not important. Per participant, the mean accuracy per letter (L1-L2-L3) and location (Loc 1 to Loc 9) was calculated. To avoid floor and ceiling effects individually adjusted stimulus presentation times were used. Also by using trigrams, top-down contributions from phonology, lexicality, or semantics, were minimized so that the results maximally reflect the contribution of orthographic (visual) processing. The assumption is that if the location gradient formation is indeed deficient in students with dyslexia, specific patterns of results on accuracy per location and letter are predicted. Dyslexic readers should perform very similar to normal readers in the RVF given that the acuity gradient agrees with the location gradient in the RVF and no inversion is needed. In the LVF, where the locational gradient is of essence, a divergence in results is expected between groups. A strong advantage for the first letter of the trigram is predicted for the control group but not for the dyslexic group. In this group, the last letter is expected to be identified more often than the other two letters.

Academic performance of students with dyslexia

a. Participants

Our initial group for this study was identical to the one in the general cognitive study. However, when collecting the longitudinal data we noticed that not all participants were generation students. This means that the student in question was registered for the first time in a bachelor program in higher education, usually right after the termination of secondary school. These students are typically in the age range of 18-19 years. The omission of non-generation students was done to avoid an influence of previous experiences on study performance and to be able to compare trajectories of pure first year bachelor students. As a result, 10 students from the control group and one from the dyslexia group were omitted. Of 1 control student, we could not collect data on academic performance. The final sample therefore consisted of 89 control students and 99 students with dyslexia for this longitudinal study.

b. Data collection

The personality test (NEO-PI-R (Hoekstra et al., 2007)) and learning skills instrument (LASSI, Learning and Study Strategies Inventory (Lacante & Lens, 2005)) were administered during the general assessment but within the context of this PhD, this data was only used in the study on study success.

All 200 participants signed a consent form, giving their educational institution permission to transfer their study results to us. After three years into their bachelor programs data on academic performance was collected (October 2012). For each of the participants the institutions provided us with the following data: drop-out per year, the number of credits the student registered for per year, the number of credits obtained per year and whether or not the student obtained a bachelor degree after three years. In this context, the term drop-out was used for every student who terminated their study before formal graduation. This did not necessarily mean the student stopped studying. They could also switch to a different program at the same or a different level. Unfortunately, at the time of the study we did not have quantitative data from any subsequent program. Therefore, participants that dropped out were contacted by phone and email to collect qualitative information on their current occupation.

What did we find?

In the following section, a brief overview is given of the most important findings of the different studies. The order corresponds to the subsequent chapters in this PhD.

In Chapter 2 the cognitive profile of students with dyslexia in higher education is described. Performances on a multitude of cognitive skills such as reading, spelling, phonology, math, speed of processing and reasoning were compared between a group of first-bachelor students with dyslexia (N=100) and a group control students matched on gender and field of study. The results clearly demonstrated that students with dyslexia in higher education show persistent problems with several reading and writing skills (effect sizes for accuracy between $d = 1$ and $d = 2$). Besides these obvious impairments in reading and spelling, other associated cognitive deficits could be noted. Problems with mental calculation ($d \approx 1$), phonological processing ($d > 0.7$) and lexical retrieval are among them. Speed related measures were more affected than accuracy related measures. Students with dyslexia also performed slightly inferior on the KAIT tests of crystallized intelligence, due to the retrieval of verbal information from long-term memory. As for fluid intelligence, no significant differences were observed in the KAIT. Based on these findings that agree with recent findings in the English language it can be suggested that the cognitive profile of Dutch students in higher education can be generalized to all alphabetic languages. In this chapter some implications for special arrangements for students with dyslexia in higher education are outlined.

The question we put forward in Chapter 3, is how many factors are needed to extract the pattern of relationships in the wide range of variables -as described in Chapter 1- that are important in higher education. As such, an attempt is made to cross the bridge between the existing theoretical frameworks and everyday practice by using an exploratory factor analysis (EFA) in combination with effect sizes. EFA reduces the number of factors by using the covariation in the observed variables. This is assumed to be due to the presence of an underlying, latent variable that exerts a causal influence on the observed variables. In this study, the EFA was applied across groups. The more the groups differ from each other on a variable, the more the factor to which the variable is allocated summarizes the difference between the groups rather than the variability within each group. The scores obtained for all the administered tests in Chapter 1 -plus the ones on the computer based assessment battery (IDAA) - were entered in an exploratory factor analysis. A model with 10 factors fitted the data best. Effect sizes were used to express the processing costs of students with dyslexia. Factors related to reading, spelling, flashed orthography, phonology, rapid naming, math, and reading fluency resulted in large effect sizes. A factor combining all measures of crystallized IQ had a medium effect size. The subtests for fluid intelligence were divided in two separate factors with no difference between students with and without dyslexia. With this new approach, we unfolded a more general profile of differences between normal reading students and students with dyslexia, helping professionals to recognize a dyslexia profile. Also, information is provided on how to create a better and more cost-efficient protocol for dyslexia in HE.

Chapter 4 gives an overview on how well students with dyslexia perform throughout their bachelor program compared to their peers. Data was collected from all first generation students that participated in the study in Chapter 1. Demographic givens, the results on the NEO-PI-R and on the LASSI were used to predict drop-out and study outcome. At the time of data collection results showed that being dyslexic has an impact on both study continuance and study success. In the group of students with dyslexia there is a higher dropout rate, and less students manage to finish their bachelor program within the model trajectory of three years. Logistic modeling in the two groups separately did not lead to models of satisfactory quality for the control group so models between groups could not be compared. For the dyslexia group, a higher educational attainment of the parents was positively linked to better performance in HE (less dropout and more study success after three years). Female students with dyslexia have more chances of dropping out but those who do continue perform better than their male peers. Concerning personality the following was observed. More agreeable, less conscientious and more neurotic students tend to drop out more. Extraversion negatively impacts dropout but has a positive effect on obtaining a degree. Learning strategies mainly influence study outcome after three years. Only low goal strategies relate to a higher risk of dropping out. This also has a negative impact on study duration; we believe this to be mainly driven by higher anxiety levels. Well developed affective strategies and comprehension monitoring strategies are important in study success after three years. Finally, applying compensatory means increases the chance of obtaining a degree after three years in the group that persists. The presence of comorbid disorders decreases the chance of dropping out but also decreases the chance of succeeding after three years. A general remark is that at the time of data collection some students had not yet terminated their program. A follow-up study is therefore recommended to get a full overview of study success and time to graduation.

Finally, in Chapter 5 a more theoretical approach was applied. The focus lies on the possible contribution of a visual deficit in the development of dyslexia. In a paper on letter position encoding and dyslexia the authors of the SERIOL model for visual word recognition (Whitney & Cornelissen, 2005) postulated a hypothesis on the existence of a visual deficit in dyslexics. They conjectured that the impairment observed in dyslexia could be the result of problems with the left-to-right processing of words, particularly in the part of the word between the word beginning and the reader’s fixation position. In order to examine this hypothesis, consonant trigrams (TRV, VMZ, etc) were tachistoscopically presented in both visual fields (LVF, RVF) to 20 first-bachelor students with dyslexia and 20 matched controls. These students were recruited at random from the same pool of students from Chapter 1. The trigrams were presented at different locations (from -2.5° to + 2.5°) in both visual half fields. Participants were asked to identify the letters and accuracy rates were compared. The letter accuracy predictions made by Whitney and Cornelissen (2005) are visually presented in Figure 11.

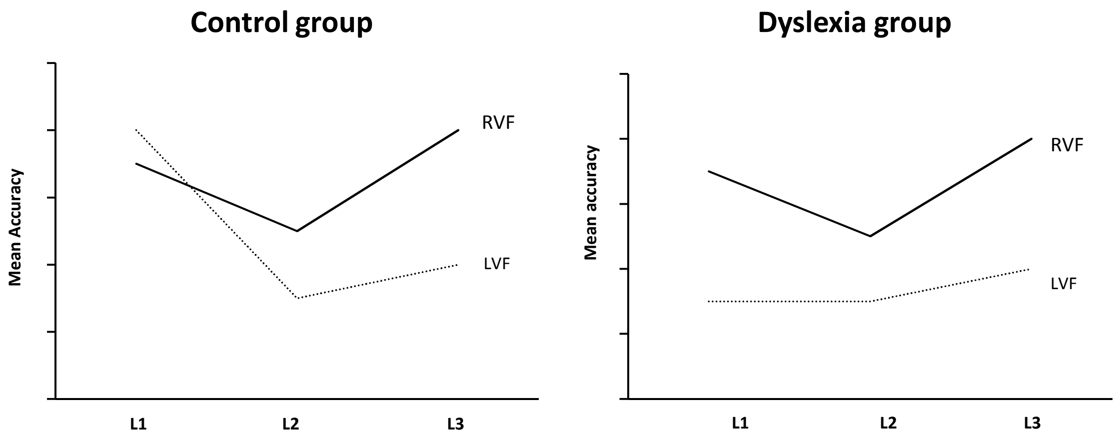

Figure 11. Predictions made by the authors of the SERIOL model for control readers and dyslexic readers in the LVF and RVF for the three letters in the trigram.

For normal readers the predictions are presented in the left figure. The SERIOL model predicts a clear right visual field advantage for the last letter and a left field advantage for the first letter. In the right figure the expected mean accuracy rates in the right and left visual field for the dyslexia group are presented. An absence of this left field advantage for the first letter is predicted. In line with the predictions for normal reading, a typical U-shaped pattern was found at all retinal locations. Accuracy also decreased the further away the stimulus was from the fixation location, with a steeper decrease in the LVF than in the RVF. However, the students with dyslexia clearly showed the same pattern of results as the control participants. In the dyslexia group we did find a lower accuracy rate in the LVF, particularly for the central letter. The latter is in line with the possibility of enhanced crowding in dyslexia which is often reported in the literature. This enhanced crowding was put in relation with the word reading scores of the students. In the dyslexia group but not in the control group the degree of crowding correlated significantly with the students' word reading scores. These findings suggest that lateral inhibition and not attention allocation between letters is associated with word reading performance in students with dyslexia.

References

Ahissar, M. (2007). Dyslexia and the anchoring-deficit hypothesis. *Trends in Cognitive Sciences, 11*(11), 458-465. doi: 10.1016/j.tics.2007.08.015

Bishop, D. V. M. (2006). Dyslexia: what's the problem? *Developmental Science, 9*(3), 256-257. doi: 10.1111/j.1467-7687.2006.00484.x

Blomert, L., & Willems, G. (2010). Is There a Causal Link from a Phonological Awareness Deficit to Reading Failure in Children at Familial Risk for Dyslexia? *Dyslexia, 16*(4), 300-317. doi: 10.1002/dys.405

Broeninck, N., & Gorter, K. (2001). *Studeren met een handicap. Belemmeringen die studenten met een lichamelijke beperking, psychische klachten of dyslexie in het hoger onderwijs ondervinden*. Verwey-Jonker Instituut.

Brus, B., & Voeten, M. (1991). *Een-minuut-test vorm A en B, schoolvorderingstest voor de technische leesvaardigheid bestemd voor groep 4 tot en met 8 van het basisonderwijs. Verantwoording en handleiding*. Lisse, The Nederlands: Swets & Zeitlinger.

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive profile of students who enter higher education with an indication of dyslexia. *PLos One, 7*(6). doi: 10.1371/journal.pone.0038081

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition, 91*(1), 77-111. doi: 10.1016/S0010-0277(03)00164-1

De Pessemier, P., & Andries, C. (2009). *GL&SCHR Dyslexie bij +16-jarigen. Test voor Gevorderd Lezen en Schrijven*. Antwerpen, Belgium: Garant.

de Vos, T. (1992). *Tempo Test Rekenen*. Amsterdam: Pearson Education.

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Nunes, G., Jobert, A., . . . Cohen, L. (2010). How Learning to Read Changes the Cortical Networks for Vision and Language. *Science, 330*(6009), 1359-1364. doi: 10.1126/science.1194140

Dekker, R., Dekker, P. H., & Mulder, J. L. (2004). *Kaufman Adolescent and Adult Intelligence Test - Nederlandstalige versie: Handleiding*. Leiden, The Nederlands: PITS.

Dekker, R., Dekker, P. H., & Mulder, J. L. (2007). *De ontwikkeling van vijf nieuwe Nederlandstalige tests*. Leiden: PITS.

Elbro, C., Nielsen, I., & Petersen, D. K. (1994). Dyslexia in Adults - Evidence for Deficits in Non-Word Reading and in the Phonological Representation of Lexical Items. *Annals of Dyslexia, 44*, 205-226.

Ghesquière, P. (1998). *Algemene toets gevorderde spelling van het Nederlands (AT-GSN): verantwoording en handleiding. Rapport van een specialisatiejaar: onderzoek At-GSN-dictee.*: Unpublished bachelor thesis, University Leuven, Leuven, Belgium.

Ghesquiere, P., Boets, B., Gadeyne, E., & Vandewalle, E. (2012). Dyslexie: Een beknopt wetenschappelijk overzicht. In A. Geudens, D. Baeyens, K. Schraeyen, K. Maetens, J. De Brauwer & M. Loncke (Eds.), *Jongvolwassenen met dyslexie.Diagnostiek en begeleiding in wetenschap en praktijk.* (pp. 41-54). Leuven/ Den Haag: Acco.

Gilroy, D. E., & Miles, R. (2001). *Dyslexia at College (2nd ed.), London: Routlegde*.

Goswami, U. (2008). Reading, dyslexia and the brain. [Article]. *Educational Research, 50*(2), 135-148. doi: 10.1090/00131880802082625

Hadjikakou, K., & Hartas, D. (2008). Higher education provision for students with disabilities in Cyprus. *Higher Education, 55*(1), 103-119. doi: 10.1007/s10734-007-9070-8

Harrison, A. G., & Nichols, E. (2005). A validation of the Dyslexia Adult Screening Test (DAST) in a post-secondary population. *Journal of Research in reading, 28*(4), 423-434. doi: 10.1111/j.1467-9817.2005.00280.x

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology, 72*, 119-133. doi: 10.1348/000709902158801

Heim, S., Tschierse, J., Amunts, K., Wilms, M., Vossel, S., Willmes, K., . . . Huber, W. (2008). Cognitive subtypes of dyslexia. *Acta Neurobiologiae Experimentalis, 68*(1), 73-82.

Henneman, K., Kleijnen, R., & Smits, A. (2004). *Protocol Dyslexie Voortgezet Onderwijs: Deel 2- Signalering, diagnose en begeleiding.* : KPC Groep, Expertisecentrum Nederlands, Werkverband Opleidingen Speciaal Onderwijs.

Hoekstra, H. A., Ormel, J., & de Fruyt, F. (2007). *NEO-PI-R/NEO-FFI: Handleiding*. Amsterdam, The Netherlands: Hogrefe Uitgevers.

Hofmeester, N. (2002). *Studeren met dyslexie.* Apeldoorn, Nederland: Maklu Uitgevers nv.

Jimenez, J. E., Guzman, R., Rodriguez, C., & Artiles, C. (2009). Prevalence of specific learning disabilities: The case of dyslexia in Spain. *Anales De Psicologia, 25*(1), 78-85.

Kleijnen, R., & Loerts, M. (2006). *Protocol Dyslexie Hoger Onderwijs*. Antwerpen/Apeldoorn: Garant.

Lacante, M., & Lens, W. (2005). *Nederlandse bewerking van de Weinstein-Palmer LASSI-scales [Dutch adaptation of the Weinstein-Palmer LASSI-scales]*. Unpublished research paper. University of Leuven, Department of Psychology. Leuven, Belgium.

Lefly, D., & Pennington, B. (1991). Spelling errors and reading fluency in compensated adult dyslexics. *Annals of Dyslexia, 41*(1), 141-162. doi: 10.1007/bf02648083

Legge, G. E., Mansfield, J. S., & Chung, S. T. L. (2001). Psychophysics of reading XX. Linking letter recognition to reading speed in central and peripheral vision. *Vision Research, 41*(6), 725-743. doi: 10.1016/s0042-6989(00)00295-9

Lewis, C., Hitch, G. J., & Walker, P. (1994). The Prevalence of Specific Arithmetic Difficulties and Specific Reading Difficulties in 9-Year-Old to 10-Year-Old Boys and Girls. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 35*(2), 283-292. doi: 10.1111/j.1469-7610.1994.tb01162.x

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia, 53*, 1-14. doi: 10.1007/s11881-003-0001-9

Madriaga, M., Hanson, K., Heaton, C., Kay, H., Newitt, S., & Walker, A. (2010). Confronting similar challenges? Disabled and non-disabled students' learning and assessment experiences. *Studies in Higher Education, 35*(6), 647-658. doi: 10.1080/03075070903222633

Menghini, D., Finzi, A., Benassi, M., Bolzani, R., Facoetti, A., Giovagnoli, S., . . . Vicari, S. (2010). Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia, 48*(4), 863-872. doi: 10.1016/j.neuropsychologia.2009.11.003

Nicolson, R. I., Fawcett, A. J., Berry, E. L., Jenkins, I. H., Dean, P., & Brooks, D. J. (1999). Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults. *Lancet, 353*(9165), 1662-1667. doi: 10.1016/s0140-6736(98)09165-x

Parrila, R., Georgiou, G., & Corkett, J. (2007). University students with a significant history of reading difficulties: What is and is not compensated? *Exceptionality Education Canada, 17*, 195-220.

Patrikakou, E. N. (1996). Investigating the academic achievement of adolescents with learning disabilities: A structural modeling approach. *Journal of Educational Psychology, 88*(3), 435-450. doi: 10.1037//0022-0663.88.3.435

Pennington, B. F., Vanorden, G. C., Smith, S. D., Green, P. A., & Haith, M. M. (1990). Phonological processing skills and deficits in adult dyslexics. *Child Development, 61*(6), 1753-1778. doi: 10.1111/j.1467-8624.1990.tb03564.x

Plume, E., & Warnke, A. (2007). Definition, symptoms, prevalence and diagnosis of dyslexia. *Monatsschrift Kinderheilkunde, 155*(4), 322-+. doi: 10.1007/s00112-007-1480-2

Reid, A. A., Szczerbinski, M., Iskierka-Kasperek, E., & Hansen, P. (2007). Cognitive profiles of adult developmental dyslexics: Theoretical implications. *Dyslexia, 13*(1), 1-24. doi: 10.1002/Dys.321

Singleton, C. H. (1999). *Dyslexie in Higher Education: Policy, provision and practice (Report of the National Working Party on Dyslexia in Higher Education).* Hull: University of Hull, on behalf of the Higher Education Funding of England.

Snowling, M. (2000). *Dyslexia. Second Edition.* Oxford: Blackwell Publishers.

Stanovich, K. E. (1988). Explaining the difference between the dyslexic and garden-variety poor readers: The phonological-core variable difference model. *J Learn Disabil, 21*(10), 590-&.

Stein, J., & Walsh, V. (1997). To see but not to read; The magnocellular theory of dyslexia. [Article]. *Trends in Neurosciences, 20*(4), 147-152. doi: 10.1016/s0166-2236(96)01005-3

Sullivan, B. K., May, K., & Galbally, L. (2007). Symptom exaggeration by college adults in attention-deficit hyperactivity disorder and learning disorder assessments. *Applied Neuropsychology, 14*(3), 189-207. doi: 10.1080/09084280701509083.

Swanson, H. L., & Hsieh, C. J. (2009). Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. *Review of Educational Research, 79*(4), 1362-1390. doi: 10.3102/0034654309350931

Szenkovits, G., & Ramus, F. (2005). Exploring dyslexics' phonological deficit I: Lexical vs sub-lexical and input vs output processes. *Dyslexia, 11*(4), 253-268. doi: 10.1002/dys.308

Szmalec, A., Loncke, M., Page, M. P. A., & Duyck, W. (2011). Order or Disorder? Impaired Hebb Learning in Dyslexia. *Journal of Experimental Psychology-Learning Memory and Cognition, 37*(5), 1270-1279. doi: 10.1037/a0023820

Tops, W., Callens, M., Lammertyn, J., & Brysbaert, M. (2012). Identifying students with dyslexia in higher education. *Annals of Dyslexia, 62*(3), 186-203. doi: 10.1007/s11881-012-0072-6

van den Bos, A., Spelberg, H., Scheepsma, A., & de Vries, J. (1999). *De Klepel vorm A en B: een test voor leesvaardigheid van pseudowoorden. Verantwoording, handleiding, diagnostiek en behandeling*. Lisse, The Nederlands: Swets & Zeitlinger.

Van der Leij, A., Bekebrede, J., Geudens, A., Schraeyen, K., G.M., S., Garst, H., . . . Schijf, T. J. (2012). *Interactieve Dyslexietest Amsterdam-Antwerpen: Handleiding.* Uithoorn.

Vaughn, S., & Fuchs, L. S. (2003). Redefining learning disabilities as inadequate response to instruction: The promise and potential problems. *Learning Disabilities Research & Practice, 18*, 137-146.

Vogel, S. A., Leonard, F., Scales, W., Hayeslip, P., Hermansen, J., & Donnells, L. (1998). The national learning disabilities postsecondary data bank: An overview. *J Learn Disabil, 31*(3), 234-247.

Vogel, S. A., Vogel, G., Sharoni, V., & Dahan, O. (2003). *Adults with learning disabilities in higher education and beyond: An international perspective*. Baltimore: MD: York Press.

Whitney, C., & Cornelissen, P. (2005). Letter-position encoding and dyslexia. *Journal of Research in reading, 28*(3), 274-301.

Wilkinson, G. S. (1993). *Wide Range Achievement test*. Lutz, Florida: PAR.

Wolff, U. (2009). Phonological and Surface Subtypes among University Students with Dyslexia. *International Journal of Disability Development and Education, 56*(1), 73-91. doi: 10.1080/10349120802682083

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*(1), 3-29. doi: 10.1037/0033-2909.131.1.3

Cognitive profile of students who enter higher education with an indication of dyslexia

Chapter 2

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For languages other than English there is a lack of empirical evidence about the cognitive profile of students entering higher education with a diagnosis of dyslexia. To obtain such evidence, we compared a group of 100 Dutch-speaking students diagnosed with dyslexia with a control group of 100 students without learning disabilities. Our study showed selective deficits in reading and writing (effect sizes for accuracy between d = 1 and d = 2), arithmetic (d ≈ 1), and phonological processing (d > 0.7). These deficits were larger for speed related measures than for accuracy related measures. Students with dyslexia also performed slightly inferior on the KAIT tests of crystallized intelligence, due to the retrieval of verbal information from long-term memory. No significant differences were observed in the KAIT tests of fluid intelligence. The profile we obtained agrees with a recent meta-analysis of English findings suggesting that it generalizes to all alphabetic languages. Implications for special arrangements for students with dyslexia in higher education are outlined.

Introduction

An increasing number of students with dyslexia enter higher education, most likely due to better assessment, guidance and remediation in primary and secondary education [1] [2]. This creates a need for information about the characteristics of these students and the best ways to support them. Higher education differs significantly from primary and secondary school. At this age education is no longer compulsory and students have a much wider range of options (certainly compared to primary education, which in most countries is inclusive, with nearly all children given the same curriculum). Therefore, dyslexic students entering higher education can be expected to be a select group, with better than average coping skills and possibly less comorbidity (for the issue of comorbidity in dyslexia, see [3] [4] [5])

Still, there is a need for scientific evidence about the cognitive profile of students with dyslexia in higher education, particularly for non-English speaking countries. There are a number of manuals about adult dyslexia and dyslexia in higher education (e.g. [6] [7] [8]), which contain valuable information for students with dyslexia and their counselors and tutors, but they mainly base their information and recommendations on clinical and educational practice and they focus on the state of affairs in English-speaking countries.

Because of the scarcity of scientific data, at present there are no generally-accepted guidelines, regulations, and standards for compensatory measures. Instead, the clinical experience of the local office of disability services and their considerations tend to prevail [9]. As a result, the special arrangements differ between institutes and are not appreciated by all lecturers. In the absence of theoretical and empirical evidence for the efficacy of such measures lecturers fear that reading disabled students could be beneficiaries of needless exceptions, which create extra work and may be unfair to the other students. Exceptionally, some even doubt whether students with a diagnosis of dyslexia belong in higher education, questioning their cognitive skills and work attitude. Given the current situation, these reactions are not completely without grounds. Sparks and Lovett [9] [10], for instance, found that offices of disability services in American colleges often give learning disability certificates without empirical justification, and that these certificates tend to be popular when they are linked to course exemptions in colleges with foreign-language requirements.

In the present paper we first discuss what is known about the cognitive profile of students with dyslexia in American and British higher education. Then, we discuss the reasons why generalization to other countries is not straightforward, and we present the data of a new study addressing the limitation.

The cognitive profile of students with dyslexia in higher education: Evidence from English

A first series of studies in the 1990s [11] [12] [13] addressed the question whether individuals with dyslexia continued to have problems with reading and spelling in adulthood, or whether remediation, teaching and reading practice in primary and secondary education were able to bridge the initial gap. They had a strong focus on reading and spelling and did not take into account other functions such as memory, attention, planning, and organization. These studies all came to the conclusion that dyslexia is an enduring problem with remaining suboptimal performance for reading and writing in dyslexic university students.

A particularly interesting study was published in the UK by Hatcher, Snowling, and Griffiths [14], because it investigated a broader range of skills. The authors compared the cognitive skills of 23 university students with dyslexia and 50 controls matched on verbal and non-verbal abilities. Participants completed 17 tasks assessing literacy (reading and writing), processing skills (perceptual speed, memory span, and arithmetic), phonological skills (spoonerisms and rapid naming), verbal fluency, verbal abilities (vocabulary test), non-verbal abilities (Raven matrices), and self-reported problems in attention and organization. Surprisingly, the students with dyslexia performed worse on all but the two tasks of general cognitive abilities (Wechsler Adult Intelligence Scale Vocabulary and Raven Matrices). They showed significant deficits in reading and writing and in reading-related phonological processes. Additionally, their processing rate was overall slower and their short-term memory spans were shorter. The students with dyslexia also had poorer arithmetic performance. Dyslexic students further reported more problems with memory ("I easily forget about what has been said"), attention ("I lose track in required reading"), effort ("I do not work to my potential"), affect ("I am sensitive to criticism"), and – less so – organizing and activating ("I have difficulty getting organized and started"). Based on these results, Hatcher et al. [14] doubted about the generality of the statement that higher education students with dyslexia have compensated for their problems.

Surprisingly, Hatcher et al.'s [14] rather pessimistic conclusion was not followed by other studies of the same standards. Subsequent studies again involved small numbers of tasks and small numbers of participants, making it difficult to obtain reliable estimates of the overall cognitive profile of dyslexic students in higher education [15] [16]. A further step forward was made when Swanson and Hsieh [17] published the results of a meta-analysis. By applying such an analysis, researchers can distill a coherent pattern out of a multitude of heterogeneous, small-scale studies. Swanson and Hsieh's meta-analysis was based on 52 published articles (but surprisingly without Hatcher et al. [14] and 776 comparisons of participants with reading disabilities versus participants without reading disabilities. An additional advantage of meta-analyses is that the results are communicated as effect-sizes. Swanson and Hsieh used Cohen's d statistic. This is a standardized measure with very much the same interpretation as a z-score [18]. As a rule of thumb, d-values larger than .5 have practical value and d-values larger than .8 point to a substantial difference between the groups. These effect sizes make it easy to translate research findings to the counseling practice. In contrast, individual studies have a tendency to focus on the statistical significance of their effects, often overlooking issues of power and practical importance.

Table 1 summarizes the findings reported in the meta-analysis of Swanson and Hsieh [17] as effect sizes (d) of differences between participants with reading disabilities and participants without reading disabilities. Positive values indicate poorer performance of participants with dyslexia; negative values indicate better performance of this group. For comparison purposes, we also include the data of Hatcher et al. [14] expressed as effect sizes. The convergences between both studies are clear. The top problems of adults with dyslexia are, not surprisingly: writing, reading, and phonological processing (non-word naming and spoonerisms, which involve exchanging the first sounds of two words, e.g., turning "Terry Wogan" into "Werry Togan"). The effect sizes are mostly larger than 1. In addition, reading disabled adults seem to be poorer in retrieving verbal information from long-term memory, either because this information has been processed less frequently or because of an additional weakness in individuals with dyslexia. One of the most robust findings in cognitive psychology is the (word) frequency effect, the finding that the efficiency of information processing depends on the number of times the information has been processed before (e.g. [19]). There was also poorer performance on arithmetic. This finding has recently been confirmed [20] [21] and linked to the fact that arithmetic operations often depend on verbal fact retrieval, in particular for multiplication. This would explain why the difference between individuals with dyslexia and controls is larger for multiplication than for subtraction [20].

On the positive side, there were no differences of practical significance for general intelligence, problem solving / reasoning, cognitive monitoring, perceptuo-motor skills, auditory and visual perception, social and personal skills, personality, and neuropsychological measures (such as EEG patterns). Dyslexics slightly outperformed controls in visuo-spatial memory and tended to be rated more favorably by third persons than controls.

All in all, Swanson and Hsieh's [17] analysis paints a rather clear picture of the strengths and weaknesses of adults with dyslexia. Still, two caveats should be kept in mind. The first is that meta-analyses involve a combination of very heterogeneous studies, with varying degrees of methodological rigor. This is particularly a concern when the number of studies on which an effect size has been calculated is rather small. Then, the presence or absence of an effect could be due to a single unrepresentative study involving a less valid test or a less representative participant sample. This issue is known as the apples-and-oranges problem in meta-analyses [22]. Although the convergence between Swanson and Hsieh [17] and Hatcher et al. [14] is reassuring in this respect, one would feel more confident if the picture were confirmed in an independent series of studies given to the same groups of participants. The second caveat with respect to Swanson and Hsieh's [17] conclusions is that they are almost entirely based on English-speaking adults. Only 5% of the data were from non-English studies. Below we discuss two reasons why generalization to other languages/ countries is not straightforward.

Factors that may prevent generalization to other languages

A first factor that may hinder the generalization of English findings to other languages, such as Dutch, is that languages differ in the difficulty of the letter-sound mappings. This feature has been linked to the time children need for reading acquisition [23] [24] [25] and also to the prevalence of dyslexia ([26]; see also [27] and [28] for a discussion of the ways in which English differs from other languages and what impact this may have for dyslexia). Readers of languages with inconsistent mappings need more time to reach ceiling performance and also have higher chances of not succeeding. There are two types of mapping: from letters to sounds and from sounds to letters (particularly important for correct spelling but also involved in word reading; [29]). Alphabetical languages differ in the degree of complexity of these mappings [30] [31] with English consistently being the most opaque for both directions, and Dutch more towards the transparent end of the continuum (the extent depending on the specific measure used).

In the absence of empirical evidence, it is not clear what to expect as a result of the language differences in letter-sound mappings. On the one hand, one could imagine that dyslexia would be less of a problem in a transparent language; on the other hand, someone with dyslexia in a transparent language may on average have a stronger deficit than someone with dyslexia in an opaque language (if indeed differences in prevalence of dyslexia because of language transparency exist).

Another factor that may limit the findings of Table 1 to English-speaking countries is the organization of the education system in different countries. In general, British-inspired education is characterized by ability-based selection at the entry together with a commitment to bring the selected candidates to a successful completion (the master-apprentice model). In many other countries, however, there are no hard entrance criteria for higher education, and selection occurs as part of the curriculum. In Belgium, for instance, everyone who has completed secondary education, is entitled to start whatever type of higher education they want (except for medicine and dentistry, where an additional entrance exam must be passed). As a result, the number of students starting higher education tends to be higher and completion rates are lower. In particular, the first year is considered as a selection year with less than half of the student succeeding. Classes in the first year, therefore, tend to be plenary lectures before large groups, and exams often are multiple choice.

Needless to say, ability-based admission criteria are likely to have implications for the cognitive profiles of the students, certainly in the first year of education. For instance, the observation that Swanson and Hsieh [17] and Hatcher et al. [14] found no differences in general intelligence or problem solving between students with and without reading problems may be a consequence of the fact that British and American universities select their students on the basis of SAT-scores (US) and A-levels (UK). Indeed, Lovett and Sparks [32] noticed that a discrepancy between general intelligence and reading skills in American university students with reading disabilities is often due to average text reading skills combined with above-average IQ. Such a pattern might be a direct consequence of the admission criteria. As these criteria are not present in Belgium, students with quite different IQ-scores can start the same degree and there is no built-in guarantee that students who present themselves with a diagnosis of dyslexia have the same abilities as students without such an assessment. On the other hand, because students with a reading disability know of the selection taking place in the first year of higher education, they may be less inclined to start a degree that is perceived as demanding, given the chances of failure.

The cognitive profile of students with dyslexia in higher education: Evidence from non-English speaking countries

As stated before, literature on dyslexia in young adults who do not have English as mother tongue, is limited. In addition, in line with the first studies in English, they all focused on weaknesses rather than on the full pattern of strengths and weaknesses. Reid, Szczerbinski, Iskierka-Kasperek, and Hansen [33] ran a study in Polish on 15 dyslexic university students and 15 control students. As primary deficits they reported inferior word reading rate, pseudoword reading rate and text reading (both speed and accuracy). Spelling accuracy was also significantly lower. In relation to the underlying causes of dyslexia the authors observed impaired rapid automatized naming (pictures, colors, letters and digits) and phonological difficulties on a timed sound deletion task. However, group differences on spoonerism accuracy/ time and sound deletion accuracy only approached significance. Similar results were found in a French study by Szenkovits and Ramus [34]. Students with dyslexia (N=17) performed worse than a control group on a text reading task when a combined time and accuracy measure was reported (but see Bruyer and Brysbaert [35] for difficulties with such combined measures). Orthographic skills were also significantly lower. Moreover, a combined RAN (colors, digits and letters) score revealed impaired automatized naming and working memory. Students with dyslexia also displayed phonological deficits. Wolff [36] examined Swedish university students (N=40) on a range of reading, writing and phonological skills tasks. Significant differences with large effect sizes were reported for several tasks: spoonerisms, non-word reading and writing (time and accuracy), exception word spelling, and orthographic skills (time and accuracy).

The above studies agree with the English studies showing that difficulties in reading and writing and phonological impairments persist into adulthood. However, none addressed abilities beyond reading and writing. Furthermore, they were all characterized by small sample sizes, making it dangerous to interpret the effect sizes.

A new study

Given the limitations of the available evidence, we decided to run a new study, which would enable us to compare the American-British profile (Table 1) to the Belgian profile. In order to do things properly, we took into account the following methodological considerations.

A problem with small-scale studies for applied research is the large confidence intervals around the obtained statistics, certainly in between-groups designs involving the comparison of two samples of individuals. Only recently have researchers become sensitive to the power problem related to small-group comparisons (e.g [37] [38]). The smaller the samples, the larger the difference between the groups at population level must be before it can be found reliably in an empirical study. As a rule of thumb, to assess effect sizes as small as d = .4, one requires two groups of 100 participants (Figure 1). Samples of this size also result in reasonably small confidence intervals, so that the observed effect sizes can be trusted and compared to those from the English studies (Table 1).

To further improve the relevance of our study for offices of disability studies, we ran the study on the first 100 students who were entitled to special educational support on the basis of dyslexia by a learning disability support office in the city of Ghent (Belgium) and who were willing to take part in our study. For each student we then looked for a control student matched on age, gender, and field of study. The local support office serves Ghent University as well as other colleges of higher education (including technical colleges), meaning that we could examine a wide range of students.

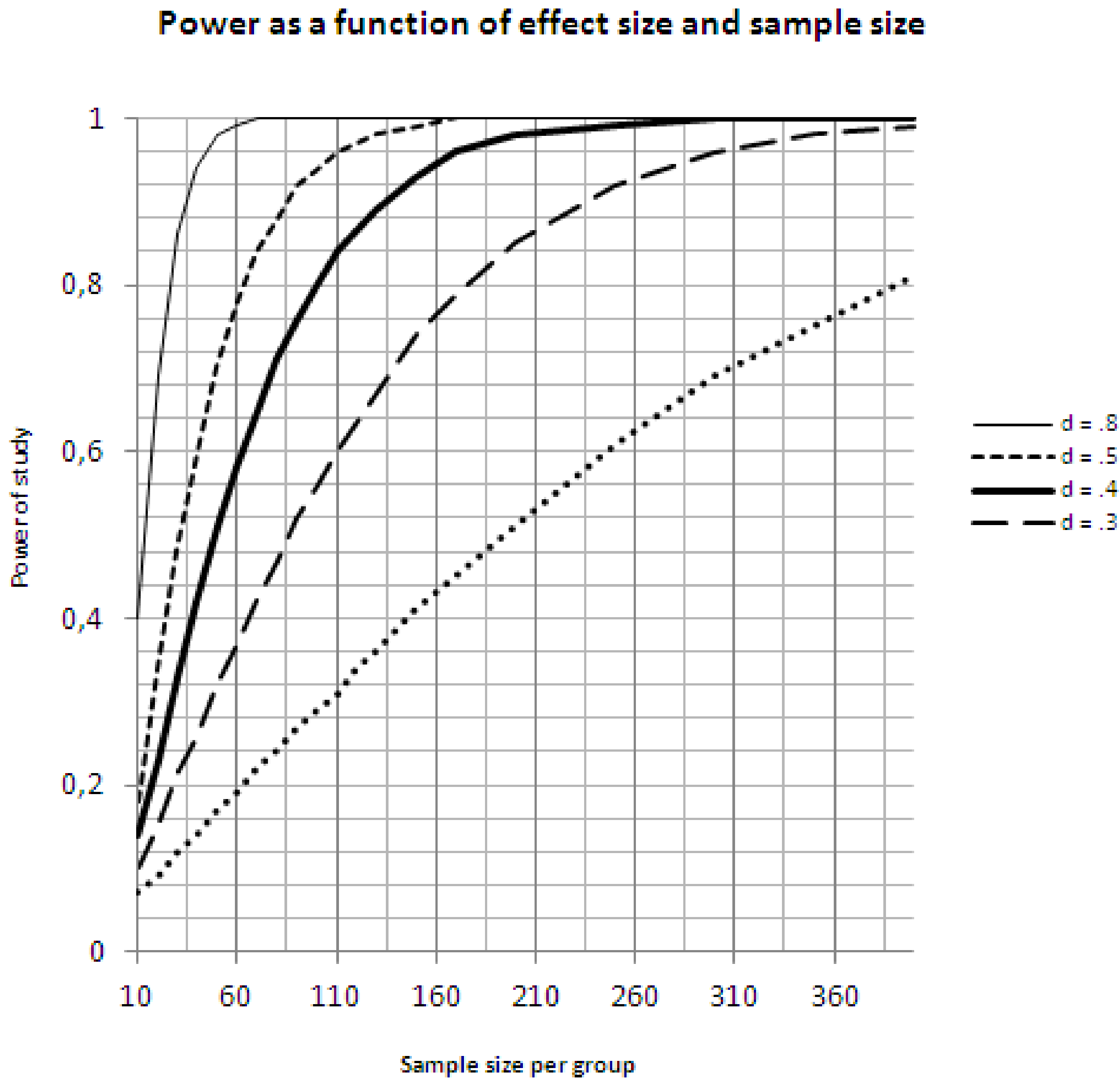

Figure 1. This figure shows the power of a study with two independent groups as a function of sample size for different levels of effect size (assuming that alpha, 2-tailed, is set at .05). For a small effect size (d = .2) we would need two samples of 393 participants to yield a power of 80%. This means that there is 80 % chance of finding a significant difference between the groups, given that an effect of this size exists at the population level. For a medium effect size (d = .5) we would need two samples of 64 participants to achieve this level of power. For a large effect size (d = .8) we need 26 participants per group.

Table 1
Effect sizes (d) of differences between participants with reading disabilities and participants without reading disabilities.

	S&H09	HSG02
Literacy		
Reading comprehension	1.20	-
Word reading	1.37	1.14
Non-Word Reading	1.33	1.47
Word Spelling	1.57	1.31
Text Writing	0.72	1.12
Processing skills		
Perceptual speed	-	0.89
Short-term memory span	-	1.05
Phonological skills		
Phonological processing	0.87	1.32
Rapid naming	0.96	1.19
Verbal fluency		
Semantic fluency	-	0.46
Rhyme fluency	-	1.26
General intelligence		
Arithmetic	0.75	0.58
Verbal memory	0.20	-
Verbal intelligence	0.63	-
Vocabulary	0.71	0.10
General information	0.47	-
Problem solving / reasoning	0.11	-0.01
Verbal memory	0.62	-
Visuospatial memory	-0.39	-
Cognitive monitoring	0.27	-
Perceptual motor skills	-0.13	-
Auditory perception	-0.18	-
Visual perception	0.13	-
Other		
Social and personal skills	0.10	-
Personality	0.28	-
Neuropsychological (e.g., EEG)	-0.02	-
Ratings by third persons	-0.23	-

Note: S&H09 = Swanson & Hsieh [17]; HSG02 = Hatcher, Snowling & Griffiths [14].

Method

Participants

Two hundred first-year undergraduate students of higher education participated in the study, both students of professional bachelors (in colleges for higher education) and academic bachelors (in some colleges for higher education and in university). They all attended higher education in Ghent, one of the major cities of Flanders (the Northern, Dutch-speaking half of Belgium) and had just graduated from secondary school. The group consisted of 100 students diagnosed with dyslexia and a control group of 100 students with no known neurological or functional deficiencies. All had normal or corrected-to normal vision and were native speakers of Dutch. Students were paid for their participation. The study followed the ethical protocol of Ghent University, meaning that students gave informed consent and were informed that they could stop at any time if they felt they were treated incorrectly.

The students with dyslexia had a diagnosis prior to our study in accordance with the definition of SDN (Stichting Dyslexie Nederland [Foundation Dyslexia Netherlands] [39]). Because of the ongoing debate about the origin of dyslexia, the SDN uses a purely descriptive definition of dyslexia. In their guidelines dyslexia is defined as an impairment characterized by a persistent problem in learning to read and/or write words or in the automatization of reading and writing. The level of reading and/or writing has to be significantly lower than what can be expected based on the educational level and age of the individual. Finally, the resistance to instruction has to be confirmed by looking at the outcome of remedial teaching. Remedial teaching is considered adequate when it meets the requirements as stated in the "response to instruction" model [40] or the "response to intervention' model [41]. Also, the SDN definition requires ensuring that the reading and writing impairment cannot be attributed to external and/or individual factors such as socio-economic status, cultural background or intelligence. Students entering higher education in Ghent are assessed anew by the local support office (*vzw Cursief*) if their previous assessment does not meet the criteria. All students with dyslexia had (sub) clinical scores (< pc 10) on a word reading test [42] and/or, pseudo word reading test [43] and/or word spelling test [44]. These tests are addressed further in the text. All -but two- students with dyslexia had received individual tutoring in primary or secondary education for a period of minimum 6 months by either a speech-therapist or a remedial teacher.

All students with dyslexia who applied for special facilities at the local support office in the academic year 2009-2010 were asked to participate in the study until we had a total of one hundred. To find a group of 100 participants with dyslexia who completed the full study, we had to approach an initial cohort of some 120 students. Of these 120 students a small number of students chose not to cooperate once the study was explained to them. A few more students were lost because they failed to show up at appointments.

When recruiting the subjects we tried to reflect the inflow in the first year of higher education as much as possible. Matching criteria for the control students were therefore restricted to field of study, gender and age. Because one of the goals of our project is to see how dyslexic students succeed in higher education compared to their peers and to assess the impact of their disability on their study skills we matched them on field of study. We did add age and gender as matching criteria to construct homogenous groups. To recruit the control students we used different methods. We asked the students with dyslexia for several names of fellow classmates who would be interested in participating. Amongst these names we selected someone at random. In case the dyslexic student failed to deliver any names (which was the case for about 50% of the participants), we recruited them ourselves by means of electronic platforms or the guidance counselors of the institution in question. Table 2 contains the general information on the two groups: mean age, gender, professional bachelor v. academic bachelor students, fields of study and the educational level of the parents.

The socio-economical level of the parents was not a matching criteria but no difference was found between the two groups in socio-economical level based on the educational level of the mother [χ^2 (3) = 4.855, p = .183] and father [χ^2 (3) =2.634 , p =.452]. Educational levels were: lower secondary education, higher secondary education, post secondary education either at university or a college for higher education.

Table 2
General information on the control group and the group with dyslexia.

	Control group		Dyslexia group	
Mean age	19 years and 11 months		19 years and 4 months	
Gender	41 male students		41 male students	
	59 female students		59 male students	
Degree taken	66 non university college students		66 non university students	
	34 university students		34 university students	
Field of study				
	Non university students	University college students	Non university students	University college students
Educational sciences	16	0	16	0
Health and behavioral sciences	21	19	21	19
Management	9	0	9	0
Sciences and Engineering	19	10	19	10
Arts and humanities	0	5	0	5
Other	1	0	1	0
Educational level father				
Lower secondary	4		7	
Higher secondary	44		36	
College	28		31	
University	16		22	
Missing	8		4	
Total	100		100	
Educational level mother				
Lower secondary	4		4	
Higher secondary	36		35	
College	45		41	
University	7		18	
Missing	8		2	
Total	100		100	

Cognitive measures and tests administered

In the following section, we group the tests as a function of cognitive skill. Although this is not 100% how the assessment happened (which was battery-based), it makes it easier to compare our data to those of Swanson and Hsieh [17] and Hatcher and colleagues [14]. Most cognitive skills were assessed with validated and widely used Dutch-language screening instruments. We used the Dutch version of the Kaufman Adolescent and Adult Intelligence Test [45] and an established test battery for diagnosing dyslexia in young adults [44]. We tried to obtain converging evidence from a second test designed to measure the same skill when no data about reliability and validity were available. In particular, we compared the data to the IDAA or *Interactive Dyslexia Test Amsterdam-Antwerp*, a test battery that at the time of our testing was being normed and validated [46].

The American KAIT, developed in 1993 by A.S. Kaufman and N.L. Kaufman, was translated by Dekker, Dekker, and Mulder in 2004 and norms were collected on a standardization sample in the Netherlands and Flanders. The main goal of the KAIT is to evaluate analytic intelligence in individuals from 14 to 85 years. In our study the complete version was administered. It consists of 10 subtests categorized into two types of intelligence: fluid and crystallized intelligence. The crystallized scale consists of 4 subtests: Word Definitions, Double Meanings, Auditory Comprehension, and Famous People (for more information see below). It reflects how well a person has learned concepts and knowledge that are part of one's cultural and scholar context. It is influenced by verbal conceptual development and education. The fluid intelligence scale gives an indication of the person's potential and flexibility to solve new problems, either verbal or non-verbal. The 6 subtests are Symbol Learning, Logical Reasoning, Secret Codes, Block Patterns, Delayed Auditory Memory, and Delayed Symbol Learning (for more information see below). The combination of fluid and crystallized IQ results in a total IQ-score. All three scores have a mean of 100 and a standard deviation of 15 points. Psychometric information can be found in Table 3.

We used the KAIT instead of the Wechsler Adult Intelligence Scale III [47] to avoid retest effects. Many students with dyslexia had been tested previously with the WISC or the WAIS as part of their assessment. Other reasons for choosing the KAIT were the less rigorous time constraints, which we considered an advantage for students with learning disabilities, and the inclusion of two subtests of delayed memory, namely Delayed Symbol Learning and Delayed Auditory Memory. Both subtests are considered valid measures of long term memory capacities.

Table 3
Reliability and validity indices for the different subtests of the KAIT [45].

	Internal consistency Chronbach's alpha for age groups 16-19	Test-retest reliability for age group 14-24	Content validity: correlation with WAIS –R Total IQ scores
CIQ	.92	.80	.79
Definitions	.82	.81	-
Double Meanings	.81	.72	-
Auditory Comprehension	.81	.71	-
Famous People	.76	.87	-
FIQ	.93	.84	.76
Symbol Learning	.93	.85	-
Logical Reasoning	.81	.66	-
Secret Codes	.80	.61	-
Block Patterns	.80	.82	-
Delayed Auditory Comprehension	.55	.49	-
Delayed Symbol Learning	.93	.81	-
TIQ	.95	.89	.84

We also administered the GL&SCHR, a Dutch reading and writing test battery for (young) adults [44]. This test includes many of the tasks frequently administered in dyslexia assessment (e.g.[14]). There are three tests specifically designed to evaluate reading and writing skills, namely Word Spelling, Proofreading, and Text Reading (for more information see below). Seven additional tests focus on associated language deficits such as phonological processing, rapid naming, short term memory and working memory, morphology, and vocabulary (for more information see below). Information about reliability can be found in Table 4. Different methods were used for different subtests, namely the KR20, the Guttman split-half, and a test-retest correlation.

Table 4
Reliability indices for the different subtests of the GL&SCHR

	KR20	Guttman split half (γ)	test-retest
Text Reading	-	.77 < r < .90	-
Word Spelling (Word Spelling and Proofreading)	-	.69 < r <.80	-
Reading Comprehension	-	.61	-
Morphology and Syntax	-	.65	-
Short Term Memory	-	.54 < r < .77	-
Vocabulary	.90	-	-
Phonological Awareness (Spoonerisms and Reversals)	-	-	.78 < r < .90
Rapid naming	-	-	.62 < r < .84

The IDAA or Interactive Dyslexia Test Amsterdam-Antwerp [46] is a new diagnostic instrument for the diagnosis of dyslexia in secondary school children and students in higher education. It is a test battery developed by The University of Amsterdam, Lessius College for Higher Education (Antwerp), and Muiswerk for the screening of young adults. It focuses on core skills of reading and writing such as automatized word recognition, decoding at lexical and sublexical level, and orthographic and phonological competence. The individual administration is fully computer controlled. The battery consists of six subtests. The first one is a questionnaire that assesses print exposure in Dutch and English. Next, phonological skills are evaluated with a reversal task where the participant has to state whether the second orally presented nonword is the reversal of the first (e.g. rol-lor). Then, four tests focus on orthographical skills: flash reading in Dutch, flash typing in Dutch, flash typing of nonwords in Dutch, and flash typing in English. In these tasks participants are presented with a word or nonword for 200 ms followed by a mask (###). Depending on the task the participant has to identify whether the target item was a word or nonword, or type in the word/nonword. As the names indicate, this is done both for Dutch and English. As this instrument is still in development and copyright protected, the results can only be used as validation criterion for other measures.

Finally, we also administered some standard tests for reading and calculation problems, used in the Dutch-speaking countries, such as word and nonword reading tests, and a standard arithmetic test. All in all, the following cognitive functions were assessed.

Literacy

Text comprehension. In this test from the GL&SCHR, a text is presented in printed form and at the same time read out by the computer. Afterwards, the participant has to answer questions about the text. These questions rely on either literal comprehension or deductive knowledge.

Word reading. A classic word reading test in the Dutch-speaking countries is the *EMT* [One Minute Test] [42]. Parallel-form reliability ranges from .89 to .97 in various studies, whereas test-retest reliability lies between .82 and .92. For more psychometric information about the EMT we refer to the test's manual. The list consists of 116 words of increasing difficulty printed in four columns. The participant has to read aloud as many words as possible in one minute trying to minimize reading errors. Raw scores are obtained for the total number of words read, the number of errors made, and the number of words read correctly.

English word reading. We also administered an English version of the EMT, namely the One Minute Test or OMT [48]. Validity and reliability data of the OMT have been collected by Kleijen, Steenbeek-Planting, and Verhoeven [49]. Test-retest reliability varies between 0.87 and 0.92. This test is in all aspects comparable to the Dutch EMT, except that English words are presented instead of Dutch ones.

Text reading. In this test from the GL&SCHR participants are asked to read aloud a Dutch text which becomes increasingly difficult. Substantial errors (e.g. addition/substitution/omission of letters, syllables and/or words) and time consuming errors (e.g. repeating a word/sentence, spelling a word aloud) are registered as well as the total reading time.

Silent text reading. The test that was used -"Hoe gevaarlijk is een Tekenbeet? [How Dangerous Can a Tick Be?] "- is part of a screening instrument published by Henneman, Kleijnen, and Smits [50]. It provides an indication of silent reading speed and the ability to retain information. There are no norms for Flanders. So, we made use of the raw scores. To obtain further information about the validity of the test, we looked at the correlation with the EMT word reading test in our sample. A Pearson correlation coefficient of .66 (N = 200) was found. The silent reading test works as follows. Participants are instructed to read a text of 1023 words in silence, taking into account that they will have to write a short summary afterwards. During reading participants have to indicate the word they just read when a signal is given after one, two, and three minutes. Afterwards, the average number of words read per minute is calculated. The written summary is evaluated based on measures of content, structure and syntax but the results of these analyses are beyond the scope of the present paper [50].

Nonword reading. The standard Dutch nonword reading test is *De Klepel* [43]. The parallel-forms correlation varies between .89 and .95. In various studies, the results of the Klepel correlate between .74 and .91 with those of the EMT. For more psychometric information about the Klepel we refer to the test's manual. The test contains 116 nonwords that follow the Dutch grapheme-phoneme correspondence rules. Administration and scoring are identical to the EMT.

Word spelling. Word spelling was measured with two tests of the GL&SCHR: *Word Spelling* and *Proofreading.* In the Word Spelling test participants write down 30 words dictated by means of an audio file with a 3 seconds interval. Afterwards they are given the opportunity to correct their answers. Half of the words follow the Dutch spelling rules; the other half are exception words (involving inconsistent sound-letter mappings that must be memorized). Participants are also asked to rate how certain they feel about each answer (certain, almost certain, uncertain). There is a score for the number of correct responses, one for the number of words written during dictation (speed of writing), and one total weighted score where the certainty per item is taken into account. When a correct answer is given and the participant is certain, the weighted item score is 5. When the word is spelled correctly but the participant is uncertain the score is only 2. The difference between the raw score and the weighted score can be considered as a measure of meta-cognitive knowledge [51] [52]. In the Proofreading test participants are given 20 sentences in which they have to correct possible spelling mistakes and rate their certainty per item. Two scores are given: one for the total number of correct responses and a weighted score (see Word Spelling).

English word spelling. Given the importance of English in higher education, we also included an English word dictation test. We used a standardized English test for word spelling: the *WRAT-III English Word Dictation* [53]. The internal consistency coefficients for the English age groups 17-18 and 19-24 are both .90. For more information on validity and reliability in English we refer to the manual. Because this test has not yet been validated for bilinguals with Dutch as mother tongue, we calculated the Pearson correlation with the English flash typing test of the IDAA ($r = 0.72$; $N = 200$). The test was administered according to the guidelines in the English manual. The examiner says a word, uses it in a significant context, and repeats the word. The participant writes it down. The test consists of 42 words.

Sentence dictation. Because higher education involves academic language, we also administered an advanced spelling test (AT-GSN [General Test for Advanced Spelling in Dutch]) , developed and used at the University of Leuven [54]. This test has been used in a number of scientific studies [55] [56]. Further information about the validity was obtained by correlating the scores with those of the Word Spelling test of the GL&SCHR (r=.79) and with the Dutch flash typing test of the IDAA (r=.70). The test consists of 12 paragraphs with exception words and challenging spelling rules (e.g. for the verbs). The correct use of capitals and punctuation marks is also taken into account. The score is the total number of errors made.

Morphology and syntax. In this subtest of the GL&SCHR 20 sentences are presented, in which the participant has to identify the syntactical or grammatical errors. The same principles as in the Proofreading test are applied. The total score gives the number of correct answers, whereas the weighted score takes into account the certainty of the participant about the answer given.

Processing skills

Speed of processing. To measure the participants' speed of processing, we used the CDT or Cijfer Doorstreep Test [Digit Crossing Test] [57]. This is a standardized Dutch test to detect attentional deficits and measure the speed and accuracy of processing in a task of selective attention involving task-switching. It is one of the 23 tests of the DVMH [Differential Aptitude Tests for Middle and Higher Level], a test battery published in 2003 by Dekker and De Zeeuw [58]. This test battery was developed according to Carroll's [59] Three Stratum Model in order to assess a large variety of cognitive skills such as verbal and numerical reasoning, attentional skills and language skills. The test – retest reliability scores vary between 0.79 and 0.95. The test can be administered from 14 years up to 80. There are 960 digits from 0 to 9 presented in 16 columns. Students have three minutes to underline as many fours and to cross out as many threes and sevens as possible. Scores for working pace (total numbers of items processed), concentration (total number of correct items), number of target errors, number of missed target digits and percentage of errors are obtained.

Phonological Skills

Phonological processing. Phonological awareness was tested with 2 subtests from the GL&SCHR: *Spoonerisms* and *Reversals*. In the *Spoonerisms* test the first letters of two orally presented words must be switched (e.g., Harry Potter becomes Parry Hotter). Accuracy and speed (measured with a stop-watch) are measured. In the *Reversals* test participants have to judge if two spoken words are reversals or not (e.g. rac-car). Again, accuracy and speed (measured with a stop-watch) are measured.

Rapid naming. In the RAN test of the GL&SCHR participants are asked to rapidly name letters, digits, colors, or objects presented one-by-one on a computer screen (4 tests). The participant determines the pace by pressing the Enter button. Accuracy and speed are measured.

General intelligence

Arithmetic. We used the *Tempo Test Rekenen* (*TTR;* [60]), a Dutch standardized test for mental calculations. It is designed to examine the rate at which participants mentally perform simple mathematical operations (single and double digits). There are five lists, consisting of additions, subtractions, multiplications, divisions below 100, and a random sequence of all four operations. Participants are given one minute per list to solve as many problems as possible. The score per subtest is the number of items minus the number of errors made.

General intelligence*.* The scores for crystallized IQ, fluid IQ and total IQ of the KAIT give us measures of general intelligence.

Vocabulary. We used three tests to evaluate this language function: *Vocabulary* from the GL&SCHR and *Definitions* and *Double Meanings* from the KAIT. In the *Vocabulary* test participants are asked to find the low frequency word for which a definition is given (e.g., the Dutch equivalents of anonymous or simultaneous). In the *Definitions* test the participant has to find a word based on a number of letters given and a short description of the word (e.g., “A dark color : .r..n”). In the *Double Meanings* test the participant has to find a word that is in some way connected to two word pairs (e.g., the connection between biology-body and jail-lock is the target word cell).

General information. To obtain information about the participants’ non-verbal long-term memory, we used the *Famous People* test of the KAIT. In this test pictures of famous people are shown and participants have to name the person (e.g., Ghandi).

Problem solving/reasoning. Three subtests for fluid intelligence of the KAIT [45] were used to evaluate this cognitive skill: *Symbol Learning*, *Logical Reasoning*, and *Secret codes*. In the Symbol Learning test, the participant has to remember and reproduce series of symbols in different sentence-like combinations. In the Logical Reasoning test, information is given about the relative location of a number of items (people or animals). By logical reasoning the participant has to infer the location of a target item. In the Secret Codes test three or four items are given a unique code consisting of different parts. Based on these codes the participant has to infer which codes new target items should get.

Memory

Short-term memory span*.* The GL&SCHR contains a short-term memory test for phonemes and non-verbal shapes (which must be drawn), and a test in which participants have to reproduce randomly presented series of letters or digits in ascending order. The participant is placed in front of a computer screen. After pressing the enter button the participant sees and hears a series of items presented one item per 2 seconds. At the end of each series the participant has to reproduce the items remembered. The number of items within a series increases steadily.

Verbal Memory. The GL&SCHR contains a short-term memory test for objects. Administration is identical to the short term memory spans test of the GL&SCHR described in the previous section.

Auditory memory. The *Auditory Memory Test* of the KAIT is a delayed memory task in which questions have to be answered about a text that was read out at the beginning of the administration of the KAIT (see the Auditory Comprehension Test discussed below).

Visuo-spatial memory. Visual-spatial memory was tested with two subtests of the KAIT: *Delayed Symbol Learning*, and *Block Patterns*. The Delayed Symbol Learning test is a delayed retention task of the symbols used in the Symbol Learning test. In the Block Patterns test a yellow-black pattern has to be reproduced with cubes.

Auditory perception

The *Auditory Comprehension* test of the KAIT comprises the presentation of *s*hort audio fragments about which the experimenter asks content questions. The participant has to provide an answer.

Procedure

The complete test protocol was administered during two sessions of about three hours each. The protocol was divided into two counterbalanced parts. The order of tests in part one and two was fixed and chosen to avoid succession of similar tests. There was a break halfway each session. If necessary, students could take additional breaks. Students with dyslexia started with part one or two according to an AB-design. Their control student always started with the same part. All tests were administered individually by three test administrators according to the manuals guidelines. The test administrators were the two first authors and a test psychologist. To standardize administration each administrator read the manuals of the tests, had a practice session, and followed three sessions of the starting administrator. Testing occurred in a quiet room with the test administrator seated in front of the student.

Results

To improve comparison with Table 1, results are given as Cohen's d effect sizes (derived from parametric or non-parametric tests, see below). In line with the English studies (Table 1), the sign of the d-values was adapted so that positive d-values represent better performance of the controls and negative values better performance of the students with dyslexia. All data were first checked on normality and equality of variance between groups (dyslexic group and control group). When the constraints for parametric statistics were satisfied, means were compared using a Student's t-test. Otherwise, the data were analyzed with the non-parametric Mann-Whitney-U test and converted into the appropriate d-value by means of the equation given in Field ([61], p. 530 on how to transform a U-value into an r-statistic) and an equation to derive the d-value from the r-statistic. Values of the t-statistics and U-statistics are not given, as these can be calculated from the d-scores. Table 5 shows performances of students with dyslexia on literacy skills in comparison with their non-dyslexic peers. For variables that were analyzed using with a t-test, confidence intervals for the effect sizes could be calculated with the use of the ESCI-CIdelta program [62]. In Table 6 the results of phonological skills and processing skills are listed. In Table 7 results on general intelligence measures are reported.

With respect to the literacy skills (Table 5), the following results stand out:

1. As in English speaking individuals, the deficiency of students with dyslexia tends to be worse in the writing tests than in the reading tests. In particular, the Word Spelling test of the GL&SCHR and the Sentence Dictation (AT-GSN) resulted in large effect sizes ($d \approx 2$).
2. Deficiencies in spelling are similar at the word level ($d = 2$) and at the sentence level ($d = 2.1$).
3. Dutch word reading ($d =1.97$) seems to be more affected in students with dyslexia than nonword reading ($d = 1.57$), possibly because the former involved more instances of inconsistent spelling-sound mappings.

4. For our group of students in higher education deficiencies in reading and writing are not more pronounced in a second language (English) than in the first language. In English word reading the same pattern in effect sizes was found for the percentage of errors and the number of words read as in Dutch.
5. Reading deficiencies are most pronounced in speed (1.60 < d < 1.90). Smaller but still substantial effect sizes were found for percentage of number of errors made (d ≈ .80).
6. Text comprehension was nearly equivalent for both groups (d = .4) when the text was read aloud, and better than expected on the basis of the reading scores.

Turning to the wider cognitive skills (Table 6 and 7), the following are the most important findings:

7. The differences on the IQ test are negligible and particularly caused by definitions to words (d = .75), although there is also a small difference for the recognition of famous persons (d = .35). There are no differences in fluid intelligence (d = .1).
8. Students with dyslexia tend to be slower than controls in processing speed as measured with the CDT(d = .6), and a small effect size can be noted for the percentage of errors (d = .35).
9. Except for phonological short-term memory (d = .71), memory spans are quite comparable (0.28 < d < .45).
10. There is considerable dyslexia cost for arithmetic (d ≈ 1), which tends to be larger for divisions (d = 1) and multiplications (d = .90) than for subtractions (d = .61).
11. There is a non-negligible cost (d > 1.3) for phonological processing. This cost again is largely due to the speed of processing, and less to the accuracy of processing.
12. Dyslexics are slower at naming letters, digits and colors, but not at naming objects (d = .2).

Table 5
Performances of students with dyslexia on literacy skills in comparison with their non-dyslexic peers.

	Students with dyslexia		Students without dyslexia		Cohen's d			p
	M1	SD1	M2	SD2	d	lower CI	upper CI	
Text comprehension (GL&SCHR)								
Number correct responses	19.38	5.05	21.59	4.4	0.47[b]			**
Word reading (EMT)								
Total number read words	79.08	14.32	101.33	10.6	1.87[b]			**
Number of errors	2.05	2.10	0.91	1.12	0.67[b]			**
Correctly read words	77.03	14.21	100.42	10.58	1.97[b]			**
Percentage of errors	2.63	2.77	0.90	1.08	0.88[b]			**
English word reading (OMT)								
Total number read words	71.18	10.72	84.99	9.49	1.36[a]	1.05	1.67	**
Number of errors	3.99	2.70	2.53	2.15	0.59[b]			**
Correctly read words	66.52	10.2	82.49	10.20	1.40[a]	1.09	1.71	**
Percentage of errors	5.64	3.98	3.07	2.71	0.75[b]			**
Text reading (GL&SCHR)								
Substantial errors	15.71	10.80	7.81	5.19	0.98[b]			**
Time consuming errors	14.29	8.72	9.17	4.91	0.64[b]			**
Reading time	311.14	51.97	258.53	25.26	1.29[a]	0.98	1.59	**
Silent text reading (Tekenbeet)								
Words per minute	184.63	59.25	243.64	57.59	1.13[b]			**
Nonword reading (Klepel)								
Total number read words	46.07	9.84	63.26	12.90	1.50[b]			**
Number of errors	5.20	3.77	3.67	3.10	0.44[b]			**
Correctly read words	40.88	10.46	59.72	13.10	1.59[b]			**
Percentage of errors	11.75	9.11	6.05	5.28	0.88[b]			**
Word spelling								
Word Spelling								
Weighted score word spelling	91.59	15.87	121.40	12.84	2.28[b]			**
Correct word spelling	17.49	4.02	24.60	2.81	2.05[b]			**
Writing speed	24.89	4.01	26.50	3.40	0.43[a]	0.15	0.71	**
Proofreading	51.23	10.96	63.49	11.69	1.08[a]	0.78	1.38	**
English word spelling (WRAT)								
Correctly spelled words	16.57	4.81	24.27	5.42	1.50[a]	1.19	1.82	**
Sentence dictation (AT-GSN)								
number of errors	54.04	24.17	23.20	11.65	2.10[b]			**
Morphology and syntax (GL&SCHR)								
Weighted score	50.34	10.35	59.57	9.86	0.91[a]	0.62	1.2	**
Total score	9.06	2.64	11.24	9.06	0.87b			**

$p < .05$; $^{**}p < .01$

Note: Parametric test results are marked with a. When the data violated the constraints for a parametric test, results are marked with b. GL&SCHR = Dutch reading and writing test battery for (young) adults; EMT = Een Minuut Test [One Minute Test]; OMT = One Minute Test;WRAT = Wide range Achievement Test; AT-GSN = Algemene Test- Gevorderde Spelling Nederlands [General Test Advanced Spelling Dutch].

Table 6
Performances of students with dyslexia on phonological skills and processing skills in comparison with their non-dyslexic peers.

	Students with dyslexia		Students without dyslexia		Cohen's d			p
	M1	SD1	M2	SD2	d	lower CI	upper CI	
Processing skills								
Speed of processing (CDT)								
Working pace	421.94	84.63	467.80	79.99	0.62[b]			**
Concentration	119.25	22.85	134.29	22.03	0.51[b]			**
Number of errors	0.19	0.56	0.15	1.73	0.23[b]			
Number of missed digits	8.08	6.96	6.60	6.76	0.19[b]			
Percentage of errors/missed	2.03	1.49	1.60	1.51	0.35[b]			*
Phonological skills								
Spoonerisms (GL&SCHR)								
Number correct responses	16.72	2.50	18.19	1.67	0.70[b]			**
Time	179.88	65.98	116.48	41.22	1.42[b]			**
Reversals (GL&SCHR)								
Number correct responses	15.63	2.41	17.72	2.03	1.00[b]			**
Time	106.00	33.996	76.61	16.18	1.3[b]			**
Rapid naming (GL&SCHR)								
Letters	25.72	5.85	20.62	3.99	1.02[b]			**
Digits	23.83	5.26	19.28	3.64	1.05[b]			**
Colours	32.55	6.03	28.25	4.314	0.81[b]			**
Objects	39.55	7.39	37.84	6.82	0.24[b]			

p < .05; **p < .01
Note: Parametric test results are marked with a. When the data violated the constraints for a parametric test, results are marked with b. CDT = Digit Crossing Test [Cijfer Doorstreep Test]. GL&SCHR = Dutch reading and writing test battery for (young) adults.

Table 7

Performances of students with dyslexia on general intelligence in comparison with their non-dyslexic peers.

	Students with dyslexia		Students without dyslexia		Cohen's d			p
	M1	**SD1**	**M2**	**SD2**	**d**	**lower CI**	**upper CI**	
General Intelligence								
Arithmetic (TTR)								
Total number calculations	121.24	20.67	144.75	23.83	1.05[a]	0.76	1.35	**
Addition	30.46	3.51	33.81	3.41	0.97[a]	0.67	1.26	**
Subtraction	27.31	4.17	30.14	3.98	0.61[b]			**
Multiplication	21.74	5.02	26.78	6.19	0.90[b]			**
Division	19.73	5.82	26.29	7.27	1.00[b]			**
Mixed operations	22.93	4.45	28.33	4.98	1.12[b]			**
General Intelligence (KAIT)								
Total IQ	105.50	12.97	109.83	9.29	0.38[a]	0.1	0.66	**
Crystallized IQ	106.66	8.11	111.31	8.83	0.55[a]	0.27	0.83	**
Fluid IQ	105.36	11.04	106.78	10.83	0.13[a]	- 0.14	0.41	
Vocabulary								
Vocabulary (GL&SCHR)	7.83	4.14	10.83	4.77	0.67[b]			**
Definitions (KAIT)	20.89	1.92	22.16	1.98	0.75[b]			**
Double meanings (KAIT)	14.44	3.91	16.10	3.71	0.43[b]			**
General information (KAIT)	7.26	3.14	8.41	3.25	0.35[b]			*
Problem Solving / Reasoning (KAIT)								
Symbol learning	80.45	12.64	80.93	13.14	0.07[b]			
Logical reasoning	11.32	3.48	11.78	3.18	0.12[b]			
Secret codes	26.78	5.49	27.46	4.91	-0.13[b]			
Memory								
Short term memory span (GL&SCHR)								
STM phonemes	20.11	4.7	23.23	4.56	0.71[b]			**
STM shapes	10.44	4.00	11.84	5.05	0.28[b]			*
Memory with sorting	39.34	5.03	41.54	4.34	0.45[b]			**
Verbal memory (GL&SCHR)								
STM words	35.41	5.78	37.24	5.37	0.30[a]	0.05	0.61	*
Auditory memory (KAIT)	4.99	1.40	5.54	1.50	0.37[b]			**
Visual Memory (KAIT)								
Delayed Symbol Learning	50.98	10.4	51.34	10.53	0.03[a]	-0.23	0.32	
Block Patterns	12.23	2.71	11.71	2.97	-0.17[b]			
Auditory Perception (KAIT)								
Auditory comprehension	13.26	2.96	13.60	2.80	0.09[b]			

*p < .05; **p < .01

Note: EMT = Een Minuut Test [One Minute Test]; GL&SCHR = Dutch reading and writing test battery for (young) adults; AT-GSN = Algemene Test- Gevorderde Spelling Nederlands [General Test Advanced Spelling Dutch]; CDT = Cijfer Doorstreep Test [Digit Crossing Test]; TTR = Tempo Test Rekenen [Speed Test Mental Calculations], KAIT = Kaufmann Adult Intelligence Test; STM = short term memory.

Table 8

Correspondence between the effect sizes reported in English and the effect sizes found in the current study.

	S&H09	HSG02	Dutch
Literacy			
Reading comprehension	1.2		
Word reading	1.4	1.1	2.0 (EMT correctly read)
Non-Word Reading	1.3	1.5	1.6 (Klepel correctly read)
Word Spelling	1.6	1.3	2.0 (GL&SCHR, N correct)
Text Writing	0.7	1.1	
Sentence dictation			2.0 (AT-GSN)
Processing skills			
Perceptual speed		0.9	0.6 (CDT Time)
Phonological skills			
Phonological processing	0.9	1.3	1.4 (GL&SCHR time)
Rapid naming	1.0	1.2	1.0 (GL&SCHR, without objects)
General intelligence			
Arithmetic	0.7	0.6	1.0 (TTR)
Verbal memory	0.2	1.1	0.3 (GL&SCHR, STM words)
General intelligence	0.2		0.4 (KAIT)
Vocabulary	0.7	0.1	0.6 (KAIT, GL&SCHR)
Problem solving / reasoning	0.1	-0.01	0.1 (KAIT fluid)
Auditory perception	-0.2		0.1 (KAIT, aud.compr)

Note: S&H09 = Swanson & Hsieh [17]; HSG02 = Hatcher, Snowling & Griffiths [14].EMT = Een Minuut Test [One Minute Test]; GL&SCHR = Dutch reading and writing test battery for (young) Adults; AT-GSN = Algemene Test- Gevorderde Spelling Nederlands [General Test Advanced Spelling Dutch]; CDT = Cijfer Doorstreep Test [Digit Crossing Test]; TTR = Tempo Test Rekenen [Speed Test Mental Calculations], KAIT = Kaufmann Adult Intelligence Test; STM = short term memory.

Finally, to facilitate comparison with English, Table 8 includes our results together with those of Swanson and Hsieh [17] and Hatcher et al. [14]. In particular, the correspondence with Swanson and Hsieh is impressive. The Pearson correlation between both sets is $r = .94$ ($N = 11$, $p < .001$). The correlation with Swanson and Hsieh is lower if we also include the text comprehension difference of the present study ($d = .5$) and correlate it with the reading comprehension difference reported by Swanson and Hsieh (d = 1.2). Then the correlations drops to r = .74 (N = 12). However, this comparison is not really justified, because in our text comprehension test the text was additionally read out by the computer. Correlation is lower with Hatcher and colleagues [14], partly because of a lack of data in that study on aspects where students with dyslexia show good performance. The correlation coefficient is .67 and reaches significance (p< .05).

Discussion

We designed this study to obtain an empirically based cognitive profile of students with dyslexia in higher education in a language other than English. We started from the tests we thought worthwhile, making sure those of Hatcher et al. [14] were included. Shortly after data collection began, Swanson and Hsieh [17] published their meta-analysis, providing us with an even more complete image of English-speaking students.

Despite the differences in language and educational context, our findings are remarkably similar to those in English: The pattern of strengths and weaknesses of students with reading disabilities is very much the same in Dutch as in English (Table 8). This is good news, because it means that the profile is likely to be applicable to all alphabetical languages. Also, different educational systems do not seem to play an important role in defining which students with dyslexia enter higher education.

A further important conclusion from our findings is that the data agree very well with the traditional definition of dyslexia as a combination of normal intelligence with deficient reading and writing. This definition has been questioned in recent years, because it has proven difficult to find the discrepancy in all individuals. Researchers have disagreed about whether this has theoretical consequences for the relationship between reading/writing skills and other abilities, or whether it is simply a consequence of the notoriously low correlations one is bound to find for difference scores of highly correlated variables (e.g. [63]). Our data leave little doubt that, as a group, dyslexics entering higher education show exactly the profile predicted by the traditional definition of dyslexia, even though at an individual level the difference scores may show large variability. As such, our findings reinforce a similar, tentative conclusion reached by Swanson and Hsieh [17].

The affirmation of the traditional definition of dyslexia shows that some lecturers' doubts about the existence of isolated reading disabilities in combination with normal intelligence are unjustified. For the group we tested, we found – just like the authors before us – a pattern of results that is extremely hard to obtain on the basis of deficient general abilities, motivation, or outright malingering. Although we cannot exclude the possibility that one or two of the students who refused to take part in our study did so because they wanted to play the system, our results emphatically testify that the vast majority of students entering higher education with a diagnosis of dyslexia are the same as the other students, except for a language-related deficiency that arguably hurts them most during the school years when they have to rapidly acquire and produce a lot of new information in written form.

At the same time, it is important to keep in mind that, although the differences are not large, all test scores tended to be lower for the students with dyslexia than for the controls. When looking at the full cognitive profile of students with dyslexia, it cannot be denied that there is a quite consistent deficiency on a wide range of tasks, predominantly those involving speed of processing and retrieval of verbal information from long term memory. It would be good if students with dyslexia were properly informed about this extra challenge they are facing. The most prominent example of such a "hidden" cost is the extra time they need for mental calculations (total of operations: d=1), arguably because of the extra effort to retrieve arithmetic facts from memory (see the triple code model [64]). This additional deficit was not mentioned by many students, but is likely to cause problems in courses involving the calculation of many elementary arithmetic operations (e.g., the calculation of a standard deviation in a course of statistics).

Sometimes it has been hypothesized that successful individuals with dyslexia have fully compensated for their reading and writing difficulties [65]. Hatcher et al. [14] raised doubts about this possibility, and our data confirm this to some extent, although the picture is much less pessimistic. What is encouraging is the finding that students with dyslexia tended to perform equally good on the text comprehension test, in which the text was additionally read out by the computer (see also their good scores on the auditory comprehension test). This suggests the usefulness of text-to-speech arrangements, although ideally we would have more data on this aspect, directly comparing text comprehension with and without text-to-speech assistance.

A further interesting finding of our study is that the effect sizes are not larger for tests based on sentences than for tests based on individual words (word reading d = 1.87, text reading d = 1.29; word writing d = 2.05, text writing d = 2.10). This agrees with the descriptive definition of SDN [39] arguing that the impairment in reading and spelling can be measured at the word level. Our data indicate that tests of reading and writing at the word level are enough to make a valid diagnosis. This is valuable information for diagnosticians, as it leads to a substantial time gain.

Finally, our findings have clear implications for guidelines about special arrangements. We think the following arrangements are incontestable:

1. It is clear that students with dyslexia have a specific and pervasive problem with reading and writing. This means that they are entitled to arrangements that help them with these particular deficiencies, such as text-to-speech software (also during exams) and the use of spellcheckers and word completion software when spelling errors are likely to lead to lower marks (e.g., for essay-type questions).
2. Students with dyslexia are at a disadvantage under time constraints, meaning that situations should be avoided in which they are likely to suffer more (e.g., exams and tests with strict time limits). This does not mean that students with reading disabilities should be given extended deadlines for all tasks (e.g., for the submission of essays and lab reports, which can be planned well in advance), but it does entail that they are denied a fair chance if they have to complete an exam in the same time as their peers.
3. Many students with dyslexia have a pervasive problem with mathematical tables. This should be taken into account when an exam strongly relies on them (e.g., for problem solving, where different alternatives have to be tried out). This problem can easily be solved by allowing students to use a calculator.
4. Finally, there is scope for better feedback to the students themselves. It is important for them to know of the limitations they are confronted with, so that they can prepare themselves well and insist on having the arrangements outlined above. A better knowledge of their limitations may also help them not to overestimate their abilities. One cannot deny that the average performance of the dyslexics on nearly all tests tended to be lower than that of controls. Although these differences often are too small to justify special arrangements, students with reading disability should know about these differences, so that they can better organize their studies. For instance, many institutes of higher education nowadays provide their students with ways to spread the burden (e.g., by studying part-time or distributing the exams over extra sessions). It may be an idea to discuss these options with students (and their parents), certainly when their test performances are below average, so that they can prepare themselves better in the light of the specific difficulties they will be confronted with.

The above (minimal) arrangements are easy to implement if they are part of the general organization of exams, certainly with the current availability of text-to-speech software and text writing software with built-in spellcheckers. Additionally, these measures are so specifically tailored to the proven needs of students with dyslexia that they are unlikely to be contested or misused. To our knowledge there is no evidence that text-to-speech software, spellcheckers, and a few extra hours for exams are any good in compensating for a lack of knowledge, deficient intellectual abilities, or missing achievement motivation. However, our results strongly suggest that they will make a significant difference for students with dyslexia.

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References

1 Hadjikakou K, Hartas D(2008) Higher education provision for students with disabilities in Cyprus. Higher Education 55: 103-119.

2Madriaga M, Hanson K, Heaton C, Kay H, Newitt S et al. (2010) Confronting similar challenges? Disabled and non-disabled students' learning and assessment experiences. Studies in Higher Education 35: 647-658.

3 Landerl K, Moll K (2010) Comorbidity of learning disorders: prevalence and familial transmission. Journal of Child Psychology and Psychiatry 51: 287-294.

4 Pieters S, De Block K, Scheiris J, Eyssen M, Desoete A, et al. (2012) How common are motor problems in children with a developmental disorder: rule or exception? Child: Care, Health and Development 38: 139-145.

5 Yoshimasu K, Barbaresi WJ, Colligan RC, Killian JM, Voigt RG, et al. (2010) Gender, Attention-Deficit/Hyperactivity Disorder, and Reading Disability in a Population-Based Birth Cohort . Pediatrics 126: 788-795.

6 Du Pré EA, Gilroy DE, Miles TR (2008) Dyslexia at College. NY : Routledge.

7 Farmer M, Riddick B, Sterling CM, (2002) Dyslexia and Inclusion. Assessment and Support in Higher Education. London: Whurr Publishers Ltd.

8 Wolf LE, Schreiber HE, Wasserstein J (2008) Adult Learning Disorders: Contemporary Issues (A Neuropsychologist's Handbook). NY: Psychology Press.

9 Sparks RL, Lovett B (2009) College Students With Learning Disability Diagnoses Who Are They and How Do They Perform? Journal of Learning Disabilities 42: 494-510.

10 Sparks RL, Lovett B (2009) Objective Criteria for Classification of Postsecondary Students as Learning Disabled Effects on Prevalence Rates and Group Characteristics. Journal of Learning Disabilities 42: 230-239.

11 Everatt J, Bradshaw MF, Hibbard PB, Lages M (1997) Visual processing deficits and dyslexia. Perception 26: 1330-1330.

12 Felton RH, Naylor CE, Wood FB (1990) Neuropsychological profile of adult dyslexics. Brain and Language 39: 485-497.

13 Lefly DL, Pennington BF (1991) Spelling-errors and reading fluency in compensated adult dyslexics. Annals of Dyslexia 41: 143-162.

14 Hatcher J, Snowling MJ, Griffiths JM (2002) Cognitive assessment of dyslexic students in higher education. British Journal of Educational Psychology 72: 199-133.

15 Ransby MJ, Swanson HL (2003) Reading comprehension skills of young adults with childhood diagnoses of dyslexia. Journal of Learning Disabilities 36: 538-555.

16 Trainin G, Swanson HL (2005) Cognition, metacognition and achievement of college students with learning disabilities. Learning Disability Quarterly 28: 264-272.

17 Swanson HL, Hsieh CJ (2009) Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. Review of educational Research 79: 1362-1390.

18 Brysbaert M (2011) Basic statistics for psychologists. London: Palgrave Macmillan.

19 Keuleers E, Diependaele K, Brysbaert M (2010) Practice effects in large-scale visual word recognition studies: a lexical decision study on 14,000 Dutch mono- and disyllabic words and nonwords. Frontiers in Psychology: 1- 174.

20 De Smedt B, Boets B (2010) Phonological processing and arithmetic fact retrieval: evidence from developmental dyslexia. Neuropsychologia 48: 3973-3981.

21 Göbel SM, Snowling MJ (2010) Number-processing skills in adults with dyslexia. Quarterly Journal of Experimental Psychology 63: 1361-1373.

22 Sharpe D (1997) Of Apples and Oranges, File Drawers and Garbage: Why Validity Issues in Meta-analysis Will Not Go Away. Clinical Psychology Review 17: 881-901.

23 Hanley JR, Masterson J, Spencer LH, Evans D (2004) How long do the advantages of learning to read a transparent orthography last? An investigation of the reading skills and reading impairment of Welsh children at 10 years of age. Quarterly Journal of Experimental Psychology 57: 1393-1410.

24 Seymour PHK, Aro M, Erskine JM, et al. (2003) Foundation literacy acquisition in European orthographies. British Journal of Psychology 94: 143-174.

25 Ziegler JC, Goswami U (2005) Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. Psychological Bulletin 131: 3-29.

26 Lindgren SD, De Renzi E, Richman LC (1985) Cross-national comparisons of developmental dyslexia in Italy and the United-States. Child Development 56: 1404-1417.

27 Landerl K, Wimmer H, Frith U (1997) The impact of orthographic consistency on dyslexia: A German-English comparison. Cognition 63: 315-334.

28 Share DL (2008) On the anglocentricities of current reading research and practice: The perils of overreliance on an "Outlier" orthography. Psychological Bulletin 134: 584-615.

29 Stone GO, Vanhoy M, VanOrden GC (1997) Perception is a two-way street: Feedforward and feedback phonology in visual word recognition. Journal of Memory and Language 36: 337-359.

30 Borgwaldt S, Hellwig F (2004) Onset entropy matters: Cross-linguistic sound-spelling analyses and empirical validation. Australian Journal of Psychology 56: 106-107.

31 Van den Bosch A, Content A, Daelemans W, De Gelder B (1994) Measuring the Complexity of Writing Systems. Journal of Quantitative Linguistics 1: 178-188.

32 Lovett BJ, Sparks RL (2010) Exploring the Diagnosis of "Gifted/LD": Characterizing Postsecondary Students With Learning Disability Diagnoses at Different IQ Levels. Journal of Psycho-educational Assessment 28: 91-101.

33 Reid AA, Szczerbinski M, Iskierka-Kasperek E, Hansen P (2006) Cognitive Profile of Adult Developmental Dyslexics: Theoretical Implications. Dyslexia 13: 1-24.

34 Szenkovits G, Ramus F (2005) Exploring dyslexics' phonological deficit I: Lexical versus sublexical and input versus output processes. Dyslexia 11: 253-268.

35 Bruyer R, Brysbaert M (2011) Combining speed and accuracy in cognitive psychology: Is the Inverse Efficiency Score (IES) a better dependent variable than the mean Reaction Time (RT) and the Percentage of Errors (PE)? Psychologica Belgica 51: 5-13

36 Wolff U (2009) Phonological and Surface Subtypes among University Students with Dyslexia. International Journal of Disability, Development and Education 59: 73-91.

37 Campbell JID, Thompson VA (2002) More power to you: Simple power calculations for treatment effects with one degree of freedom. Behavior Research Methods, Instruments, & Computers 34: 332-337.

38 Faul F, Erdfelder E, Lang AG, Buchner A (2007) G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods 39: 175-191.

39 Stichting Dyslexie Nederland (2008) Diagnose dyslexie. Brochure van de Stichting Dyslexie Nederland. Herziene versie. Bilthoven: Stichting Dyslexie Nederland.

40 Vaughn S, Fuchs LS (2003) Redefining learning disabilities as inadequate response to instruction: The promise and potential problems. Learning Disabilities Research & Practice 18: 137-146.

41 Haager D, Klinger J, Vaughn S (2007) Evidence-Based Reading Practices for Response to Intervention. Baltimore, London, Sydney: Paul H. Brookes Publishing Co.

42 Brus B, Voeten M (1991) Eén-minuut-test vorm A en B, schoolvorderingstest voor de technische leesvaardigheid bestemd voor groep 4 tot en met 8 van het basisonderwijs. Verantwoording en handleiding. Lisse: Swets & Zeitlinger.

43 van den Bos K, Spelberg H, Scheepsma A, de Vries J (1999) De klepel vorm A en B, een test voor leesvaardigheid van pseudowoorden. Verantwoording, handleiding, diagnostiek en behandeling. Lisse: Swets & Zeitlinger.

44 De Pessemier P, Andries C (2009) Test voor Gevorderd Lezen en Schrijven. Antwerpen- Apeldoorn : Garant.

45 Dekker R, Dekker PH, Mulder JL (2004) Kaufman Adolescent and Adult Intelligence Test – Nederlandstalige Versie: Handleiding. PITS: Leiden.

46 Van der Leij A, Bekebrede JI, Geudens A, Schraeyen K, Schijf, GM et al. (in press) Interactieve Dyslexietest Amsterdam- Antwerpen [Interactive Dyslexia Test Amsterdam-Antwerp] : handleiding. Uithoorn : Muiswerk Educatief.

47 Wechsler Dv (2001) WAIS-III, Nederlandstalige bewerking, technische handleiding. Lisse: Swets & Zeitlinger.

48 Kleijnen R, Loerts M (2006) Protocol Dyslexie Hoger Onderwijs. Antwerpen/Apeldoorn: Garant Uitgeverij.

49 Kleijen R, Steenbeek-Planting E, Verhoeven L (2008) Toetsen en Interventies bij Dyslexie in het Voortgezet Onderwijs. Nederlands en Moderne Vreemde Talen. Antwerpen/Apeldoorn: Garant Uitgeverij.

50 Henneman K, Kleijnen R, Smits A (2004) Protocol Dyslexie Voortgezet Onderwijs : Deel 2 - Signalering, diagnose en begeleiding. KPC Groep, Expertisecentrum Nederlands, Werkverband Opleidingen Speciaal Onderwijs.

51 Tops W, Callens M, Van Cauwenberghe E, Adriaens J, Brysbaert, M Beyond spelling: the writing skills of students with dyslexia in higher education. Annals of Dyslexia: in press.

52 Desoete A, Roeyers H (2002) Off-line metacognition. A domain-specific retardation in young children with learning disabilities? Learning Disability Quarterly 25: 123-139.
53 Wilkinson GS (1993) Wide Range Achievement Test. Jastak Assessment.
54 Ghesquière P (1998) Algemene toets gevorderde spelling van het Nederlands (AT-GSN) : Verantwoording en handleiding. Rapport van een specialisatiejaar: Onderzoek AT-GSN-dictee. Unpublished bachelor thesis, University Leuven, Leuven, Belgium.
55 Gauderis K, Heirman E, Vandenhoof T (2004) Normering van AT-GSN, TTR en CDR-5 bij leerlingen van het zesde jaar Algemeen Secundair Onderwijs [Standardisation of AT-GSN, TTR and CDR-5 among sixth-year students in General Secondary Education]. Unpublished bachelor thesis, University College Arteveldehogeschool, Ghent, Belgium.

56 Vanderswalmen R, Vrijders J, Desoete A (2010) Metacognition and spelling performance in college students. In A Efklides & P Misailidi (Eds.). Trends and Prospects in Metacognition Research. Springer: New York, 367-394.
57 Dekker R, Mulder JL, Dekker PH (2007) De ontwikkeling van vijf nieuwe Nederlandstalige tests. PITS: Leiden.
58 Dekker R, De Zeeuw J (2003) DVMH: Differentiële Vaardighedentests voor Midden en Hoger Niveau. PITS: Leiden.
59 Carroll JB (1993) Human Cognitive Abilities. A Survey of Factor-Analytic Studies. Cambridge: Cambridge University Press.
60 de Vos T (1992) Tempo Test Rekenen. Amsterdam: Pearson Education.
61 Field A (2005) Discovering Statistics using SPSS. London: SAGE Publications Ltd.
62 Cumming G, Finch S (2001) A primer on the understanding, use and calculation of confidence intervals based on central and noncentral distributions. Educational and Psychological Measurement 61: 530-572.
63 Cotton SM, Crewther DP, Crewther SG (2005) Measurement error: Implications for diagnosis and discrepancy models of developmental dyslexia. Dyslexia 11: 186-202.
64 Dehaene S, Piazza M, Pinel P, Cohen L (2003) Three parietal circuits for number processing. Cognitive Neuropsychology 20: 487-506.
65 Snowling MJ (2000) Dyslexia (2nd ed.). Oxford: Blackwell.

An exploratory factor analysis of the cognitive functioning of first-year bachelor students with dyslexia

Chapter 3

Chapter 3: An exploratory factor analysis of the cognitive functioning of first-year bachelor students with dyslexia

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An increasing number of students with dyslexia register in higher education. As a consequence, information on their pattern of strengths and weaknesses is essential to construct adequate assessment protocols. In a sample of 100 first-year bachelor students with dyslexia and 100 control students a large range of cognitive skills were tested with a variety of standardized tests. When we applied exploratory factor analysis to the scores, a model with 10 factors fitted the data best. Effect sizes were used to express the processing costs of students with dyslexia. Factors related to reading, spelling, flashed orthography, phonology, rapid naming, math, and reading fluency resulted in large effect sizes. A factor combining all measures of crystallized IQ had a medium effect size. The subtests for fluid intelligence were divided in two separate factors with no difference between students with and without dyslexia. The relationships between all subtest scores and the factors are visualized in a general framework.

Introduction

Reading and writing are necessary skills for everyday functioning. Unfortunately, a small percentage of people do not succeed in developing these skills to an adequate level. When the failure to automate these skills cannot be attributed to dysfunctions in intellectual, sensory or emotional abilities, or to inadequate instruction, the presence of a specific learning disorder or dyslexia is suspected. In Belgium, dyslexia is diagnosed when the symptoms are in accordance with the SDN definition (Stichting Dyslexie Nederland, 2008 [Foundation Dyslexia Netherlands]). This implies first that the level of reading and/or spelling is significantly lower than can be expected on the basis of the individual's educational level and age. Secondly, following the criterion of "response to instruction" (RTI), the low reading and writing scores remain present despite some form of remedial teaching. Finally, the SDN definition requires the attestation that the reading and writing impairment cannot be attributed to external and/or individual factors such as socio-economic status, cultural background or intelligence.

There is a growing body of research on dyslexia in higher education, because worldwide a larger number of students with dyslexia are performing well enough in primary and secondary school to go through to higher education (Hadjikakou & Hartas, 2008; Hatcher, Snowling, & Griffiths, 2002; Madriaga et al., 2010). This creates new challenges for these institutions, as not all students have a valid and recent assessment (Gilroy & Miles, 2001; Harrison & Nichols, 2005; Parrila, Georgiou, & Corkett, 2007; Singleton, 1999). The main concern in the assessment of dyslexia at a later stage is the fact that symptoms are possibly not as pronounced because of received remediation and adapted compensatory techniques (Singleton, Horne, & Simmons, 2009; Wilson & Lesaux, 2001). Also, the specific group of students taking the step to higher education is more likely to have developed skills that enable them to partially overcome their reading and writing problems (Mapou, 2008; Spinelli et al., 2005). However, only few diagnostic protocols have been validated for higher education. Compared to the tests available for primary school children, there are but a small number of diagnostic instruments available for adolescents.

A pioneer study on dyslexia in higher education was published by Hatcher et al. (2002). These authors ran a study with the aim to produce guidelines for the intake of dyslexic students in higher education. An inventory was made of a range of relevant skills such as reading and writing but also intelligence, verbal fluency and speed of processing. Additionally, Hatcher et al. (2002) used a discriminant analysis to find out how many tests were needed for valid diagnosis. They concluded that a diagnosis with 95% accuracy was possible on the basis of four tests only: Word spelling, nonword reading, digit span and writing speed. Swanson and Hsieh (2009) made a further contribution by carrying out a meta-analysis of 52 studies -yielding 776 effect sizes- in which they compared the academic, behavioral and cognitive performances of undergraduates with dyslexia to those of controls. Partially based on the above two studies, Callens, Tops, and Brysbaert (2012) ran a similar study on a group of first-year bachelor control students (N= 100) and a group of dyslexic students (N= 100) in the Dutch language. A large number of cognitive functions reported in Hatcher et al. (2002) and Swanson and Hsieh (2009) were assessed with a large variety of standardized tests and validated instruments (see below for a more detailed list of the selected variables). Based on an original pool of 53 variables, Tops, Callens, Lammertyn, and Brysbaert (2012) identified 27 variables that were most discriminative between dyslexics and controls, and they investigated how many of these were needed for valid assessment. On the basis of a classification algorithm, the authors showed that the number of tests could be reduced to three without loss of predictive power (i.e., the power to correctly classify a new group of participants). These tests were: word spelling, word reading, and phoneme reversal time. The prediction accuracy –based on a 10-fold cross validation technique- was 90.9% (95% CI [87.1, 94.8]). Sensitivity was 91% and specificity 90% (Tops et al., 2012). Adding more variables did not increase the diagnostic power.

When the confirmation or rejection of a diagnosis is the primary goal, a test protocol with a maximum of 3 to 5 predictors (Hatcher et al., 2002; Tops et al., 2012) is sufficient. However, this does not mean that students struggle only on these three tasks. It just means that adding more tasks does not help to better discriminate students with dyslexia from others. Experience shows that students generally seek more than a mere diagnostic label. Often they are in need of a wider overview of their strengths and weaknesses in order to optimize their performance throughout their academic career. For researchers it is also important to know how the various skills are interrelated and affected in students with dyslexia. Therefore, in the present study we try to bridge the gap between the existing theoretical frameworks and everyday practice by using an exploratory factor analysis (EFA) in combination with effect sizes.

In factor analysis the goal is to reduce the variables by using the covariation in the observed variables. This covariation is assumed to be due to the presence of an underlying, latent variable that exerts a causal influence on the observed variables. Variables that vary together are grouped together under a latent variable. Factor analysis can be applied to a homogeneous group to investigate how the variables in the group covary. Factor analysis, however, can also be applied across groups. In that case, the more the groups differ from each other on a variable, the more the factor to which the variable is allocated summarizes the difference between the groups rather than the variability within each group.

We opted for an EFA across a group of readers with dyslexia and a normal reading group. In such an analysis, the factors emerging from the EFA are driven by the difference between the groups and the variance within the groups. Because the EFA itself does not make a distinction between these two types of variances, effect sizes of the latent variables are added. The larger the difference between the groups, the more the latent variable is influenced by the between-groups variance. Latent variables with small effect sizes are mostly due to variance within the groups. The question we put forward is how many factors are needed to extract the pattern of relationships in a wide range of variables that are important in higher education. With this new approach we hope to unfold a more general profile of differences between normal reading students and students with dyslexia, helping professionals to recognize a dyslexia profile (with the notion that individual differences are possible). Also, by getting a clear view on how the different subtests relate to each other and which latent variables are essential in a diagnostic protocol for dyslexia, we hope to give information about how to make a better and a more cost-efficient protocol for dyslexia.

In the next section we give a short review of the cognitive skills that are known to distinguish between normal readers and readers with dyslexia in young adulthood and the reason for including them in our study (see also Callens et al., 2012). The core problem of individuals with dyslexia concerns reading and/or spelling. Even in adulthood specific difficulties with reading and spelling can be detected using instruments that are sensitive enough. Impaired accuracy in whole word reading and text reading were found by Lindgren and Laine (2011). A meta-analysis conducted by Swanson (2012) also identified single word recognition as the main characteristic (d=1.37) of adults with reading disability. As a specific reading skill, decoding is usually evaluated with the use of pseudowords. Readers with dyslexia are said to process pseudowords less accurately and more slowly than normal readers, a finding often referred to as an increased lexicality-effect. This is an effect replicated in many studies and age groups (Bekebrede, van der Leij, & Share, 2009; Gottardo, 1997; Greenberg, Ehri, & Perin, 1997; Herrmann, Matyas, & Pratt, 2006; Pennington, Vanorden, Smith, Green, & Haith, 1990) , but was recently called into question by Van den Broeck and Geudens (2012), who argued that the increased nonword reading deficit in disabled readers could be an artifact of the methods used. Opinions also differ on the influence of dyslexia on reading comprehension as a subskill of reading development. Some studies report impaired reading comprehension in adult dyslexics (Everatt, 1997; Swanson, 2012) while Lindgren and Laine (2011) found no or only minor differences in university students on a task without time constraints.

Apart from reading related aspects, spelling is the second core problem in adult individuals with dyslexia. Word spelling accuracy was found to be highly discriminative for dyslexia in higher education (Hatcher et al., 2002; Lindgren & Laine, 2011; Wilson & Lesaux, 2001). As a result, measurements of spelling performance are usually included in assessment protocols for dyslexia in higher education (Re, Tressoldi, Cornoldi, & Lucangeli, 2011; Tops, Callens, Bijn, & Brysbaert, in press; Warmington, Stothard, & Snowling, 2012).

Some aspect of phonological processing is typically included in the diagnostic process of dyslexia as well, even in adults. The fact that individuals with dyslexia suffer from phonological problems is generally accepted (de Jong & van der Leij, 1999; Griffiths & Snowling, 2002; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wagner & Torgesen, 1987). Even adults with dyslexia show phonological deficiencies in comparison to proficient readers/spellers on more demanding phonological tasks such as spoonerisms or reversals[1] (Bruck, 1992; Wilson & Lesaux, 2001; Wolff & Lundberg, 2003).

Although the phonological deficit theory has long been the leading theory in dyslexia, studies now have shown that other processes also play a role in the prediction of differences between adolescents and adults with and without dyslexia. Next to the traditional reading and spelling related aspects (i.e. single word recognition, reading comprehension, and spelling), verbal memory, vocabulary, math and naming speed have been identified as relevant in the distinction between the groups (for a review see Swanson & Hsieh, 2009) yielding medium to large effect sizes. Functions such as general intelligence, problem solving, reasoning and visual memory appear less impaired with only low to moderate effect sizes (therefore with less practical relevance). In a comparative study of the Wechsler Adult Intelligence Test-Revised (WAIS) and the Kaufman Adolescent and Adult Intelligence Test (KAIT) on college students with and without dyslexia, no differences were found in fluid or crystallized intelligence (Morgan, Sullivan, Darden, & Gregg, 1997).

In light of the close relationship between reading and vocabulary development, the finding of Swanson and Hsieh (2009) that vocabulary is often impaired, is not surprising. In their study an effect size of d=0.71 was reported for measures related to word meaning and semantic word knowledge. However, in vocabulary measurements it is often not possible to distinguish whether actual word knowledge or some aspect of lexical retrieval has been evaluated.

[1] In a spoonerism task the first letters of two words need to be interchanged (e.g. Harry Potter becomes Parry Hotter). In a reversal task individuals need to determine whether two presented words or pseudowords are exact reversals (e.g. ran-nar)

Researchers consider rapid naming (RAN) as a more specific measure of lexical retrieval. In this task a small number of high frequency stimuli must be named repeatedly. How a participant performs on the RAN task is said to reflect the ability to retrieve phonological codes from long-term memory and, therefore, the level of performance is seen as an expression of phonological processing (besides phonological awareness and verbal short term memory). The rapid naming skill consistently discriminates normal from dyslexic individuals (Wolf & Bowers, 1999) and is an independent predictor of fluency in word reading (Lervag & Hulme, 2009; Manis, Doi, & Bhadha, 2000; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007). The slowness in RAN typically seen in individuals with dyslexia is not only visible in children but stretches out in adulthood (Bekebrede et al., 2009; de Jong & van der Leij, 2003; Shaywitz & Shaywitz, 2005). Studies have demonstrated that continuous presentation versions of the RAN are more strongly related to reading fluency than discreet versions (Bowers & Swanson, 1991). This could be because dyslexics have more difficulties inhibiting previously activated information and processing upcoming items (lateral inhibition or crowding). Still, there is evidence that both the discrete and the continuous versions discriminate between groups of dyslexic readers and normal readers (Castel, Pech-Georgel, George, & Ziegler, 2008; Jones, Branigan, & Kelly, 2009).

Another closely related cognitive function often discussed in relation to dyslexia is working memory. Working memory is said to be a system involved in temporary storage, processing, maintenance, and integration of information from a variety of sources. It consists of a central executive that controls attention and oversees three components: the phonological loop (which deals with phonologically based information), the visuo-spatial sketchpad (visual and spatial information), and the episodic buffer (time-limited integration of information) (Baddeley, 2000). Impairments in working memory have been well documented in individuals with dyslexia. Smith-Spark and Fisk (2007) reported that these impairments were not limited to the phonological loop but extended into the visuo-spatial domain. In contrast, other authors postulated that the visuo-spatial working memory skills exceed the verbal-phonological ones in individuals with dyslexia (Brosnan et al., 2002; Swanson, Howard, & Saez, 2006).

A further source of difficulties with word recognition can be found at the level of morphological processing. Although not much research has been done on this topic, Schiff and Raveh (2007) and Leikin and Hagit (2006) reported specific deficiencies in morphological processing in adults with dyslexia compared to normal readers. Closely related to morphology is syntactic processing. Using ERP measures, Leikin (2002) observed significant differences in syntactic processing which could reflect a general syntactic processing weakness in dyslexia.

As described above, in the meta-analysis of Swanson (2012) math was also identified as a factor distinguishing normal readers from disabled readers. Simmons and Singleton (2006) were among the first to report deficient number fact retrieval in adults with dyslexia. Gobel and Snowling (2010) further found that basic number processing is intact but that adults with dyslexia have difficulties with arithmetic problems that rely on a verbal code. The authors found impairments in addition and multiplication but not in subtraction. They explained this set of findings on the basis of the triple code model of numerical cognition (Dehaene, 1992; Dehaene, Piazza, Pinel, & Cohen, 2003), which states that numbers can be stored in three different codes (analog, Arabic, verbal), with the verbal code particularly important for table-related arithmetical operations (multiplication and addition). Gobel and Snowling (2010) further made sure that the arithmetic differences they observed were not due to low-level phonological deficits. De Smedt and Boets (2010) also found that adult dyslexics were worse at arithmetic, but this was true both for multiplication and subtraction in their group. The authors examined their results in more detail and observed slower executive retrieval strategies. Phonological awareness was specifically related to fact retrieval.

Finally, we would like to report some studies that focused on speed of processing (SOP). Romani, Tsouknida, di Betta, and Olson (2011) studied speed of processing with an array-matching task where two strings of either consonants or symbols were presented side by side and had to be judged as same or different. Here, the dyslexia group did not perform worse on SOP. In a paper by Stenneken et al. (2011), however, a group of high achieving young adults with dyslexia showed a striking reduction in perceptual processing speed (by 26% compared to controls). Peter, Matsushita, and Raskind (2011) also found slower processing in poor readers, and Hatcher et al. (2002) found dyslexic students to be slower in speed of processing as measured with a digit copying task.

In light of the exploratory character of our study, we opted to analyze the data with an exploratory factor analysis (EFA) inserting both the data from a group of students with dyslexia and a control group into the analysis. In relation to learning disabilities, this technique has been used in the past but mainly with the purpose of determining dyslexia subtypes in samples (Heim et al., 2008; Laasonen, Service, Lipsanen, & Virsu, 2012). The rationale behind the approach is that variance between groups will lead to a large effect size in the emerging latent variables. This informs us about the interrelations of the various measures discriminating between students with dyslexia and control students. So in this paper, we focus on the coherence between the cognitive skills in order to optimize the construction of valid diagnostic protocols for dyslexia in higher education and guide professionals in the selection of subtests.

Method

Participants

We recruited 200 first-year bachelor students in higher education (Callens et al., 2012), following either a professional bachelor program (in colleges for higher education) or an academic bachelor program (in some colleges for higher education and at the university) in Ghent[2]. The group consisted of 100 students diagnosed with dyslexia and a control group of 100 students with no known neurological or functional deficiencies. All had normal or corrected-to-normal vision and were native speakers of Dutch. Participation was compensated financially. In each group 41 males and 59 females participated, 63 students were following a professional bachelor program and 37 an academic bachelor program. The study was approved by the ethical protocol of Ghent University, meaning that students gave written informed consent and were informed that they could stop at any time if they felt they were treated incorrectly.

The group of 100 students with dyslexia was recruited with the assistance of the non-profit organization *Cursief*, which is primarily responsible for the attestation and guidance of students with learning disabilities. Every first-year bachelor student applying for special educational measures related to dyslexia was asked to participate in our study until a total of 100 was reached. Based on the results of the assessment procedure in combination with reports from remedial teachers proving a lack of response to intervention, it was clear that the group met the three criteria for dyslexia put forward by the Foundation Dyslexia Netherlands (Stichting Dyslexie Nederland, 2008) (see above).

The control group matched the dyslexia group on field of study and gender. The students with dyslexia provided us with some names of fellow classmates who were interested in participating in the study. In case they failed to provide any, we recruited them ourselves by means of electronic platforms or the guidance counselors at the institution in question. The presence of any undetected reading/spelling disorders in the control group was ruled out by asking the students if they had experienced any learning problems in previous education. The mean age of the group with dyslexia was 19 years and 4 months. The mean Fluid IQ as measured with the KAIT (Dekker, Dekker, & Mulder, 2004) was 105 [SD = 11.04]. The mean age of the control group was 19 years and 11 months. The mean Fluid IQ was 107 [SD= 10.83]. Groups differed neither in age [$t(198) = -0.91$; $p = .36$] nor in Fluid IQ [$t(198) = 0.92$; $p = .36$].

[2] Ghent is one of the major cities in Flanders, the Dutch speaking half of Belgium.

Test materials

Several cognitive skills were assessed with validated and widely used Dutch instruments. We in particular used 3 instruments namely the Dutch version of the KAIT (Dekker et al., 2004) for measures of intelligence, an established test battery for diagnosing dyslexia in young adults (GL&SCHR, (De Pessemier & Andries, 2009), and a computer based assessment for dyslexia in higher education (IDAA or Interactive Dyslexia Test Amsterdam-Antwerp, (Van der Leij et al., 2012)). In these batteries several cognitive functions are measured. Next to these three test batteries, several other tests were applied. We first describe the core test batteries in general followed by a detailed description of all administered subtests categorized according to the cognitive skill they evaluate. Psychometric information of all tests can be found in the chapter 2.

KAIT

The American KAIT, developed in 1993 by A.S. Kaufman and N.L. Kaufman, was translated by Dekker, Dekker, and Mulder in 2004 and norms were collected on a standardization sample in the Netherlands and Flanders. The main goal of the KAIT is to evaluate analytic intelligence in individuals from 14 to 85 years old. In our study the complete test was administered. It consists of 10 subtests categorized into two types of intelligence: fluid and crystallized intelligence. The crystallized scale consists of 4 subtests: Word Definitions, Double Meanings, Auditory Comprehension, and Personalities. It reflects how well a person has learned concepts and knowledge that are part of the cultural and scholar context. It is influenced by verbal conceptual development and education. The fluid intelligence scale gives an indication of the person’s potential and flexibility to solve new problems. The 4 subtests are Symbol Learning, Logical Reasoning, Secret Codes and Block Patterns. Additionally, there are two measures of long term memory, namely Delayed Auditory Memory and Delayed Symbol Learning. The combination of the fluid IQ score, the crystallized IQ score and the delayed subtests results in a total IQ-score. All three scores have a mean of 100 and a standard deviation of 15 points.

We used the KAIT instead of the Wechsler Adult Intelligence Scale III (Wechsler, 2001) to avoid retest effects on the WAIS. Many students with dyslexia had been tested previously with the WISC or the WAIS as part of their assessment. Other reasons for choosing the KAIT were the less rigorous time constraints, which we considered an advantage for students with learning disabilities, and the inclusion of two subtests of delayed memory, namely Delayed Symbol Learning and Delayed Auditory Memory. Both subtests are considered valid measures of long term memory capacities.

GL&SCHR.

We also administered the GL&SCHR, a Dutch reading and spelling test battery for (young) adults (De Pessemier & Andries, 2009). This test includes many of the tasks frequently administered in dyslexia assessment (see above). There are three main tests specifically designed to evaluate reading and writing skills, namely Word Spelling, Proofreading, and Text Reading. Seven additional tests focus on associated language deficits such as phonological processing, rapid naming, short term memory and working memory, morphology and syntax, automatization, text comprehension and vocabulary.

IDAA.

The IDAA (Van der Leij et al., 2012) is a new, standardized diagnostic instrument for dyslexia in young adults. Norms have been collected on secondary school children (final two years, ages from 16 to 18). This test battery was developed by The University of Amsterdam, Lessius College for Higher Education (Antwerp), and Muiswerk.

The 5 subtests we used in this study form the core of the IDAA, namely Reversals, Lexical decision, Flash typing words, Flash typing pseudowords and Flash typing English words[3]. For this test the participant is seated in front of a computer screen wearing headphones. The test battery is fully computer administered. Instructions are given visually on the computer screen and auditory through headphones. For the registration of reactions a standard computer keyboard is used. The sequence of the tasks is identical for each participant. During administration, no interaction takes place between the participant and the test leader.

To make comparisons with other studies easier, in the remainder we itemize the subtests administered according to the cognitive function they assess rather than the test battery they come from: reading and spelling, phonological processing, general intelligence, vocabulary, speeded naming, memory, morphology and syntax, math and speed of processing. The variable names used in the analysis are mentioned between brackets.

[3] There are two more subtests in the IDAA (all administered) that were not included in this study: a questionnaire rating print exposure and a test to measure baseline reaction speed. This second subtest is only used to rule out significant problems with a computer based administration. None of the participants exhibited any problems on this domain.

Reading and spelling

Word reading. A classic word reading test in the Dutch-speaking countries is the *EMT* [One Minute Test] (Brus & Voeten, 1991). The list consists of 116 words of increasing difficulty printed in four columns. The participant has to read aloud as many words as possible in one minute trying to minimize reading errors. Raw scores are obtained for the total number of words read correctly (Word reading correct) and the percentage of errors made (Word reading percentage error).

English word reading. Given the importance of English in higher education, we also included an evaluation of English reading and writing skills. The English version of the EMT, namely the One Minute Test or OMT (Kleijnen & Loerts, 2006) was used as a measure for English word reading skill. This test is in all aspects comparable to the Dutch EMT, except that English words are presented instead of Dutch ones (English word reading correct, English word reading percentage error)

Text reading. In this test from the GL&SCHR, participants are asked to read aloud a Dutch text which becomes increasingly difficult. Substantial errors (e.g. addition/substitution/omission of letters, syllables and/or words) and time consuming errors (e.g. repeating a word/sentence, spelling a word aloud) are registered as well as the total reading time (Text reading time consuming errors, Text reading substantive errors, Text reading time).

Silent reading. The test that was used -"Hoe gevaarlijk is een Tekenbeet? [How Dangerous Can a Tick Be?] "- is part of a screening instrument published by Henneman, Kleijnen, and Smits (2004). It provides an indication of silent reading speed and the ability to retain information. Participants are instructed to silently read a text of 1023 words, taking into account that they will have to write a short summary afterwards without looking at the text. The written summary is evaluated based on measures of content, structure and syntax but the results of these analyses are beyond the scope of the present paper (Tops, Callens, Van Cauwenberghe, Adriaens, & Brysbaert, in press). The time needed to read the text is noted (Silent reading).

Pseudoword reading**.** The standard Dutch pseudoword reading test is *De Klepel* (van den Bos et al., 1999). The test contains 116 pseudowords that follow the Dutch grapheme-phoneme correspondence rules. Administration and scoring are identical to the EMT (Pseudoword reading correct, Pseudoword reading percentage error)

Automation. This part of the GL&SCHR is administered in combination with the pseudoword reading test, the Klepel (see above). After the administration of the Klepel, the participant is asked to repeat the first column of the test 8 times, as fast as possible with as few errors as possible. Based on the number of seconds needed in the first, the second, the seventh and the eighth repetition an automatization score is calculated. From the average of the first two repetitions, the expected values for repetition 7 and 8 can be calculated through use of the data collected from the norm group. The difference in percentage between the expected and real values is the raw score for automatization (Automatization).

Flash tasks. In the four subtests of the IDAA, items are presented briefly (200ms) in the center of a computer screen after the participant clicks on a colored button (different colors to sustain attention). Items are immediately followed by a mask to avoid after-image effects. Masks are always a series of randomized symbols e.g. #%@£$. The participants are required to react as quickly as possible either by deciding whether the presented item is an existing word (lexical decision) or by typing in the items they saw (Flash typing words, pseudowords and English words). A practice set of three items is followed by three test blocks. The total number of correct answers is registered.

- *Lexical decision.* Participants have to decide whether a flashed item is a word or a pseudoword. When the item is a word, "S" must be pressed, when not "L". A total of 40 items is administered in three blocks. In each block half of the items are correct and half are incorrect. To focus on orthographic knowledge, the pseudowords are homophones of existing words. The first block consists of 10 one syllable Dutch words, and 3 English loan words. Block 2 entails 10 two syllable Dutch words and 3 English loan words of three syllables. In the last block 10 three syllable Dutch words and 4 English loan words of three syllables are presented (Lexical Decision).

- *Flash typing words.* In this subtest the presented items (words) have to be reproduced. Participants have to type in the word they saw. The composition of this test is identical to the lexical decision except for the fact that all words are spelled correctly (Flash typing words).

- *Flash typing pseudowords.* Again, reproduction of flashed items is required. All items are now pseudowords. Block 1 contains 10 monosyllabic pseudowords, block 2 10 disyllabic pseudowords and finally block 3 10 three syllable pseudowords (Flash typing pseudowords).

- *Flash typing English words.* Items in this subtest are all English words that have to be reproduced. Block 1 contains 10 one syllable words and 3 one syllable words ending with an unpronounced [e] e.g. "*tape*". In the second block 10 two syllable words and 3 two syllable words ending with an unpronounced [e] e.g. "*deceive*" are presented. The third and final block consists of 10 three syllable words and 4 three syllable words with [e] at the end (Flash typing English words).

Text comprehension. A text is presented in printed form and at the same time read out by the computer. Afterwards, the participant has to answer questions about the text. These questions rely on either literal comprehension or deductive knowledge. The number of correctly answered questions is noted (Text comprehension).

Word spelling. In the Word spelling test, participants write down 30 words that are dictated at a constant pace of one word per 3 seconds (prerecorded audio file). Afterwards they are given the opportunity to correct their answers and listen again to the words they were unable to finish. Half of the words follow the Dutch spelling rules; the other half are exception words (involving inconsistent sound-letter mappings that must be memorized). Participants are also asked to rate how certain they feel about each answer (certain, almost certain, uncertain). When a correct answer is given and the participant is certain, the weighted item score is 5. When the word is spelled correctly but the participant is uncertain the score is only 2 (Word spelling). The score is a combination of accuracy and a rating of certainty.

English word spelling. We used a standardized English test to measure English word spelling: the *WRAT-III English Word Dictation* (Wilkinson, 1993). The test was administered according to the guidelines in the English manual. The examiner says a word, uses it in a significant context, and repeats the word. The participant writes it down. The test consists of 42 words. The total number of words that are correct is noted (English word spelling).

Sentence dictation. Because higher education involves academic language, we also administered an advanced spelling test (AT-GSN [General Test for Advanced Spelling in Dutch]), developed and used at the University of Leuven (Ghesquière, 1998). The test consists of 12 paragraphs with exception words and challenging spelling rules (e.g. for the verbs). The correct use of capitals and punctuation marks is also taken into account. The score is the total number of errors made (Sentence spelling).

Proofreading (GL&SCHR). Participants are given 20 sentences in which they have to correct possible spelling mistakes. The total number of correct responses is noted (Proofreading).

Writing speed. A measure of writing speed is included in the Word spelling test by counting the number of words the participant was able to complete at the end of the audio file (Writing speed).

Phonological processing

Phonological awareness was tested with *Spoonerisms* and *Reversals* from the GL&SCHR and *Reversals* from the IDAA. In the ***Spoonerisms*** test the first letters of two orally presented words must be switched (e.g., Harry Potter becomes Parry Hotter). Accuracy and speed (measured with a stop-watch) are measured for 20 items (Spoonerisms accuracy, Spoonerisms time). In the ***Reversals*** test, participants have to judge if two spoken words are reversals or not (e.g. rac-car). Again, accuracy and speed (measured with a stop-watch) are measured for 20 items (Reversals accuracy, Reversals time). The ***Reversals*** test of the IDAA was originally designed by Buis (1996) and digitalized by Bekebrede, Van der Leij, Plakas, and Schijf (2006). This subtest consists of 3 practice items followed by 60 test items. The items are presented auditorily by means of headphones. Each item comprises a pseudoword pair e.g. kel-len or mel-lem. First items of the pseudoword pairs are constituted as followed: CVC (N=10), CVCC (N=20) , CCVC (N=20), CCVCC (N=10). Within each pseudoword pair, the vowel remains unchanged but the consonants may be switched. Randomization of item pair sequence is used to avoid the creation of an increase in difficulty. Participants are required to determine whether the second pseudoword is the exact reversal of the first. Participants respond by pressing "L" for "no" and "S" for "yes". The number of correct answers is registered (Reversals).

General Intelligence

General information. ***Personalities*** from the KAIT measures general knowledge acquired primarily through media. In this test pictures of 18 famous people are shown and participants have to name the persons (e.g., Ghandi). The total score is the number of correctly identified individuals (Personalities).

Problem solving/reasoning. Three subtests for fluid intelligence of the KAIT (Dekker et al., 2004) were used to evaluate this cognitive skill: *Symbol learning*, *Logical reasoning*, and *Secret codes*. In the ***Symbol learning*** test, the participant has to remember and reproduce series of symbols in different sentence-like combinations (with increasing difficulties). The total score is the number of correctly identified items in 20 combinations (Symbol learning). Symbol learning is said to reflect new learning and relies the least of all subtests on previously acquired knowledge. It is said to simulate reading and is comparable to learning a new language with the need to learn plurals, negations and conjugations

(Kaufman & Kaufman, 1993). As for ***Logical reasoning***, information is given about the relative location (e.g. in a line, on stairs) of a number of items (people or animals). By logical reasoning the participant has to infer the location of a target item. A total score is given on 17 (Logical reasoning). The main goal is to measure deductive and syllogistic reasoning. In the ***Secret codes*** test three or four items are given a unique code consisting of different parts. Based on these codes the participant has to infer which codes new target items should get. Eighteen codes have to be broken (Secret Codes). This subtest is developed to measure problem solving abilities.

Auditory comprehension. This test of the KAIT comprises the presentation of 6 *s*hort audio fragments about which the experimenter asks 19 content questions the participant has to answer. The raw score is the total number of correct answers (Auditory comprehension). Performance on this subtest reflects the ability to understand/reproduce auditory information, to interpret it correctly and integrate it with acquired knowledge.

Vocabulary

We used *Vocabulary* from the GL&SCHR and *Definitions* and *Double Meanings* from the KAIT to evaluate this language function: In ***Vocabulary*** participants are asked to give definitions of low frequency words (e.g., the Dutch equivalents of anonymous and simultaneous). The total number of correct answers is the raw score (Vocabulary). The participant has to find a word based on a number of letters and a short description of the word in the subtest ***Definitions*** (e.g., “A dark color: .r..n”). There are 25 items in total. The total number of correct answers is noted (Definitions). Not only vocabulary is measured but also verbal conceptualization. In the ***Double meanings*** test the participant has to find a word that is in some way connected to two word pairs (e.g., the connection between biology-body and jail-lock is the target word *cell*). The total number of correct answers out of 28 is noted (Double meanings).

Rapid naming

In the naming task of the GL&SCHR, discrete versions of the classic naming tasks are used, in which participants are asked to rapidly name letters, digits, colors, or objects presented one-by-one on a computer screen (4 tests). The participant determines the pace by pressing the Enter button. Speed is measured with a stopwatch (Letter naming, Digit naming, Object naming and Color naming) for the naming a 4 series of 35 items.

Memory

Verbal memory*.* The GL&SCHR contains a short-term memory test for syllables, the ***Phonological STM*** task, and one for words, namely the ***Verbal STM*** test. The participant is placed in front of a computer screen. After pressing the enter button the participant sees a series of items presented one at a time for 2 seconds with an interval of 0.3 seconds between items. At the end of each series the participant has to reproduce the items remembered. The number of items within a series increases steadily. The ***Delayed auditory comprehension*** test of the KAIT is a delayed memory task in which 8 questions have to be answered about a text that was read out at the beginning of the administration of the KAIT (Phonological STM, Verbal STM and Delayed auditory comprehension).

Working memory. Participants have to reproduce randomly presented series of letters or digits in ascending order in this subtest from the GL&SCHR. The number of items within a series increases steadily. Administration is identical to the above STM tasks (Working memory).

Visuo-spatial memory. Visuo-spatial memory was tested with two subtests of the KAIT namely *Block patterns, Delayed symbol learning*, and *Visual STM* from the GL&SCHR. In the ***Block patterns*** test 16 yellow-black patterns have to be reproduced with 6 cubes from memory. A score on 16 is given (Block patterns). Not only visual memory is tested but also visual and spatial construction. The ***Delayed symbol learning*** test is a delayed retention task of the symbols used in the Symbol learning test containing 13 combinations (Delayed symbol learning). In the ***Visual STM*** task the participant is placed in front of a computer screen. After pressing the enter button the participant sees a series of non-verbal shapes, presented one item at a time for 2 seconds with an interval of 0.3 seconds between items. At the end of each series the participant has to draw the items remembered (Visual STM).

Morphology and Syntax

In this subtest (GL&SCHR) 20 sentences are presented, in which the participant has to identify the syntactical or grammatical errors. This weighted score (Morphology and syntax) takes into account the certainty of the participant about the answer given (see Word spelling). This test is said to reflect morphological and syntactical knowledge and the ability to use this knowledge.

Math

We used the *Tempo Test Rekenen (TTR;* (de Vos, 1992)), a Dutch standardized test for mental calculations. It is designed to examine the rate at which participants mentally perform simple mathematical operations (single and double digits). There are five lists, consisting of additions, subtractions, multiplications, divisions below 100, and a random sequence of all four operations. Participants are given one minute per list to solve as many items as possible. The score per subtest is the number of processed items minus the number of errors made (Mental calculation addition, subtraction, multiplication, division and mix).

Speed of processing

To measure the participants' speed of processing, we used the *CDT* or *Cijfer Doorstreep Test* [Digit Crossing Test] (Dekker, Dekker, & Mulder, 2007). This is a standardized Dutch test to detect attention deficits and measure the speed and accuracy of processing in a task of selective attention involving task-switching. There are 960 digits from 0 to 9 presented in 16 columns. Students have three minutes to underline as many fours and to cross out as many threes and sevens as possible. Scores for the total number of correct items (Speed of processing correct) and the percentage of missed/errors (Speed of processing percentage error/missed) are obtained.

Procedure

The complete test protocol was administered in two sessions of about three hours each. The protocol was divided in two counterbalanced parts. The order of tests in part one and part two was fixed and chosen to avoid succession of similar tests. There was a break halfway each session. Students started with part one or two according to an AB-design. All tests were administered individually by three test administrators[4] according to the manual guidelines. Testing occurred in a quiet room with the test administrator seated in front of the student.

Statistical methods

a. Effect sizes

The aim of the analysis is to interpret the results as a function of the effect sizes obtained after comparison of the dyslexic with the control group. Effect sizes of variables and factors were calculated by means of a standardized linear regression with group as the only predictor. This corresponds to Cohen's d computed on the basis of the overall variance (in contrast to the pooled variance). Note that the effect sizes reported here may deviate slightly from the earlier analyses of the data set (Callens et

[4] The test administrators were the two first authors and a test psychologist. To standardize the administration each administrator read the manuals of the tests, had a practice session, and was observed by the others during the first ten sessions.

al., 2012). These deviations arise from the data imputation method described below and because of the choice of the effect size measure. In Callens et al. (2012), for some variables the effect size was estimated based on Cohen's d using the pooled variance, whereas for others a nonparametric approach was used.

b. Factor analysis

The most suitable statistical technique to address our research questions is Exploratory Factor Analysis (EFA). An Exploratory Factor Analysis tries to explain the common variance in a group of variables by relating the observed scores to a reduced number of underlying latent factors. Principal Component Analysis (PAC) is similar, but models *all* of the variation in the variables: the common variance, the unique variance and the error variance. Confirmatory Factor Analysis (CFA) is also similar but requires the researcher to have priory hypotheses about the connections between the variables and factors, which we did not have.

In EFA the number of latent factors is chosen by the researcher. This choice can be guided by existing theory, interpretability, or by some statistical criteria. Here, in a first stage we chose for a thirteen factor solution based on the Kaiser-Guttman rule (thirteen factors had an eigenvalue larger than one). Following the recommendations of Costello and Osborne (2005) we eliminated the variables that did not load on any specific factor and did a stage 2 EFA. This resulted in a 10-factor model.

The main outcome of an EFA is a factor loading matrix. This matrix shows how each variable can be expressed as a linear combination of the common factors, plus a unique factor that contains error variability and variability that is specific to the variable. Both the loadings and the uniqueness are reported in the supplementary materials. In an EFA, factors are extracted according to the amount of variance explained. In the result section and discussion below, we re-ordered and named them according to the factor effect size, because this is a better estimate of the difference between the groups. In the supplementary materials tables 2 and 3, the SS loadings demonstrate the amount of explained variance and thus the order of extraction. Factor loadings typically vary between -1 and 1. It is up to the researcher to determine how large a loading has to be before it is interpreted. According to Tabachnick and Fidell (2001) a good rule of thumb for the minimum loading of an item is .32, meaning that there is about 10% overlapping variance with the other variables. Uniqueness relates to the variables and gives the proportion of variance not explained by the underlying factor structure. It varies between 0 and 1 where lower is better; a high uniqueness value indicates that the variable is not really related to the other variables tested. Costello and Osborne (2005) gave some simple recommendations for the interpretation of factors. When item communalities exceed .8 they are considered high, but in social sciences these commonly vary between .4 and .7. Also, a factor is considered weak and unstable when it has fewer than three tests loading on it; strong and solid when five or more tests strongly load on it (.50 or higher).

Before interpreting the loadings one typically chooses to rotate the factor solution to a simple structure. Ideally, after rotation each variable has a high loading on one factor and a loading close to zero on the other factors. Rotations can be orthogonal or oblique. Here we did not opt for an orthogonal rotation, as we do not assume that the underlying factors are independent of each other. The specific rotation method used was the promax rotation. For each of the participants the scores on the latent factors were computed using Bartlett's method. This allows us to compare the scores of the dyslexic and control group on the latent factors. Finally, a correlation matrix of the latent variables is reported as well. However, one should keep in mind the following when interpreting these correlations in the context of the present study. For factors with large effect sizes, correlations reflect what is known in the dyslexia literature because these factors are mostly due to the variance between the groups. For small effect sizes, the interpretations have less bearing on dyslexia because these factors mainly reflect variance within the groups. When correlations are found between factors with small and large effect sizes, no interpretation can be made as it is unclear where the common variance comes from. Therefore, interpretation of the correlation matrix must remain exploratory.

c. Data preprocessing

Because of the large number of variables in the analysis, missing values and outliers were imputed instead of removed. Missing values were replaced by the median. Outliers were replaced by the first/third quartile minus/plus 1.5 times the interquartile range (i.e. outliers were replaced by the most extreme value that would have been plausible according to the box plot rule). Without imputation complete-case analysis would have reduced the data set by 12 participants because of 45 (0.22%) missing values and by 78 participants because of 190 (1.45%) outliers.

Results

Effect sizes of the variables

Effect sizes, t-values and p-values of the 53 overlap largely with those reported in chapter 2. However, because the effect sizes used in this paper can deviate slightly from those reported before, their exact values can be found in Table 1. In Figure 1, all the variables are ranked according to their observed absolute effect size between groups (from largest ES [variable nr.53] to smallest [variable nr.1]). A color scale is used, going from green for the smallest effect sizes, over yellow to red for the largest effect sizes. The figure also includes information on the p-values (n.s. = non significant, $p < .05$ and $p < .01$) and the effect sizes (small ES for the range 0.2 - 0.5, medium for 0.5 - 0.8, and large for ES above 0.8).

As expected, large effect sizes were found for nearly all measures related to reading and spelling. The only exceptions were some error-related reading variables, Writing speed, Automatization, and Text comprehension. Large effect sizes were also found for phonological processing tasks (except for Phonological STM and Spoonerisms accuracy), and for Mental calculations (except for subtractions). Finally, the letter and digit naming tasks revealed large effect sizes between the two reading proficiency groups as well. A smaller number of tasks revealed medium effect sizes such as error related measures of the reading tasks (Pseudoword reading percentage error, Text reading time consuming errors, English word reading percentage error) and several tasks of lexical retrieval (Color naming, Definitions, Vocabulary). Medium effect sizes were also found for Speed of processing correct, Phonological STM, Mental calculation subtraction and Spoonerism accuracy. All other variables had small effect sizes. These mostly included the measures of general intelligence (all measures of Fluid IQ and most of Crystallized IQ) and memory (except for Phonological STM). Other small and nonexistent effect sizes were found for some specific reading and writing related tasks such as Automatization, Text comprehension, and Writing speed. Finally, the variables Speed of processing percentage errors and Object naming did not produce practically relevant differences between the groups either.

Table 1

Variables ranged from large effect size to small effect size, t-values and exact p-values.

Variable °	Variable	Effect sizes	t-value	p-value
53	Word spelling (GL&SCHR)	1.440	-14.710	0.000
52	Word reading correct (EMT)	1.670	-13.430	0.000
51	Flash typing English words (IDAA)	1.570	-13.620	0.000
50	Sentence spelling (AT-GSN)	1.430	12.080	0.000
49	Flash typing pseudowords (IDAA)	1.950	-12.080	0.000
48	Lexical decision (IDAA)	1.760	-11.150	0.000
47	Pseudoword reading correct (KLEPEL)	1.470	-11.270	0.000
46	Flash typing words (IDAA)	1.070	-10.940	0.000
45	English word spelling (WRAT)	1.940	-10.510	0.000
44	English word reading correct (OMT)	1.870	-10.150	0.000
43	Text reading time (GL&SCHR)	1.440	9.440	0.000
42	Spoonerisms time (GL&SCHR)	1.140	9.470	0.000
41	Reversals (IDAA)	1.240	-8.410	0.000
40	Reversals time (GL&SCHR)	1.220	8.890	0.000
39	Mental calculation mix (TTR)	0.994	-8.850	0.000
38	Silent Reading (Tickbite)	0.955	7.710	0.000
37	Proofreading (GL&SCHR)	0.953	-7.530	0.000
36	Letter naming (GL&SCHR)	0.910	7.210	0.000
35	Digit naming (GL&SCHR)	0.899	7.080	0.000
34	Mental calculation division (TTR)	0.893	-7.440	0.000
33	Reversals accuracy (GL&SCHR)	0.889	-7.060	0.000
32	Text reading substantive errors (GL&SCHR)	0.886	6.730	0.000
31	Mental calculation addition (TTR)	0.875	-6.870	0.000
30	Morphology and syntax (GL&SCHR)	0.825	-6.870	0.000
29	Mental calculation multiplication (TTR)	0.818	-6.250	0.000
28	Word reading percentage error (EMT)	0.815	6.990	0.000
27	Pseudoword reading percentage error (KLEPEL)	0.763	5.280	0.000
26	Color naming (GL&SCHR)	0.760	5.970	0.000
25	English word reading percentage error (OMT)	0.705	5.170	0.000
24	Text reading time consuming errors (GL&SCHR)	0.671	5.240	0.000
23	Spoonerisms accuracy (GL&SCHR)	0.657	-4.080	0.000
22	Mental calculation subtraction (TTR)	0.639	-4.570	0.000
21	Vocabulary (GL&SCHR)	0.638	-4.480	0.000
20	Phonological STM (GL&SCHR)	0.637	-4.420	0.000
19	Speed of processing correct (CDT)	0.635	-4.260	0.000
18	Definitions (KAIT)	0.624	-4.360	0.000
17	Writing speed (GL&SCHR)	0.494	-3.980	0.000
16	Working memory (GL&SCHR)	0.469	-3.400	0.001
15	Text comprehension (GL&SCHR)	0.450	-3.610	0.001
14	Double meanings (KAIT)	0.426	-3.780	0.002
13	Delayed auditory comprehension (KAIT)	0.373	-2.770	0.008
12	Personalities (KAIT)	0.351	-2.170	0.013
11	Speed of processing percentage errors/missed (CDT)	0.347	2.880	0.014
10	Verbal STM (GL&SCHR)	0.345	-2.690	0.014
9	Automation (GL&SCHR)	0.330	2.360	0.019
8	Visual STM (GL&SCHR)	0.298	-2.290	0.035
7	Object naming (GL&SCHR)	0.251	1.860	0.076
6	Block patterns (KAIT)	0.183	1.293	0.197
5	Logical reasoning (KAIT)	0.141	-0.998	0.319
4	Secret codes (KAIT)	0.111	-0.781	0.436
3	Auditory comprehension (KAIT)	0.106	-0.745	0.457
2	Symbol learning (KAIT)	0.051	-0.362	0.717
1	Delayed symbol learning (KAIT)	0.050	-0.351	0.726

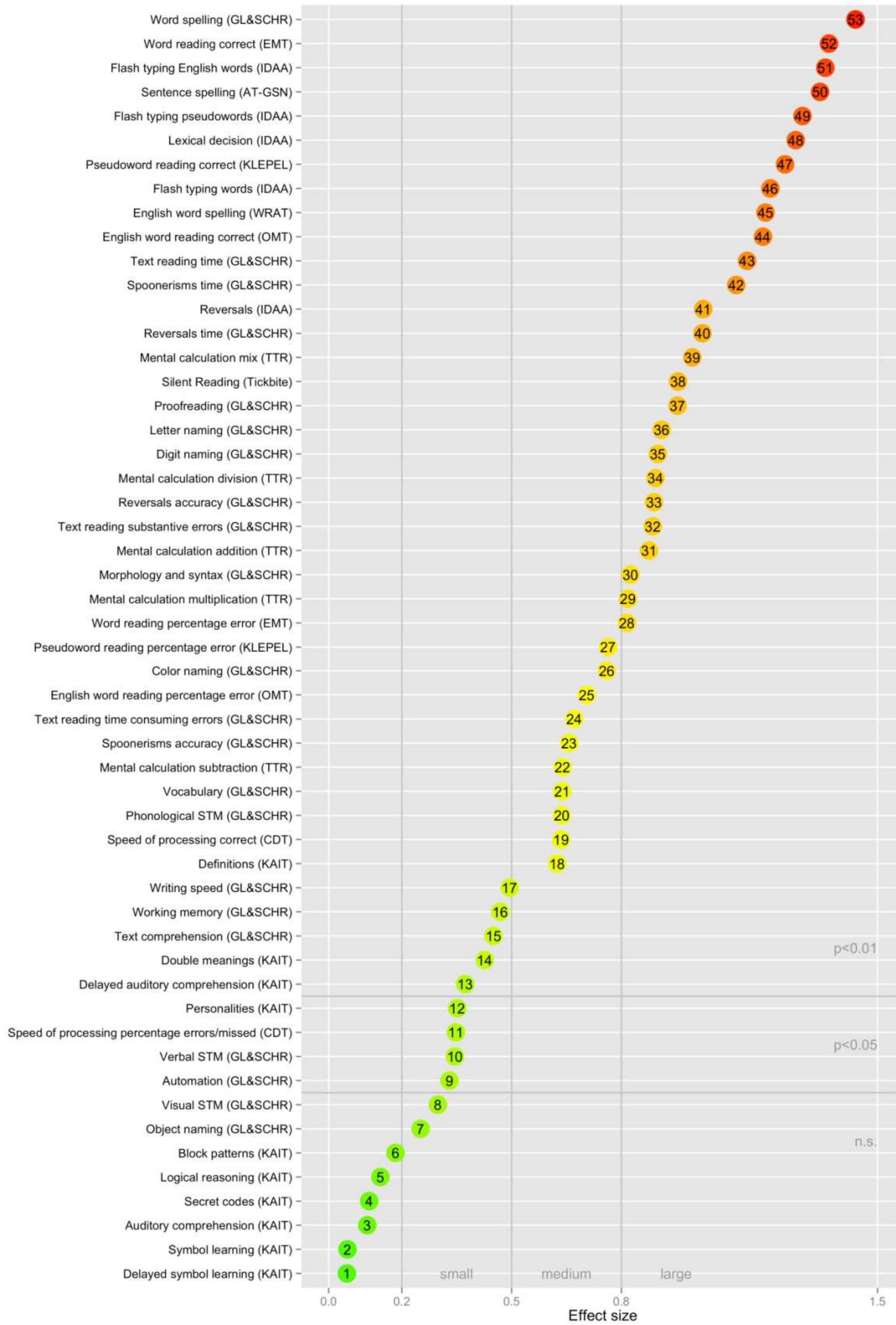

Figure 1. Effect sizes when comparing the dyslexic and the control group expressed as Cohen's d. The tests are ordered according to the absolute effect size. The effect size is reflected in both the horizontal position and in the color of the dots. Color varies from green for no effect over yellow for a medium effect to red for a large effect.

Factor analysis on the variables

The output of the stage 1 exploratory factor analysis provided us with a 13-factor model as the model with the best fit, as can be seen in Figure 2. The same coloring scheme is applied to the factor analysis plot (Figure 2) as in Figure 1. All variables and factors are colored according to their effect size between groups. Table 2 shows the variables (plus the variable numbers) that had a factor loading above .32. Factors are listed according to their effect size going from large to small. More detailed information on all factor loadings, their uniqueness and the explained variance can be found in Table 3. Together, the 13 factors explained 54.3% of variance in the variables.

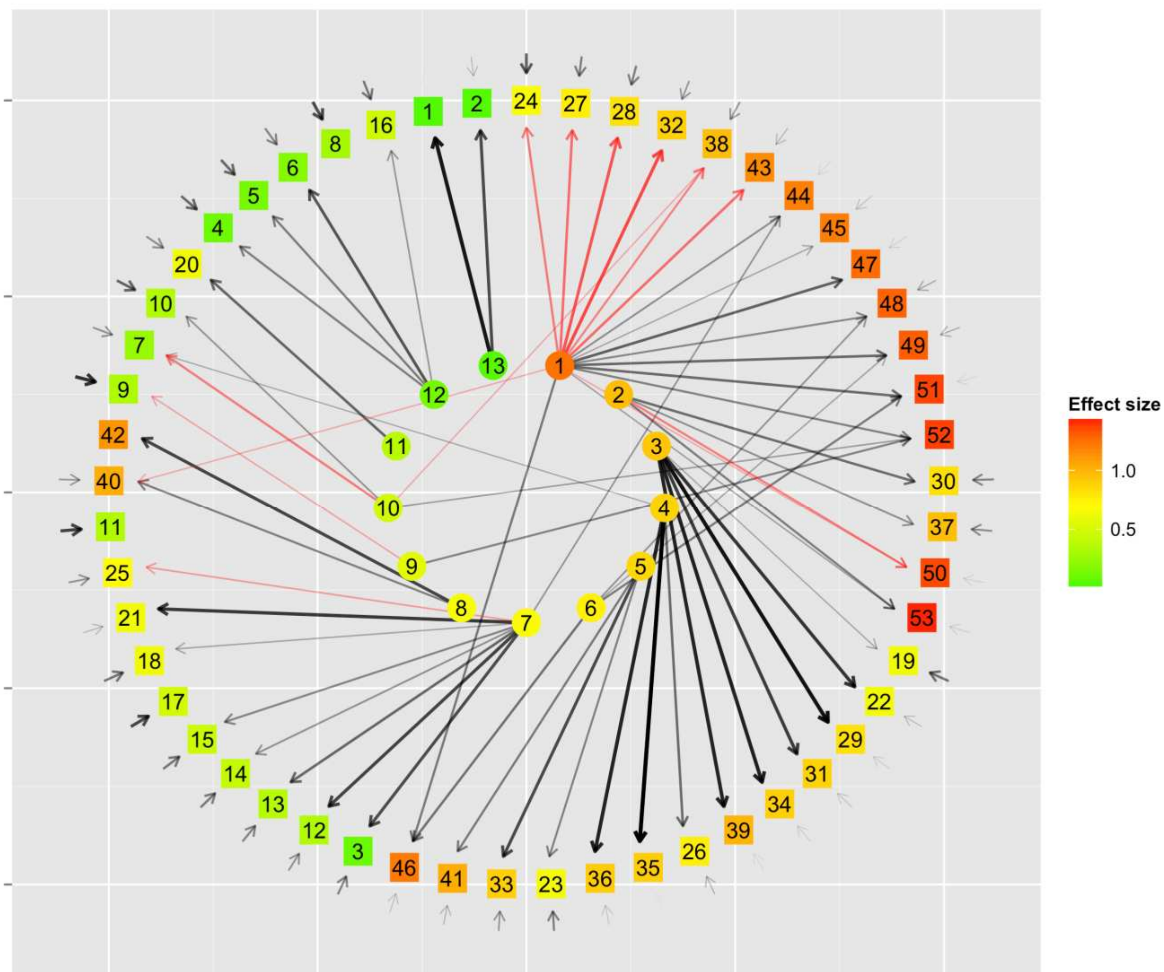

Figure 2. Visualization of the stage 1 EFA solution. The nodes in the outer circle represent the variables; the nodes in the inner circle the factors. Both the variables and factors are color coded according to the effect size. Color varies from green for no effect over yellow for a medium effect to red for a large effect. The connections between the factors and the variables represent the factor loadings. Only loadings with values above .32 or below -.32 are shown. Transparency and thickness are a function of the absolute loading. Positive loadings are plotted in black, negative loadings in red. The outer arrows arriving at the variables represent the uniqueness of each variable.

Table 2
Stage 1 EFA Factors, their Effect Sizes and their Variables with Factor Loadings above .32 or below -.32.

	Factor °	Effect size	Variable °	Variable	Loading
Large ES	**Factor 1****	**1,228**	32	Text reading substantive errors (GL&SCHR)	-0.780
			28	Word reading percentage error (EMT)	-0.731
			47	Pseudoword reading correct (KLEPEL)	0.650
			43	Text reading time (GL&SCHR)	-0.630
			27	Pseudoword reading percentage error (KLEPEL)	-0.627
			49	Flash typing pseudowords (IDAA)	0.619
			51	Flash typing English words (IDAA)	0.617
			24	Text reading time consuming errors (GL&SCHR)	-0.563
			46	Flash typing words (IDAA)	0.551
			38	Silent Reading (Tick bite)	-0.522
			52	Word reading correct (EMT)	0,512
			48	Lexical decision (IDAA)	0.478
			44	English word reading correct (OMT)	0.455
			53	Word spelling (GL&SCHR)	0.368
			50	Sentence spelling (AT-GSN)	-0.346
			40	Reversals time (GL&SCHR)	-0.345
			45	English word spelling (WRAT)	0.340
	Factor2**	**0,955**	30	Morphology and syntax (GL&SCHR)	0.600
			50	Sentence spelling (AT-GSN)	-0.538
			53	Word spelling (GL&SCHR)	0.530
			37	Proofreading (GL&SCHR)	0.449
	Factor 2**	**0,926**	29	Mental calculation multiplication (TTR)	0.924
			34	Mental calculation division (TTR)	0.884
			39	Mental calculation mix (TTR)	0.874
			22	Mental calculation subtraction (TTR)	0.823
			31	Mental calculation addition (TTR)	0.798
			19	Speed of processing correct (CDT)	0.334
	Factor 4**	**0,878**	35	Digit naming (GL&SCHR)	0.981
			36	Letter naming (GL&SCHR)	0.877
			26	Color naming (GL&SCHR)	0.610
			7	Object naming (GL&SCHR)	0.324
	Factor 5**	**0,854**	33	Reversals accuracy (GL&SCHR)	0.743
			41	Reversals (IDAA)	0.546
			23	Spoonerisms accuracy (GL&SCHR)	0.506
Medium ES	**Factor 6****	**0,753**	46	Flash typing words (IDAA)	0.585
			51	Flash typing English words (IDAA)	0.536
			48	Lexical decision (IDAA)	0.425
			49	Flash typing pseudowords (IDAA)	0.354
	Factor 7**	**0,667**	21	Vocabulary (GL&SCHR)	0.808
			12	Personalities (KAIT)	0.773
			3	Auditory comprehension (KAIT)	0.739
			13	Delayed auditory comprehension (KAIT)	0.630
			15	Text comprehension (GL&SCHR)	0.500
			14	Double meanings (KAIT)	0.445
			44	English word reading correct (OMT)	0.414
			25	English word reading percentage error (OMT)	-0.404
			18	Definitions (KAIT)	0.350
	Factor 8**	**0,664**	41	Spoonerisms time (GL&SCHR)	0.762
			40	Reversals time (GL&SCHR)	0.517
	Factor 9**	**0,572**	52	Word reading correct (EMT)	0.501
			9	Automation (GL&SCHR)	-0.369
Small ES	**Factor 10****	**0,482**	7	Object naming (GL&SCHR)	-0.560
			10	Verbal STM (GL&SCHR)	0.427
			52	Word reading correct (EMT)	0.381
			38	Silent Reading (Tickbite)	-0.349
	Factor 11**	**0,382**	20	Phonological STM (GL&SCHR)	0.636
	Factor 12	**0,139**	6	Block patterns (KAIT)	0.702
			5	Logical reasoning (KAIT)	0.539
			4	Secret codes (KAIT)	0.528
			16	Working memory (GL&SCHR)	0.409
	Factor 13	**0,056**	1	Delayed symbol learning (KAIT)	0.914
			2	Symbol learning (KAIT)	0.743

Table 3

Stage 1 EFA Factor Loadings, Uniqueness and Explained Variance of the 53 Variables Ordered from Large Effect Size to Small Effect Size.

		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Factor10	Factor11	Factor12	Factor13	*Uniqueness*
53	Word spelling (GL&SCHR)	**0.368**	0.028	-0.030	-0.031	-0.022	0.070	0.070	-0.132	**0.530**	0.043	0.107	0.057	0.143	0.073
52	Word reading correct (EMT)	**0.512**	0.042	0.031	-0.076	-0.048	-0.004	**0.501**	-0.14	0.013	**0.381**	0.009	-0.008	0.074	0.251
51	Flash typing English words (IDAA)	**0.617**	0.015	0.015	0.063	0.071	-0.015	-0.064	-0.046	0.135	-0.015	-0.024	-0.087	**0.536**	0.515
50	Sentence spelling (AT-GSN)	**-0.346**	0.004	-0.004	0.021	-0.080	0.006	-0.118	0.058	**-0.538**	-0.041	-0.033	0.077	-0.156	0.626
49	Flash typing pseudowords (IDAA)	**0.619**	-0.075	-0.084	0.009	-0.211	0.144	-0.038	0.072	0.033	-0.017	0.141	0.017	**0.354**	0.628
48	Lexical decision (IDAA)	**0.478**	0.050	-0.043	0.036	-0.195	-0.023	0.097	0.143	0.269	-0.083	0.027	0.073	**0.425**	0.505
47	Pseudoword reading correct (KLEPEL)	**0.650**	-0.007	0.003	0.021	-0.061	0.163	0.198	-0.189	-0.069	0.105	0.296	-0.011	-0.087	0.448
46	Flash typing words (IDAA)	**0.551**	-0.099	-0.015	-0.008	-0.026	-0.026	0.061	0.043	0.116	-0.024	-0.033	-0.084	**0.585**	0.750
45	English word spelling (WRAT)	**0.340**	0.233	0.088	-0.076	0.182	0.088	0.123	-0.198	0.276	-0.112	-0.043	-0.041	0.135	0.829
44	English word reading correct (OMT)	**0.455**	**0.414**	0.056	-0.096	0.217	-0.002	0.228	-0.001	-0.230	0.179	0.017	0.070	0.113	0.639
43	Text reading time (GL&SCHR)	**-0.630**	-0.072	0.072	0.040	-0.018	0.044	-0.318	0.100	0.052	-0.311	0.066	0.029	-0.001	0.771
42	Spoonerisms time (GL&SCHR)	-0.255	-0.114	-0.052	-0.069	-0.230	0.071	-0.009	0.133	-0.032	0.046	-0.105	**0.762**	-0.105	0.446
41	Reversals (IDAA)	0.315	-0.106	-0.114	-0.080	0.079	0.057	0.021	0.287	0.015	-0.029	**0.546**	0.006	-0.015	0.511
40	Reversals time (GL&SCHR)	**-0.345**	0.015	0.066	0.068	-0.130	-0.107	0.039	0.183	0.007	0.067	0.012	**0.517**	-0.022	0.554
39	Mental calculation mix (TTR)	0.001	0.067	-0.122	0.060	0.021	**0.874**	0.016	0.067	0.061	-0.018	0.038	0.006	0.054	0.571
38	Silent Reading (Tickbite)	**-0.522**	-0.192	0.027	0.011	0.024	0.011	-0.164	-0.044	0.006	**-0.349**	0.156	-0.014	-0.037	0.560
37	Proofreading (GL&SCHR)	0.311	-0.037	0.089	-0.090	-0.144	0.112	-0.008	-0.022	**0.449**	0.166	-0.036	0.074	0.033	0.749
36	Letter naming (GL&SCHR)	0.065	0.070	0.061	**0.877**	0.064	0.030	-0.193	0.025	-0.104	0.001	-0.033	0.037	0.015	0.580
35	Digit naming (GL&SCHR)	0.023	0.110	-0.025	**0.981**	-0.048	0.013	-0.184	-0.011	-0.013	0.012	-0.086	-0.089	0.040	0.594
34	Mental calculation division (TTR)	-0.036	0.050	0.068	0.032	-0.012	**0.884**	0.004	-0.009	0.195	-0.050	-0.083	-0.002	-0.027	0.467
33	Reversals accuracy (GL&SCHR)	0.091	-0.017	-0.097	-0.129	-0.035	-0.032	-0.049	0.042	-0.052	-0.021	**0.743**	-0.098	-0.027	0.278
32	Text reading substantive errors (GL&SCHR)	-0.780	0.086	-0.055	0.007	-0.055	0.150	-0.0100	-0.116	0.011	0.070	-0.036	0.070	-0.009	0.245
31	Mental calculation addition (TTR)	0.138	-0.008	-0.006	-0.039	-0.017	**0.798**	-0.018	0.132	-0.105	0.044	-0.005	0.054	0.034	0.513
30	Morphology and syntax (GL&SCHR)	0.129	0.072	-0.012	-0.064	0.073	0.023	-0.119	0.005	**0.600**	0.011	-0.126	-0.052	0.020	0.680
29	Mental calculation multiplication (TTR)	-0.035	0.021	0.026	-0.004	0.011	**0.924**	-0.053	-0.142	0.160	0.015	0.059	0.040	-0.184	0.434
28	Word reading percentage error (EMT)	**-0.731**	0.121	-0.086	-0.119	-0.039	0.096	0.127	-0.080	-0.103	-0.012	0.046	0.024	-0.072	0.297
27	Pseudoword reading percentage error (KLEPEL)	**-0.627**	0.114	-0.070	-0.106	-0.052	-0.111	-0.018	-0.006	-0.067	0.080	-0.099	-0.048	0.045	0.524
26	Color naming (GL&SCHR)	-0.032	0.077	-0.094	**0.610**	0.029	-0.039	0.068	0.104	-0.049	-0.295	0.050	0.052	-0.058	0.521
25	English word reading percentage error (OMT)	-0.027	**-0.404**	-0.029	0.153	-0.250	0.094	0.286	-0.018	0.002	0.092	-0.265	0.013	-0.180	0.187
24	Text reading time consuming errors (GL&SCHR)	**-0.563**	0.021	0.101	0.052	-0.030	-0.003	0.021	-0.014	-0.015	0.062	0.155	0.028	0.029	0.491
23	Spoonerisms accuracy (GL&SCHR)	0.192	-0.040	0.153	0.216	0.050	-0.006	0.143	-0.055	0.014	0.100	**0.506**	0.011	-0.008	0.220
22	Mental calculation subtraction (TTR)	0.037	-0.008	-0.036	-0.036	0.048	**0.823**	-0.051	0.269	-0.167	-0.112	-0.027	0.002	0.064	0.411
21	Vocabulary (GL&SCHR)	0.030	**0.808**	-0.089	0.139	0.086	0.062	-0.054	0.004	0.144	0.075	-0.070	0.052	-0.003	0.411
20	Phonological STM (GL&SCHR)	0.034	-0.052	-0.004	0.036	**0.636**	0.037	0.089	0.158	0.038	0.086	-0.008	-0.170	-0.080	0.180
19	Speed of processing correct (CDT)	0.021	-0.067	0.078	-0.088	-0.065	**0.334**	0.133	0.074	-0.190	0.068	-0.062	-0.181	0.260	0.087
18	Definitions (KAIT)	0.132	**0.350**	0.026	0.044	-0.032	0.115	0.006	-0.025	0.193	0.024	0.170	0.019	-0.125	0.212
17	Writing speed (GL&SCHR)	0.036	0.244	-0.043	-0.148	0.179	0.022	0.170	0.108	0.109	-0.078	-0.089	0.026	-0.076	0.461
16	Working memory (GL&SCHR)	0.139	-0.158	-0.003	**-0.008**	0.274	0.104	0.054	**0.409**	0.040	0.210	-0.003	-0.078	0.000	0.422
15	Text comprehension (GL&SCHR)	0.115	**0.500**	-0.008	-0.015	-0.140	-0.129	0.062	0.272	0.045	0.105	0.019	0.164	0.062	0.132
14	Double meanings (KAIT)	0.038	**0.445**	0.015	0.062	-0.081	-0.060	-0.072	0.148	0.132	0.025	0.035	-0.215	-0.069	0.404
13	Delayed auditory comprehension (KAIT)	0.059	**0.630**	0.025	0.040	-0.121	-0.071	0.026	0.145	-0.109	-0.043	0.049	-0.146	-0.059	0.281
12	Personalities (KAIT)	-0.173	**0.773**	0.029	0.025	0.017	0.077	0.065	-0.166	-0.102	0.021	0.033	-0.119	-0.020	0.063
11	SOP percentage errors/missed (CDT)	0.049	0.071	-0.106	0.062	0.090	0.024	0.034	-0.130	-0.013	-0.066	-0.212	0.265	0.075	0.273
10	Verbal STM (GL&SCHR)	-0.136	-0.114	-0.102	0.054	0.265	-0.145	0.174	0.283	0.197	**0.427**	0.070	-0.050	-0.023	0.146
9	Automation (GL&SCHR)	-0.046	0.023	-0.028	0.102	-0.095	0.067	**-0.369**	-0.118	-0.015	-0.013	-0.015	-0.053	0.046	0.236
8	Visual STM (GL&SCHR)	-0.199	0.117	-0.028	0.058	0.117	0.121	-0.046	0.300	0.061	0.195	0.020	-0.061	0.018	0.237
7	Object naming (GL&SCHR)	0.055	-0.080	-0.008	**0.324**	0.032	-0.017	0.179	0.009	0.011	**-0.560**	-0.011	-0.135	0.118	0.176
6	Block patterns (KAIT)	-0.111	-0.015	0.105	**0.093**	0.102	0.088	-0.049	**0.702**	-0.117	-0.003	0.028	0.178	0.096	0.329
5	Logical reasoning (KAIT)	-0.005	0.104	0.105	**-0.027**	-0.084	-0.093	-0.015	**0.539**	0.027	0.020	0.046	0.039	0.010	0.309
4	Secret codes (KAIT)	-0.069	0.084	0.044	**-0.020**	0.043	0.182	-0.015	**0.528**	-0.077	-0.035	0.005	0.002	-0.091	0.168
3	Auditory comprehension (KAIT)	-0.168	**0.739**	-0.023	0.005	-0.079	0.049	0.034	0.072	0.007	-0.097	-0.106	-0.027	-0.081	0.147
2	Symbol learning (KAIT)	-0.045	-0.027	**0.743**	**-0.068**	0.013	0.052	0.057	0.300	0.040	-0.101	-0.060	0.018	-0.007	0.055
1	Delayed symbol learning (KAIT)	0.070	-0.042	**0.914**	-0.003	-0.002	-0.085	0.004	0.225	-0.017	0.005	-0.050	-0.055	-0.016	0.185
	SS loadings	**5,757**	**1,73**	**4,14**	**2,481**	**1,541**	**1,283**	**3,467**	**1,243**	**1,025**	**1,247**	**1,063**	**2,207**	**1,604**	
	Proportion Variance	**0,109**	**0,033**	**0,078**	**0,047**	**0,029**	**0,024**	**0,065**	**0,023**	**0,019**	**0,024**	**0,02**	**0,042**	**0,03**	

Note: Loadings above the cut-off of .32 or below -.32 are marked in bold. Below the cut-off they are printed in gray. These were taken into account for interpretation of the factors.

Before interpreting the EFA we did some further data cleaning. The following variables did not load significantly on any of the identified latent variables: Writing speed, Visual STM, Speed of processing percentage errors/missed. Automatization loaded on only one factor, which is considered weak and unstable because of the small number (2) of items loading on it. As for Phonological STM, this item formed a factor on its own, which is considered unstable. Based on statistical recommendations (Costello & Osborne, 2005) the EFA was repeated with the exclusion of these 5 items.

The stage 2 EFA provided us with a 10-factor model as the model with the best fit, as can be seen in Figure 3 and Table 4. More detailed information on all factor loadings, their uniqueness and the explained variance can be consulted in Table 5. The intercorrelations between the factors are listed in Table 6. Together the 10 factors explain 52.8% of variance in the variables. Compared to the stage 1 EFA, little has changed for the large and solid factors.

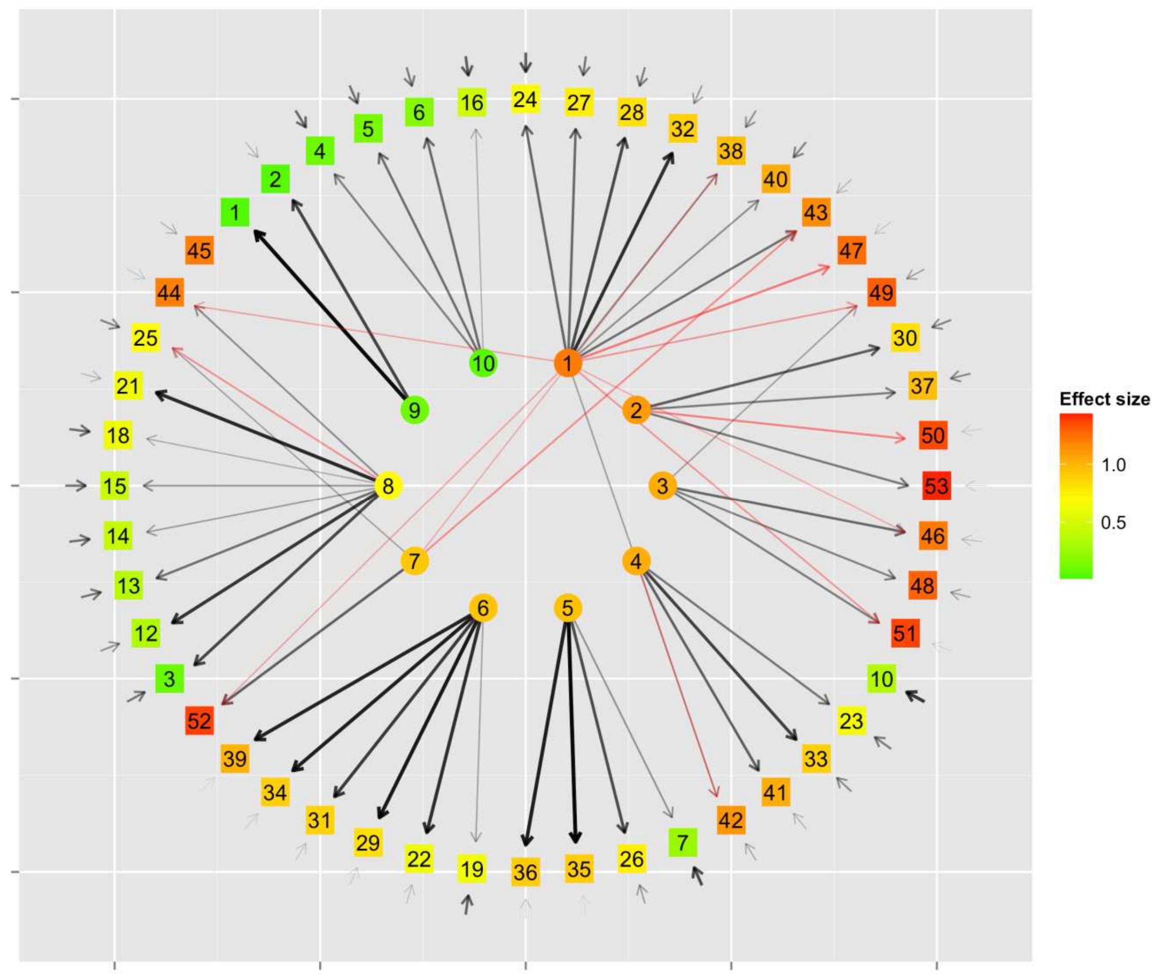

Figure 3. Visualization of the stage 2 EFA solution.

Table 4

Stage 2 EFA Factors, their Effect Sizes and their Variables with Factor Loadings above .32 or below -0.32.

	Factor °	Effect size	Variable °	Variable	Loading
Large ES	**Factor 1****	**1.200**	32	Text reading substantive errors (GL&SCHR)	0.834
			28	Word reading percentage error (EMT)	0.738
			24	Text reading time consuming errors (GL&SCHR)	0.622
			27	Pseudoword reading percentage error (KLEPEL)	0.616
			43	Text reading time (GL&SCHR)	0.586
			47	Pseudoword reading correct (KLEPEL)	-0.569
			38	Silent Reading (Tickbite)	0.457
			40	Reversals time (GL&SCHR)	0.456
			49	Flash typing pseudowords (IDAA)	-0.435
			51	Flash typing English words (IDAA)	-0.434
			42	Spoonerisms time (GL&SCHR)	0.382
			44	English word reading correct (OMT)	-0.376
			52	Word reading correct (EMT)	-0.372
			46	Flash typing words (IDAA)	-0.349
	Factor 2**	**1.092**	30	Morphology and syntax (GL&SCHR)	0.659
			53	Word spelling (GL&SCHR)	0.544
			37	Proofreading (GL&SCHR)	0.534
			50	Sentence spelling (AT-GSN)	-0.522
	Factor 3**	**1.019**	46	Flash typing words (IDAA)	0.614
			51	Flash typing English words (IDAA)	0.531
			48	Lexical decision (IDAA)	0.510
			49	Flash typing pseudowords (IDAA)	0.376
	Factor 4**	**1.018**	33	Reversals accuracy (GL&SCHR)	0.771
			41	Reversals (IDAA)	0.650
			23	Spoonerisms accuracy (GL&SCHR)	0.561
			42	Spoonerisms time (GL&SCHR)	-0.428
	Factor 5**	**0.941**	35	Digit naming (GL&SCHR)	0.950
			36	Letter naming (GL&SCHR)	0.891
			26	Color naming (GL&SCHR)	0.731
			7	Object naming (GL&SCHR)	0.437
	Factor 6**	**0.930**	29	Mental calculation multiplication (TTR)	0.909
			34	Mental calculation division (TTR)	0.892
			39	Mental calculation mix (TTR)	0.879
			22	Mental calculation subtraction (TTR)	0.837
			31	Mental calculation addition (TTR)	0.800
			19	Speed of processing correct (CDT)	0.364
	Factor 7**	**0.917**	52	Word reading correct (EMT)	0.652
			43	Text reading time (GL&SCHR)	-0.470
			25	English word reading percentage error(OMT)	0.362
			38	Silent reading (Thick bite)	-0.346
Medium ES	**Factor 8****	**0.716**	21	Vocabulary (GL&SCHR)	0.857
			12	Personalities (KAIT)	0.815
			3	Auditory comprehension (KAIT)	0.747
			13	Delayed auditory comprehension (KAIT)	0.586
			15	Text comprehension (GL&SCHR)	0.470
			14	Double meanings (KAIT)	0.390
			44	English word reading correct (OMT)	0.460
			25	English word reading percentage error (OMT)	-0.454
			18	Definitions (KAIT)	0.324
Small ES	**Factor 9**	**0.120**	1	Delayed symbol learning (KAIT)	0.950
			2	Symbol learning (KAIT)	0.765
	Factor 10	**0.070**	6	Block patterns (KAIT)	0.610
			5	Logical reasoning (KAIT)	0.594
			4	Secret Codes	0.516
			16	Working memory (GL&SCHR)	0.321

Table 5

Stage 2 EFA Factor Loadings, Uniqueness and Explained Variance of the 48 Variables Ordered from Large Effect Size to Small Effect Size.

		Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Factor10	*Uniqueness*
53	Word spelling (GL&SCHR)	-0.184	**0.544**	0.227	0.118	0.020	0.051	-0.112	0.033	-0.034	0.059	0,194
52	Word reading correct (EMT)	**-0.372**	-0.013	0.089	0.067	-0.083	-0.022	-0.097	0.034	0.030	**0.652**	0,054
51	Flash typing English words (IDAA)	**-0.434**	0.148	**0.531**	0.016	-0.020	0.001	-0.070	0.060	0.009	-0.048	0,170
50	Sentence spelling (AT-GSN)	0.216	**-0.522**	-0.200	-0.167	0.017	0.011	0.035	-0.013	-0.001	-0.051	0,186
49	Flash typing pseudowords (IDAA)	**-0.435**	0.086	**0.376**	0.027	0.030	0.154	0.086	-0.107	-0.097	0.053	0,364
48	Lexical decision (IDAA)	-0.255	0.261	**0.510**	-0.043	0.099	-0.017	0.158	0.035	-0.056	0.065	0,359
47	Pseudoword reading correct (KLEPEL)	**-0.569**	-0.058	-0.036	0.272	0.077	0.130	-0.157	-0.030	-0.004	0.317	0,212
46	Flash typing words (IDAA)	**-0.349**	0.090	**0.614**	0.010	-0.071	-0.003	0.030	-0.074	-0.021	0.034	0,235
45	English word spelling (WRAT)	-0.263	0.217	0.194	0.078	-0.064	0.062	-0.207	0.295	0.080	-0.005	0,285
44	English word reading correct (OMT)	**-0.376**	-0.243	0.150	0.069	-0.146	-0.028	-0.056	**0.460**	0.061	0.263	0,203
43	Text reading time (GL&SCHR)	**0.586**	0.059	0.002	0.037	0.066	0.055	0.077	-0.071	0.068	**-0.470**	0,269
42	Spoonerisms time (GL&SCHR)	**0.382**	-0.041	0.066	**-0.428**	0.101	-0.011	0.027	-0.107	-0.058	0.032	0,329
41	Reversals (IDAA)	-0.263	0.014	0.026	**0.650**	-0.041	0.034	0.245	-0.131	-0.104	-0.042	0,290
40	Reversals time (GL&SCHR)	**0.456**	-0.007	0.109	-0.218	0.184	-0.150	0.119	0.025	0.070	0.061	0,502
39	Mental calculation mix (TTR)	0.047	0.067	0.050	0.064	0.065	**0.879**	0.038	0.081	-0.119	0.003	0,137
38	Silent Reading (Tickbite)	**0.457**	-0.029	-0.036	0.190	0.067	0.004	-0.061	-0.183	0.024	**-0.346**	0,443
37	Proofreading (GL&SCHR)	-0.173	**0.534**	0.065	-0.123	-0.061	0.104	0.027	-0.081	0.081	0.103	0,471
36	Letter naming (GL&SCHR)	-0.040	-0.052	-0.005	-0.054	**0.891**	0.040	0.003	0.057	0.061	-0.012	0,219
35	Digit naming (GL&SCHR)	-0.003	0.043	-0.030	-0.079	**0.950**	0.036	0.021	0.074	-0.034	0.001	0,135
34	Mental calculation division (TTR)	0.064	0.208	-0.027	-0.082	0.062	**0.892**	-0.033	0.060	0.073	-0.016	0,184
33	Reversals accuracy (GL&SCHR)	-0.035	-0.013	-0.019	**0.771**	-0.102	-0.047	0.085	-0.073	-0.096	-0.047	0,464
32	Text reading substantive errors (GL&SCHR)	**0.834**	0.042	-0.031	-0.062	-0.008	0.157	-0.082	0.076	-0.061	0.012	0,401
31	Mental calculation addition (TTR)	-0.092	-0.088	0.057	-0.056	-0.047	**0.800**	0.110	-0.004	-0.009	0.044	0,220
30	Morphology and syntax (GL&SCHR)	-0.064	**0.659**	0.033	-0.046	-0.067	0.028	0.019	0.067	-0.013	-0.163	0,494
29	Mental calculation multiplication (TTR)	0.050	0.200	-0.172	0.029	0.032	**0.909**	-0.157	0.024	0.033	-0.009	0,194
28	Word reading percentage error (EMT)	**0.738**	-0.131	-0.081	0.090	-0.116	0.088	-0.026	0.109	-0.104	0.057	0,515
27	Pseudoword reading percentage error (KLEPEL)	**0.616**	-0.027	-0.045	-0.077	-0.174	-0.090	0.044	0.082	-0.078	-0.010	0,550
26	Color naming (GL&SCHR)	0.004	-0.130	-0.003	0.115	**0.731**	-0.049	0.066	0.080	-0.091	-0.041	0,390
25	English word reading percentage error (OMT)	0.000	-0.044	-0.186	-0.264	0.224	0.096	0.046	**-0.454**	-0.044	**0.362**	0,503
24	Text reading time consuming errors (GL&SCHR)	**0.622**	-0.001	0.017	0.161	0.027	-0.006	0.019	0.017	0.091	0.015	0,687
23	Spoonerisms accuracy (GL&SCHR)	-0.087	0.021	0.020	**0.561**	0.256	-0.036	-0.057	-0.061	0.167	0.207	0,535
22	Mental calculation subtraction (TTR)	-0.054	-0.193	0.076	-0.018	-0.043	**0.837**	0.222	0.018	-0.039	-0.103	0,237
21	Vocabulary (GL&SCHR)	0.007	0.165	0.031	-0.120	0.126	0.058	0.007	**0.857**	-0.093	-0.033	0,272
19	Speed of processing correct (CDT)	0.029	-0.186	0.168	0.022	-0.172	**0.364**	0.100	-0.089	0.068	0.165	0,641
18	Definitions (KAIT)	-0.094	0.227	-0.094	0.147	0.105	0.097	0.010	**0.324**	0.020	0.040	0,591
16	Working memory (GL&SCHR)	-0.168	0.041	-0.049	0.200	-0.106	0.124	**0.321**	-0.123	0.024	0.042	0,660
15	Text comprehension (GL&SCHR)	-0.005	0.076	0.117	-0.078	0.023	-0.137	0.286	**0.470**	-0.019	0.099	0,595
14	Double meanings (KAIT)	-0.063	0.197	-0.153	0.102	0.043	-0.029	0.215	**0.390**	0.001	-0.045	0,585
13	Delayed auditory comprehension (KAIT)	-0.103	-0.093	-0.099	0.035	0.059	-0.047	0.203	**0.586**	0.013	0.032	0,559
12	Personalities (KAIT)	0.149	-0.135	-0.042	0.033	-0.005	0.090	-0.142	**0.815**	0.030	0.050	0,441
10	Verbal STM (GL&SCHR)	0.148	0.193	-0.063	0.275	-0.064	-0.125	0.243	-0.079	-0.069	0.211	0,807
7	Object naming (GL&SCHR)	-0.121	-0.134	0.133	0.142	**0.437**	-0.012	-0.032	-0.036	-0.010	-0.148	0,732
6	Block patterns (KAIT)	0.144	-0.118	0.129	0.068	0.099	0.086	**0.610**	-0.017	0.113	-0.097	0,532
5	Logical reasoning (KAIT)	0.043	0.081	0.024	0.036	0.000	-0.091	**0.594**	0.043	0.078	-0.013	0,580
4	Secret codes (KAIT)	0.006	-0.077	-0.111	0.088	-0.014	0.185	**0.516**	0.056	0.032	-0.077	0,613
3	Auditory comprehension (KAIT)	0.108	-0.038	-0.064	-0.145	0.040	0.066	0.078	**0.747**	-0.021	-0.058	0,556
2	Symbol learning (KAIT)	0.036	0.011	0.007	-0.039	-0.034	0.051	0.224	-0.024	**0.765**	-0.033	0,273
1	Delayed symbol learning (KAIT)	-0.089	0.002	-0.053	-0.059	-0.012	-0.08	0.178	-0.057	**0.950**	0.024	0,063
	SS loadings	**4,519**	**1,955**	**1,481**	**2,133**	**2,816**	**4,153**	**1,325**	**3,487**	**1,688**	**1,775**	
	Proportion Variance	**0,094**	**0,041**	**0,031**	**0,044**	**0,059**	**0,087**	**0,028**	**0,073**	**0,035**	**0,037**	

Note: Loadings above the cut-off of .32 or below -.32 are marked in bold. Below the cut-off they are printed in gray. These were taken into account for interpretation of the factors.

Table 6

Correlation Matrix of the 10 Factors of the stage 2 EFA

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10
Factor 1	-	**0.549**	0.104	**0.399**	**-0.401**	-0.101	**0.359**	**-0.499**	**-0.343**	**0.541**
Factor 2		-	-0.197	**-0.497**	**0.321**	0.276	**-0.358**	**0.378**	**0.334**	**-0.470**
Factor 3			-	**0.309**	-0.032	**-0.317**	-0.052	-0.211	-0.054	0.184
Factor 4				-	-0.274	**-0.375**	0.265	**-0.359**	**-0.338**	**0.464**
Factor 5					-	0.003	-0.232	**0.498**	**0.492**	-0.276
Factor 6						-	-0.183	0.173	-0.034	**-0.372**
Factor 7							-	**-0.389**	**-0.370**	**0.426**
Factor 8								-	**0.447**	**-0.470**
Factor 9									-	-0.289
Factor 10										-

Note. Correlations higher then/ equal to .3 are printed in bold.

The factors will now be discussed in order of their factor effect size; tentative names will be assigned on the basis of the highest loading items.

Factor 1 [Reading] is the factor with the highest effect size (ES= 1.20) and contains the largest number of variables (*N*= 14), most of them reading related (with large individual effect sizes). Generally, the timed reading-related variables have the highest loadings on this factor, followed by the flashed reading/typing tasks. Apart from the specific reading-related variables, two variables (Reversals time and Spoonerisms time) that are an expression of phonological processing also load on this factor, although marginally. This factor correlates with all other factors, except for factor 6 (Math) and factor 3 (Flashed presentation).

Factor 2 [Spelling] is the factor with the second highest effect size (ES=1.09). The four variables loading on this factor are Morphology and Syntax, Sentence spelling, Word spelling, and Proofreading. Loadings vary from 0.659 for Morphology and syntax to 0.522 for Sentence spelling. This factor also correlates with most other factors, except for factor 6 (Math) and factor 3 (Flashed presentation).

Factor 3 [Flashed presentation] is the next best discriminating factor (ES=1.03). Although they also load on factor 1, all subtests of the IDAA using brief stimulus presentation (Flash typing task pseudowords to a lesser extent than the others) load on factor 3. This is a latent variable with a large effect size that does not correlate much with the other factors.

Factor 4 [Phonology] draws on variables relating to phonological processing, namely Reversals accuracy, Reversals and Spoonerisms accuracy and Spoonerisms time (ES= 1.02). This factor correlates most with factors 2 (Spelling) and 10 (Fluid intelligence).

Factor 5 [Rapid Naming] results in an ES of 0.94. Mainly Digit naming, Letter naming and Color naming load on this factor and to a lesser extent Object naming. This factor correlates above .4 with factor 8 (Crystallized IQ), factor 9 (Symbol learning), and factor 1 (Reading).

Factor 6 [Math] consist of the 5 mental calculations tasks (ES=0.93). Multiplication has the highest loading of 0.909. The lowest loading is for addition: 0.800. The test Speed of processing correct also loads above the cut-off border (r=.364). Correlations between .3 and .4 can be noted with factors 4 (Phonology), 10 (FIQ), and 3 (Flashed presentation).

Factor 7 [Reading fluency] is a weaker and more unstable factor (ES=0.92) which receives loadings above 0.4 from Text reading time and Word reading correct, and loadings between 0.3 and 0.4 from English word reading percentage error and Silent reading. This is a factor with a large effect size, showing a correlation with factors 10 (FIQ), 8 (CIQ), 9 (Symbol learning), 1 (Reading) and 2 (Spelling). With only two factors loading above 0.4 this is not considered a very stable factor.

Factor 8 [Crystallized IQ] has a medium effect size (ES=0.72). The nine variables loading on this factor are verbal in nature. All the variables *(N*= 4) that measure crystallized IQ in the KAIT load on this factor. Delayed auditory comprehension from the KAIT also loads on this factor. Definitions, however, has only a marginal loading on this latent variable. The 4 other variables in this group are Vocabulary, Text comprehension, English word reading correct and English word reading percentage error. This latent variable correlates with all factors except for factor 6 (Math) and 3 (Flashed presentation).

Factor 9 [Symbol learning] has no discriminative power between groups (ES=0.12). Only two variables load strongly on this factor, namely Symbol learning and Delayed symbol learning. Although only two items load on the factor, we consider it as a solid factor due to the very high loadings. This factor correlates most with factor 5 (Rapid naming) and 8 (CIQ) (above .4 and below .5).

Factor 10 [Fluid IQ; ES=0.07] principally draws on variables measuring fluid intelligence and working memory and is clearly non-verbal in nature. These variables are Block patterns, Logical reasoning and Secret codes from the KAIT, and Working memory from the GL&SCHR. This factor has no discriminative power between groups, as the effect size is below 0.2. Interestingly this factor correlates most with factor 1 (Reading).

The only 2 items that do not load significantly on any of the factors are the English word spelling and Verbal STM test. The WRAT has several smaller loadings under the cut-off score (e.g. on factor 1 and 8) and a small proportion of unexplained variance. The Verbal STM task does not load on any factor and is mainly left unexplained by the EFA.

Discussion

In a study on dyslexia in higher education, we compared a sample of 100 first-year bachelor students with dyslexia and a matched control group on a large number of tasks typically administered for the assessment of dyslexia (Callens et al., 2012). In a subsequent analysis (Tops et al., 2012) we observed that the prediction accuracy became saturated after three variables only: Word spelling (variable 53 from Table 1), word reading (variable 52), and phoneme reversal time (variable 40). In the present article, we look at the data from a different angle and try to understand how the various test scores are interrelated and connected to the core predictors of Tops et al. (2012). The number of factors needed to explain the systematic variance in the dataset and the identification of these factors can give us a picture of the latent variables that differ between students with and without dyslexia in higher education. This would also enable us to see if the deficit of these students with dyslexia restricts itself to one key factor or whether other factors are affected by their impairment.

To unearth the structure behind the 53 variables in our test battery, an exploratory factor analysis was run. In a first stage, the EFA resulted in a model with 13 factors as the best fit. At the same time, it became clear that some variables were unrelated to the remaining scores. When these were excluded, as recommended in the literature, a 10-factor model fitted the data best. When comparing results from the two stages, we observed that most factors were consolidated and that weak and unstable factors disappeared. As such, the final results are more solid and reliable for interpretation. An important notion in relation to the interpretation of our results is that the goal of the study involved a diagnostic protocol for dyslexia. For this reason, the resulting factor matrix is heavily influenced by the performance of students with dyslexia, and the results cannot be used straightforwardly as a framework for normal reading only.

The five variables excluded from the second stage EFA require some attention too. Automatization, Phonological STM, SOP percentage missed/errors, Visual STM, and Writing speed were not related to the solid factors and were therefore omitted in the second stage of the analysis. However, it is still possible that these skills are interesting for the distinction between the groups, but that not enough similar variables were included in our study to form a separate construct, or that the tests used to measure the skills were not sensitive or specific enough to be assigned to one specific factor. Writing speed is a skill that is not often included in studies on dyslexia in higher education but it does lead to significant differences between the groups. In Hatcher et al. (2002) writing speed (d=-1.17) was even among the four variables needed to obtain a 95% diagnostic accuracy. However, in their study writing speed was measured by letting participants copy a 13-word sentence as many times as possible in 2 minutes time. In our study, it was measured as part of a word dictation task and resulted in an effect size of only 0.49. For diagnostic purposes, the method of Hatcher et al. (2002) may be more effective and it would be interesting to investigate to what extent it depends on the motor aspect of writing. Adequate writing speed is an essential skill in higher education (e.g. note taking, exams) and has not yet been evaluated thoroughly in the literature. More extensive research on the topic could shed light on the most appropriate way of assessing writing speed and its relation to functioning in higher education. The evaluation of the ability to automate as presented in this study is a fairly new concept based on the idea that automaticity is the key feature of skilled reading (van der Leij & van Daal, 1999). The construct did not discriminate well between groups. The ES was only 0.33 and although there is little variance left unexplained in the EFA (uniqueness = 0.236) it did not load significantly on any factor. We would expect it to correlate with reading and writing skills if effective in assessing pure automaticity. As for the administered Phonological STM test, the items and administration are unlike the usual nonwords repetition tasks that are standard for the assessment of this skill (Dietrich & Brady, 2001; Laasonen, Virsu, et al., 2012; Ramus et al., 2003). With its medium effect size it does discriminate between groups but not as strongly as expected for this skill. In the paper by Ramus et al. (2003) an effect size of 1.1 was found (the other studies did not provide ES or enough info to calculate them). Also, this subtest did not group together with other phonological skills such as spoonerisms or reversals that formed a separate phonological factor. It could be that the specific way of assessment using syllables was not sensitive enough for this specific subgroup of dyslexics. The speed of processing (percentage errors/missed) variable also had little variance unexplained by the EFA (27.3%) and did not connect to any specific factor and only gave a small effect size. It looks like this subtest did not measure a specific skill but was a more dispersed variable loading on several factors. The last variable excluded from the second stage

EFA was Visual STM. With its small effect size this subtest was not crucial in the distinction between groups and only little variance was unexplained by the EFA (23.7%). So, it does not seem to measure a distinct skill that is potentially significant in the diagnostic protocol and left unevaluated by the existing EFA. In the meta-analysis of Swanson and Hsieh (2009) an effect for visuo-spatial memory of 0.39 was found in favor of the reading disabled.

Of the two variables left unaccounted for in stage 2, the following can be said. The English word spelling test appears to be influenced by too many latent factors to be exclusively attached to one factor. It does have discriminative power (ES= 1.94) but for reasons stated below we would not be inclined to insert it in a diagnostic protocol. As for the Verbal STM test, a medium effect size was found in Swanson and Hsieh (2009). However, when reviewing the literature a lot can be said about the terminology and the assessment of this skill. For one, terms such as verbal short term memory, verbal memory and verbal working memory are often mixed up and different stimuli (syllables, words or nonwords) are used to measure the construct. So, a comparison of the performance on this construct in different studies is not straightforward. In the present study, Verbal STM reflected the ability to memorize series of words relating to everyday objects and as such did not appear to discriminate well between the groups. Therefore, it can be omitted from further assessment. Further studies will have to examine whether other measure are better and whether they form a separate factor or make part of one of the factors revealed here.

Overall, our exploratory factor analysis shows that the deficits of dyslexia in higher education are not restricted to a single component. As many as seven factors resulted in large effect sizes: Reading, spelling, flashed presentation, phonology, rapid naming, math, and reading fluency. Generally speaking, a student entering higher education with dyslexia typically encounters problems with reading and spelling, has low phonological and orthographical skills, and difficulties with mental calculations and rapid naming. Retrieval of verbal information from long term memory, as reflected in crystallized IQ, is also likely to be impaired. On the other hand, fluid IQ and reasoning are not affected by the learning disability.

Reassuringly, reading skills (factor 1) form the core difference between students with and without dyslexia in higher education. This is more than a self-evident truth, as time and time again students with dyslexia are accused of using their label to play the system. This latent variable combines subtests measuring the response times of word reading, pseudoword reading, text reading, flashed reading and phonology. A point of communality among the tests is that they combine speed and accuracy. A maximum number of text, words, and items must be processed in a minimum amount of time. This indicates that the traditional paper and pen tests remain a very reliable method for diagnostic purposes. The finding that also items measuring phonological skills load on this reading factor reflects the close relationship between reading and phonology. After all, many studies have shown that phonological awareness is an important predictor of individual reading skills (For a review see Melby-Lervag, Lyster, & Hulme, 2012). The observation that the effect size was higher for word reading than for pseudoword reading is in line with the concerns recently raised about the lexicality effect (Van den Broeck & Geudens, 2012). One interpretation might be that normal readers profit more from their reading experiences for existing words than readers with dyslexia do. As a result, the difference between both groups becomes particularly pronounced for well-known words. Factor 1 correlates highly with spelling, FIQ and CIQ, followed by naming, phonology and symbol learning. However, as stated before caution must be taken when interpreting these correlations. Factor 1 is a very large factor. So, overlap with other factors us likely. This latent variable is represented in the predictive model of Tops et al (2012) by the word reading test and the reversal time test (variable 52 and 40 in Table 2), which also loads on factor 7 (Reading fluency).

The second most differentiating factor is spelling. It forms a separate construct although closely related to reading. This factor is largely rule-based because the Proofreading and the Word and Sentence spelling tests require extensive knowledge of spelling rules and the ability to apply these at the word and sentence level. The morphology and syntax test also requires the recognition of errors in sentences although on a wider range of aspects such as grammar, punctuation and syntax. The fact that Morphology and syntax load high on this factor could be explained by the finding that morphological awareness correlates highly with spelling (Casalis, Deacon, & Pacton, 2011) and the fact that the design of this test closely resembles the spelling proof reading task. However, the uniqueness of this variable is quite high, meaning that a large part of performance on this test remains unexplained. Practical implications are that in an assessment with limited resources and time a combination of a proofreading task and a word spelling test provides a good reflection of spelling skills. When directions for future remediation programs are required and time is not of the essence, a sentence level dictation could possibly provide more detailed information on error patterns. Up until now, proofreading is an under investigated skill in the context of dyslexia. This is unfortunate, because in Finnish (a very transparent language) it seems to be the most prominent difference between readers with dyslexia and controls (Lindgren and Laine (2011)). Furnham (2010) also highlighted the importance of this skill in settings such as higher education and employment where people are often required to proofread their own materials and those of others. In his study, Furnham administered an English proofreading task on a 1000 words long text; 41 errors on grammar, spelling, spacing, punctuation and word substitutions had to be identified. Hatcher et al. (2002) also used a text proofreading task in which errors in spelling, punctuation and grammar had to be detected. This factor is represented in the predictive model of (Tops et al, 2012) by the word dictation task (variable 53). Correlations are highest with reading, phonology and FIQ. The relationship with reading is very straightforward as they both involve the translation from phonology to orthography, albeit in reverse directions. This arguably also accounts for the correlation with phonology. FIQ has a small ES; so, this correlation is not easy to interpret.

All the subtests of the IDAA that used flashed item presentation, load on the same factor (factor 3). This factor has a large effect size and only seems to correlate with factor 6 (math) and factor 4 (phonology). The large amount of unaddressed variance and the low correlations with the other factors, raise some questions to what is actually measured. Although the test is apparently very effective in discriminating groups and obviously related to the core deficit in dyslexia, it remains unclear which skills are actually tapped. So, at present it is not clear what factor 3 stands for.

The phonological awareness tasks load on a dedicated factor (4) with the fourth highest effect size. Within this factor, accuracy measures clearly load more on latency variables. Spoonerism time even did not load at all. These results are in line with the findings of Vaessen, Gerretsen, and Blomert (2009) who found two distinct factors for phonology time and accuracy measures. Factor 4 seems to be a pure measure of phonological processing accuracy and high correlations could be expected with the literacy and spelling factors. However, relative to the other observed correlations they are not that high. It could be that factor 1 is too diffuse or an assembly of several variables with different relations to phonology to result in high correlations. Again, this factor shows that with the simple use of one task, general phonological processing can be evaluated. Phonological processing continues to be a crucial factor in the diagnosis of dyslexia considering the large effect size and the presence of this latent variable.

The third component within the phonological processing triad is rapid naming. Although a discreet version of the task was used, high effect sizes were found between the groups. In the EFA plot (Figure 3), a clear latent variable (factor 5) is formed by the 4 rapid naming tasks, which is different from the phonology factor and with a similar effect size. The double deficit theory on dyslexia postulates that impairments in naming speed and phonological awareness represent two independent contributions to the disability (Torppa, Georgiou, Salmi, Eklund, & Lyytinen, 2012; Vukovic & Siegel, 2006). Our findings seem to support this view. In several studies within the rapid naming task paradigm, a distinction could be made between alphanumerical (e.g. digits and letters) and non-alphanumerical (e.g. objects and colors) naming tasks. Each contributed differently to reading (Savage & Frederickson, 2005). They are thought to reflect differences in cognitive sub-processes needed for execution. Van den Bos, Zijlstra, and Van den Broeck (2003) reported that color and picture naming formed a single factor from the start of learning to read while letter and digit naming initially were separate constructs, which only became a single, stable factor from the age of 10 on. In our study, the object naming task loaded considerably less on the factor than letter and digit naming, possibly because letters and digits can be named directly whereas picture naming requires access to the semantic system (Humphreys, Riddoch, and Quinlan (1988); Savage and Frederickson (2005)). If one wants to shorten the test battery, it seems to us that the administration of a rapid naming task can be limited to letter naming or digit naming. Both have equal effect sizes and similar loadings on the rapid naming factor. Object naming does not result in a significant ES and as for Color naming it does not seem to have any real added value.

The next factor in line with a high effect size is factor 6, combining all the mental calculation tasks and a task for speed of processing. Our results correspond to those of De Smedt and Boets (2010) and the triple code model (Dehaene, 1992). The larger ESs for multiplication, addition and division than for subtraction can be seen as the outcome of a larger reliance on the verbal code. These findings agree with those of Gobel and Snowling (2010) and De Smedt and Boets (2010) except for the fact that the latter did not find a difference in performance between multiplication and subtraction, contrary to their predictions. In our math education system, simple additions, multiplications and divisions rely heavily on memorization whereas subtractions are viewed as inversed additions. The significant difference (with a medium effect size) observed in subtractions could be interpreted as evidence for De Smedt and Boets (2010) observation that adults with dyslexia also differ from normal readers in the speed of executing procedural strategies. Indeed, performance on the math tasks cannot be solely attributed to verbal skills, for some aspect of pure math skill is likely to be involved given the correlation with the FIQ factor. An addition of subtests more related to the understanding and application of mathematical concepts would provide relevant additional information for students in higher education. In relation to the speed of processing, verbal arithmetic differences have been related to problems in verbal working memory and speed of processing. Bull and Johnston (1997) found that arithmetic abilities were best predicted by speed of processing, which could explain the loading of the speed of processing variable on this factor.

Factor 7 seems to be a purer measure of timed word reading. It is a somewhat unstable factor. So, no strong conclusions can be drawn. Also, the comparison with factor 1 is tricky because of the wide range of variables grouped in factor 1.

Interestingly, the variables from the IQ test (KAIT) fall in the last three factors, with the smallest differences between students with and without dyslexia. All subtests relating to vocabulary and conceptual knowledge acquired by learning, education and cultural experience load on factor 8, which can be defined as a measure of CIQ and which shows a medium effect size between the two groups. The subtest Definitions loads only marginally on this latent variable probably due to the fact that this specific subtest relies more on the integration of instructions than on pure lexical retrieval and general knowledge. This is a confirmation of the results from a joined factor analysis with the KAIT and the WISC-R where this subtest loaded on two factors (fluid and crystallized) with almost equal loadings (Dekker et al., 2004). Two tasks of the GL&SCHR also load high on factor 8, namely Vocabulary and Text comprehension. For Vocabulary it is quite logical that it groups together with the other tests of CIQ and as such can be viewed as an extra validation of our data set. As for Text Comprehension, at the item level we see that some questions are pure measures of retention and reproduction of verbal information while others are more inferential and require an integration of previous knowledge. The latter probably is the reason why this test loads somewhat (although just below cut-off) on the FIQ factor. Possibly due to the combined visual and auditory presentation of the text in this test, performance is less influenced by the reading and spelling related factors. This is an interesting finding with respect to the use of text-to-speech software, which clearly deserves further testing with a larger variety of materials. The English word reading task also loads on factor 8 indicating that performance on this test is influenced by general verbal skills, education and experience. A suggestion for future researchers would be to not include the measures of English reading and writing when this language is not the mother tongue. These measures do not load on a single latent variable and, if anything, are more related to the general cognitive skills than to language-specific skills. As a result, they provide little additional value. The fact that little variance is left unexplained for English reading and writing, excludes the possibility that an interesting factor was overlooked because of the limited number of variables related to the English language in the study.

Finally, the fluid IQ subtests load on two factors and not on one as was expected based on the factor analysis described in the KAIT manual. Symbol learning and Delayed symbol learning apparently isolated themselves from the other measures of logical reasoning and problem solving. As said before, Symbol learning is similar to learning to read and is least influenced by previous acquired knowledge. As such, this provides some evidence for the fact that dyslexia is not a general learning deficit but language related. The Block patterns, Logical reasoning and Secret codes subtests load on a different factor together with working memory. This factor seems to form a combined latent variable that joins FIQ and working memory. Studies have demonstrated that working memory and Fluid IQ are related although the exact relationship is still under debate. In Kane, Hambrick, and Conway (2005) 50 % overlap was found between WM and FIQ while Oberauer, Schulze, Wilhelm, and Suss (2005) even go up to 70%. Some authors go as far as stating that WM and FIQ are isomorphic. Our results are more in line with an overlap model reflected by the low loading of the working memory test on this factor and the amount of unexplained variance of this test. As to the nature of the relationship Halford, Cowan, and Andrews (2007) declared that working memory and reasoning share a common link in the related capacity limits quantified in the number of elements in the working memory and the number of interrelations in reasoning that can be kept active. Remarkable is the fact that the two memory tasks of the KAIT do not group together but are more closely related to the initial skill they rely upon (Symbol learning and Auditory comprehension).

An important implication of the results on the IQ measures is that one should be wary when applying an IQ-achievement discrepancy model in the diagnostic protocol of dyslexia. Although nowadays often a more descriptive definition of dyslexia is applied, Machek and Nelson (2010) state that the majority of U.S. schools and school psychologists still rely on the discrepancy between reading achievement and IQ to define dyslexia. IQ tests traditionally contain some subtests that are more verbal in nature and some that focus on logical and deductive reasoning. In contrast with Morgan et al. (1997) we did find significant differences in CIQ as measured with the KAIT and other subtests. Furthermore, a factor grouping all subtests that tap on purely verbal skills clearly differentiates between groups. Test administrators should therefore be careful with subtests that tap into verbal skills, as they are likely to disfavor students with dyslexia. We suggest that only FIQ tests are used as a comparison measure for the discrepancy between reading/spelling and IQ if one is tempted to use a discrepancy model. Then the reading-IQ discrepancy seems to hold, at least when less time constrained IQ tests are used and the comparison is made at the group level.

All in all, our EFA can be considered as a validation of the predictive model set up by Tops et al. (2012). Within the 7 factors that differentiate students with and without dyslexia the most, three important latent variables or components (reading, spelling and reading fluency) that are considered the core of dyslexia are covered with three tests. When the goal of an individual assessment goes beyond diagnostics and the student requires an overview of his/her strengths and weaknesses, the assessment can be extended by including tests on naming, math, CIQ and FIQ (the other factors in our matrix). On the base of the present factor analysis a founded choice can be made in the selection of additional variables that would result in a maximum of information but meanwhile minimizing resources and costs.

References

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417-423. doi: 10.1016/s1364-6613(00)01538-2

Bekebrede, J., Van der Leij, A., Plakas, A., & Schijf, T. J. (2006). *IDT: Interactieve Dyslexietest*. Amsterdam/Uithoorn: Uva/Muiswerk.

Bekebrede, J., van der Leij, A., & Share, D. L. (2009). Dutch dyslexic adolescents: phonological-core variable-orthographic differences. *Reading and Writing, 22*(2), 133-165. doi: 10.1007/s11145-007-9105-7

Bowers, P. G., & Swanson, L. B. (1991). Naming Speed Deficits in Reading-Disability - Multiple Measures of a Singular Process. *Journal of Experimental Child Psychology, 51*(2), 195-219. doi: 10.1016/0022-0965(91)90032-N

Brosnan, M., Demetre, J., Hamill, S., Robson, K., Shepherd, H., & Cody, G. (2002). Executive functioning in adults and children with developmental dyslexia. *Neuropsychologia, 40*(12), 2144-2155. doi: 10.1016/s0028-3932(02)00046-5

Bruck, M. (1992). Persistence of dyslexics phonological awareness deficits. *Developmental Psychology, 28*(5), 874-886. doi: 10.1037/0012-1649.28.5.874

Brus, B., & Voeten, M. (1991). *Een-minuut-test vorm A en B, schoolvorderingstest voor de technische leesvaardigheid bestemd voor groep 4 tot en met 8 van het basisonderwijs. Verantwoording en handleiding*. Lisse, The Nederlands: Swets & Zeitlinger.

Buis, P. (1996). *Woordomkeringen test [Word Reversal test]*.

Bull, R., & Johnston, R. S. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology, 65*(1), 1-24. doi: 10.1006/jecp.1996.2358

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive profile of students who enter higher education with an indication of dyslexia. *PLos One, 7*(6). doi: 10.1371/journal.pone.0038081

Casalis, S., Deacon, S. H., & Pacton, S. (2011). How specific is the connection between morphological awareness and spelling? A study of French children. *Applied Psycholinguistics, 32*(3), 499-511. doi: 10.1017/s014271641100018x

Castel, C., Pech-Georgel, C., George, F., & Ziegler, J. C. (2008). Link between rapid automatized naming and reading in dyslexic children. *Annee Psychologique, 108*(3), 395-421.

Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assesssment, Research and Evaluation, 10*(7).

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology, 91*(3), 450-476. doi: 10.1037/0022-0663.91.3.450

de Jong, P. F., & van der Leij, A. (2003). Developmental changes in the manifestation of a phonological deficit in dyslexic children learning to read a regular orthography. *Journal of Educational Psychology, 95*(1), 22-40. doi: 10.1037/0022-0663.95.1.22

De Pessemier, P., & Andries, C. (2009). *GL&SCHR Dyslexie bij +16-jarigen. Test voor Gevorderd Lezen en Schrijven*. Antwerpen, Belgium: Garant.

De Smedt, B., & Boets, B. (2010). Phonological processing and arithmetic fact retrieval: Evidence from developmental dyslexia. *Neuropsychologia, 48*(14), 3973-3981. doi: 0.1016/j.neuropsychologia.2010.10.018

de Vos, T. (1992). *Tempo Test Rekenen*. Amsterdam: Pearson Education.

Dehaene, S. (1992). Varieties of numerical abilities. *Cognition, 44*(1-2), 1-42. doi: 10.1016/0010-0277(92)90049-n

Dehaene, S., Piazza, M., Pinel, P., & Cohen, L. (2003). Three parietal circuits for number processing. *Cognitive Neuropsychology, 20*(3-6), 487-506. doi: 10.1080/02643290244000239

Dekker, R., Dekker, P. H., & Mulder, J. L. (2004). *Kaufman Adolescent and Adult Intelligence Test - Nederlandstalige versie: Handleiding*. Leiden, The Nederlands: PITS.

Dekker, R., Dekker, P. H., & Mulder, J. L. (2007). *De ontwikkeling van vijf nieuwe Nederlandstalige tests*. Leiden: PITS.

Dietrich, J. A., & Brady, S. A. (2001). Phonological representations of adult poor readers: An investigation of specificity and stability. *Applied Psycholinguistics, 22*(3), 383-418. doi: 10.1017/s014271640100306x

Everatt, J. (1997). The Abilities and Disabilities Associated with Adult Developmental Dyslexia. *Journal of Research in Reading, 20*(1), 13-21. doi: 10.1111/1467-9817.00016

Furnham, A. (2010). Proofreading as an index of crystallised intelligence. *Educational Psychology, 30*(6), 735-754. doi: 10.1080/01443410.2010.506005

Ghesquière, P. (1998). *Algemene toets gevorderde spelling van het Nederlands (AT-GSN): verantwoording en handleiding. Rapport van een specialisatiejaar: onderzoek At-GSN-dictee.*: Unpublished bachelor thesis, University Leuven, Leuven, Belgium.

Gilroy, D. E., & Miles, R. (2001). *Dyslexia at College (2nd ed.), London: Routlegde*.

Gobel, S. M., & Snowling, M. J. (2010). Number-processing skills in adults with dyslexia. *Quarterly Journal of Experimental Psychology, 63*(7), 1361-1373. doi: 10.1080/17470210903359206

Gottardo, A., Siegel, L.S. & Stanovich, K.E. (1997). The assessment of adults with reading difficulties: What can we learn from experimental tasks? *Journal of Research in reading, 20*(1), 42-54. doi: 10.1111/1467-9817.00019

Greenberg, D., Ehri, L. C., & Perin, D. (1997). Are word-reading processes the same or different in adult literacy students and third-fifth graders matched for reading level? *Journal of Educational Psychology, 89*(2), 262-275. doi: 10.1037/0022-0663.89.2.262

Griffiths, Y. M., & Snowling, M. J. (2002). Predictors of exception word and nonword reading in dyslexic children: The severity hypothesis. *Journal of Educational Psychology, 94*(1), 34-43. doi: 10.1037//0022-0663.94.1.34

Hadjikakou, K., & Hartas, D. (2008). Higher education provision for students with disabilities in Cyprus. *Higher Education, 55*(1), 103-119. doi: 10.1007/s10734-007-9070-8

Halford, G. S., Cowan, N., & Andrews, G. (2007). Separating cognitive capacity from knowledge: a new hypothesis. *Trends in Cognitive Sciences, 11*(6), 236-242. doi: 10.1016/j.tics.2007.04.001

Harrison, A. G., & Nichols, E. (2005). A validation of the Dyslexia Adult Screening Test (DAST) in a post-secondary population. *Journal of Research in reading, 28*(4), 423-434. doi: 10.1111/j.1467-9817.2005.00280.x

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology, 72*, 119-133. doi: 10.1348/000709902158801

Heim, S., Tschierse, J., Amunts, K., Wilms, M., Vossel, S., Willmes, K., . . . Huber, W. (2008). Cognitive subtypes of dyslexia. *Acta Neurobiologiae Experimentalis, 68*(1), 73-82.

Henneman, K., Kleijnen, R., & Smits, A. (2004). *Protocol Dyslexie Voortgezet Onderwijs: Deel 2- Signalering, diagnose en begeleiding.* : KPC Groep, Expertisecentrum Nederlands, Werkverband Opleidingen Speciaal Onderwijs.

Herrmann, J. A., Matyas, T., & Pratt, C. (2006). Meta-analysis of the nonword reading deficit in specific reading disorder. *Dyslexia, 12*(3), 195-221. doi: 10.1002/dys.324

Humphreys, G. W., Riddoch, M. J., & Quinlan, P. T. (1988). Cascade Processes in Picture Identification. *Cognitive Neuropsychology, 5*(1), 67-103. doi: 10.1080/02643298808252927

Jones, M. W., Branigan, H. P., & Kelly, M. L. (2009). Dyslexic and nondyslexic reading fluency: rapid automatized naming and the importance of continuous lists. *Psychon Bull Rev, 16*(3), 567-572. doi: 10.3758/PBR.16.3.567

Kane, M. J., Hambrick, D. Z., & Conway, A. R. A. (2005). Working memory capacity and fluid intelligence are strongly related constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin, 131*(1), 66-71. doi: 10.1037/0033-2909.131.1.66

Kaufman, A. S., & Kaufman, N. L. (1993). *Kaufman Adolescent and Adult Intelligence Test. Manual.* Circle Pines MN: American Guidance Service.

Kleijnen, R., & Loerts, M. (2006). *Protocol Dyslexie Hoger Onderwijs*. Antwerpen/Apeldoorn: Garant.

Laasonen, M., Service, E., Lipsanen, J., & Virsu, V. (2012). Adult developmental dyslexia in a shallow orthography: Are there subgroups? *Reading and Writing, 25*(1), 71-108. doi: 10.1007/s11145-010-9248-9

Laasonen, M., Virsu, V., Oinonen, S., Sandbacka, M., Salakari, A., & Service, E. (2012). Phonological and sensory short-term memory are correlates and both affected in developmental dyslexia. *Reading and Writing, 25*(9), 2247-2273. doi: 10.1007/s11145-011-9356-1

Leikin, M. (2002). Processing syntactic functions of words in normal and dyslexic readers. *Journal of Psycholinguistic Research, 31*(2), 145-163. doi: 10.1023/a:1014926900931

Leikin, M., & Hagit, E. Z. (2006). Morphological processing in adult dyslexia. *Journal of Psycholinguistic Research, 35*(6), 471-490. doi: 10.1007/s10936-006-9025-8

Lervag, A., & Hulme, C. (2009). Rapid Automatized Naming (RAN) Taps a Mechanism That Places Constraints on the Development of Early Reading Fluency. *Psychological Science, 20*(8), 1040-1048. doi: 10.1111/j.1467-9280.2009.02405.x

Lindgren, S. A., & Laine, M. (2011). Cognitive linguistic Performances of Multilingual University Students Suspected of Dyslexia. *Dyslexia, 17*(2), 184-200. doi: 10.1002/dys.422

Machek, G. R., & Nelson, J. M. (2010). School psychologists' perceptions regarding the practice of identifying reading disabilities: cognitive assessment and response to intervention considerations. *Psychology in the Schools, 47*(3), 230-245. doi: 10.1002/pits.20467

Madriaga, M., Hanson, K., Heaton, C., Kay, H., Newitt, S., & Walker, A. (2010). Confronting similar challenges? Disabled and non-disabled students' learning and assessment experiences. *Studies in Higher Education, 35*(6), 647-658. doi: 10.1080/03075070903222633

Manis, F. R., Doi, L. M., & Bhadha, B. (2000). Naming speed, phonological awareness, and orthographic knowledge in second graders. *J Learn Disabil, 33*(4). doi: 10.1177/002221940003300405

Mapou, R. L. (2008). Comprehensive evaluation of adults with learning disabilities. In L.E. Wolf, H.E. Schreiber, & J. Wasserstein (Eds), Adult Learning Disorders. Contemporary Issues. (pp. 248-273). Hove, NY: Psychology Press, Taylor & Francis Group.

Melby-Lervag, M., Lyster, S. A. H., & Hulme, C. (2012). Phonological Skills and Their Role in Learning to Read: A Meta-Analytic Review. *Psychological Bulletin, 138*(2), 322-352. doi: 10.1037/a0026744

Morgan, A. W., Sullivan, S. A., Darden, C., & Gregg, N. (1997). Measuring the intelligence of college students with learning disabilities: A comparison of results obtained on the WAIS-R and the KAIT. *J Learn Disabil, 30*(5), 560-565.

Nederland, S. D. (2008). *Diagnose dyslexie. Brochure van de Stichting Dyslexie Nederland. Herziene versie*. Bilthoven, The Nederlands: Stichting Dyslexie Nederland.

Oberauer, K., Schulze, R., Wilhelm, O., & Suss, H. M. (2005). Working memory and intelligence - Their correlation and their relation: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin, 131*(1), 61-65. doi: 10.1037/0033-2909.131.1.61

Parrila, R., Georgiou, G., & Corkett, J. (2007). University students with a significant history of reading difficulties: What is and is not compensated? *Exceptionality Education Canada, 17*, 195-220.

Pennington, B. F., Vanorden, G. C., Smith, S. D., Green, P. A., & Haith, M. M. (1990). Phonological processing skills and deficits in adult dyslexics. *Child Development, 61*(6), 1753-1778. doi: 10.1111/j.1467-8624.1990.tb03564.x

Peter, B., Matsushita, M., & Raskind, W. H. (2011). Global Processing Speed in Children With Low Reading Ability and in Children and Adults With Typical Reading Ability: Exploratory Factor Analytic Models. *Journal of Speech Language and Hearing Research, 54*(3), 885-899. doi: 10.1044/1092-4388(2010/10-0135

Powell, D., Stainthorp, R., Stuart, M., Garwood, H., & Quinlan, P. (2007). An experimental comparison between rival theories of rapid automatized naming performance and its relationship to reading. *Journal of Experimental Child Psychology, 98*(1), 46-68. doi: 10.1016/j.jecp.2007.04.003

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain, 126*, 841-865. doi: 10.1093/brain/awg076

Re, A. M., Tressoldi, P. E., Cornoldi, C., & Lucangeli, D. (2011). Which Tasks Best Discriminate between Dyslexic University Students and Controls in a Transparent Language? *Dyslexia, 17*(3), 227-241. doi: 10.1002/dys.431

Romani, C., Tsouknida, E., di Betta, A. M., & Olson, A. (2011). Reduced attentional capacity, but normal processing speed and shifting of attention in developmental dyslexia: Evidence from a serial task. *Cortex, 47*(6), 715-733. doi: 10.1016/j.cortex.2010.05.008

Savage, R., & Frederickson, N. (2005). Evidence of a highly specific relationship between rapid automatic naming of digits and text-reading speed. *Brain Lang, 93*(2), 152-159. doi: 10.1016/j.bandl.2004.09.005

Schiff, R., & Raveh, M. (2007). Deficient morphological processing in adults with developmental dyslexia: Another barrier to efficient word recognition? *Dyslexia, 13*(2), 110-129. doi: 10.1002/dys.322

Shaywitz, S. E., & Shaywitz, B. A. (2005). Dyslexia (specific reading disability). *Biological Psychiatry, 57*(11), 1301-1309. doi: 10.1016/j.biopsych.2005.01.043

Simmons, F. R., & Singleton, C. (2006). The mental and written arithmetic abilities of adults with dyslexia. *Dyslexia, 12*(2), 96-114. doi: 10.1002/dys.312

Singleton, Horne, J., & Simmons, F. (2009). Computerised screening for dyslexia in adults. *Journal of Research in reading, 32*(1), 137-152. doi: 10.1111/j.1467-9817.2008.01386.x

Singleton, C. H. (1999). *Dyslexie in Higher Education: Policy, provision and practice (Report of the National Working Party on Dyslexia in Higher Education).* Hull: University of Hull, on behalf of the Higher Education Funding of England.

Smith-Spark, J. H., & Fisk, J. E. (2007). Working memory functioning in developmental dyslexia. *Memory, 15*(1), 34-56. doi: 10.1080/09658210601043384

Spinelli, D., De Luca, M., Di Filippo, G., Mancini, M., Martelli, M., & Zoccolotti, P. (2005). Length effect in word naming in reading: Role of reading experience and reading deficit in Italian readers. *Developmental Neuropsychology, 27*(2), 217-235. doi: 10.1207/s15326942dn2702_2

Stenneken, P., Egetemeir, J., Schulte-Korne, G., Muller, H. J., Schneider, W. X., & Finke, K. (2011). Slow perceptual processing at the core of developmental dyslexia: A parameter-based assessment of visual attention. *Neuropsychologia, 49*(12), 3454-3465. doi: 10.1016/j.neuropsychologia.2011.08.021

Swanson, H. L. (2012). Adults With Reading Disabilities: Converting a Meta-Analysis to Practice. *J Learn Disabil, 45*(1), 17-30. doi: 10.1177/0022219411426856

Swanson, H. L., Howard, C. B., & Saez, L. (2006). Do different components of working memory underlie different subgroups of reading disabilities? *J Learn Disabil, 39*(3), 252-269.

Swanson, H. L., & Hsieh, C. J. (2009). Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. *Review of Educational Research, 79*(4), 1362-1390. doi: 10.3102/0034654309350931

Tabachnick, B. G., & Fidell, L. S. (2001). *Using Multivariate Statistics*. Boston: Allyn and Bacon.

Tops, W., Callens, M., Bijn, E., & Brysbaert, M. (in press). Spelling in adolescents with dyslexia: Errors and modes of assessment. *Journal of Learning Disabilities*.

Tops, W., Callens, M., Lammertyn, J., & Brysbaert, M. (2012). Identifying students with dyslexia in higher education. *Annals of Dyslexia, 62*(3), 186-203. doi: 10.1007/s11881-012-0072-6

Tops, W., Callens, M., Van Cauwenberghe, E., Adriaens, J., & Brysbaert, M. (in press). Beyond spelling: the writing skills of students with dyslexia in higher education. *Reading and Writing*. doi: 10.1007/s11145-012-9387-2

Torppa, M., Georgiou, G., Salmi, P., Eklund, K., & Lyytinen, H. (2012). Examining the Double-Deficit Hypothesis in an Orthographically Consistent Language. *Scientific Studies of Reading, 16*(4), 287-315. doi: 10.1080/10888438.2011.554470

Vaessen, A., Gerretsen, P., & Blomert, L. (2009). Naming problems do not reflect a second independent core deficit in dyslexia: Double deficits explored. *Journal of Experimental Child Psychology, 103*(2), 202-221. doi: 10.1016/j.jecp.2008.12.004

van den Bos, A., Spelberg, H., Scheepsma, A., & de Vries, J. (1999). *De Klepel vorm A en B: een test voor leesvaardigheid van pseudowoorden. Verantwoording, handleiding, diagnostiek en behandeling*. Lisse, The Nederlands: Swets & Zeitlinger.

Van den Bos, K. P., Zijlstra, B. J. H., & Van den Broeck, W. (2003). Specific relations between alphanumeric-naming speed and reading speeds of monosyllabic and multisyllabic words. *Applied Psycholinguistics, 24*(3), 407-430. doi: 10.1017/s014271640300213

Van den Broeck, W., & Geudens, A. (2012). Old and new ways to study characteristics of reading disability: The case of the nonword-reading deficit. *Cognitive Psychology, 65*(3), 414-456. doi: 10.1016/j.cogpsych.2012.06.003

Van der Leij, A., Bekebrede, J., Geudens, A., Schraeyen, K., G.M., S., Garst, H., . . . Schijf, T. J. (2012). *Interactieve Dyslexietest Amsterdam-Antwerpen: Handleiding.* Uithoorn.

van der Leij, A., & van Daal, V. H. P. (1999). Automatization aspects of dyslexia: Speed limitations in word identification, sensitivity to increasing task demands, and orthographic compensation. *J Learn Disabil, 32*(5), 417-428. doi: 10.1177/002221949903200507

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*(1), 2-40. doi: 10.1046/j.0021-9630.2003.00305.x

Vukovic, R. K., & Siegel, L. S. (2006). The double-deficit hypothesis: A comprehensive analysis of the evidence. [Article]. *J Learn Disabil, 39*(1), 25-47. doi: 10.1177/00222194060390010401

Wagner, R. K., & Torgesen, J. K. (1987). The Nature of Phonological Processing and its Causal Role in the Acquisition of Reading Skills. *Psychological Bulletin, 101*(2), 192-212. doi: 10.1037//0033-2909.101.2.192

Warmington, M., Stothard, S. E., & Snowling, M. J. (2012). Assessing dyslexia in higher education: the York adult assessment battery- revised. *Journal of Research in Special Educational Needs*. doi: 10.1111/j.1471-3802.2012.01264.x

Wechsler, D. (2001). *WAIS-III, Nederlandstalige bewerking, technische handleiding.* Lisse: Swets & Zeitlingen.

Wilkinson, G. S. (1993). *Wide Range Achievement test*. Lutz, Florida: PAR.

Wilson, A. M., & Lesaux, N. K. (2001). Persistence of phonological processing deficits in college students with dyslexia who have age-appropriate reading skills. *J Learn Disabil, 34*(5), 394-400. doi: 10.1177/002221940103400501

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*(3), 415-438. doi: 10.1037/0022-0663.91.3.415

Wolff, U., & Lundberg, I. (2003). A technique for group screening of dyslexia among adults. *Annals of Dyslexia, 53*, 324-339.

Students with dyslexia in higher education: study outcome and predictors for success

Chapter 4

Chapter 4: Students with dyslexia in higher education: study outcome and predictors for success

Callens, M., Tops, W., Stevens, M., & Brysbaert, M.

Little information is available on the study outcome of students with dyslexia in higher education. Data was collected from a group of 99 first generation students with dyslexia and a control group of 89. Demographic givens, the results on the NEO-PI-R and on the LASSI were used to predict drop-out and study outcome after three years. At the time of data collection results showed that being dyslexic has an impact on both study continuance and study success. Students with dyslexia are more at risk for dropout and have less chance to finish their bachelor program within the model trajectory of three years. Logistic modeling in the two groups separately did not lead to models of satisfactory quality in the control group so a comparison could not be made between groups. For the dyslexia group, a higher educational attainment of the parents was positively linked to better performance in HE (fewer dropouts and more study success after three years). Female students with dyslexia have more chances of dropping out, those who do continue, perform better than their male peers. For personality the following was observed. More agreeable, less conscientious and more neurotic students tend to drop out more. Extraversion negatively impacts dropout but has a positive effect on obtaining a degree. Learning strategies mainly influence study outcome after three years. Only low goal strategies relates to a higher risk of dropping out. Strangely, this also has a negative impact on study duration; we believe this to be mainly driven by higher anxiety levels. Well developed affective strategies and comprehension monitoring strategies are important in study success after three years. Finally, using compensatory means increases the chance of obtaining a degree after three years. The presence of comorbid disorders affects the chances of succeeding after three years. A general remark is that at the time of data collection some students had not yet terminated their program. A follow-up study is therefore recommended to get a full overview of study success and time to graduation.

Introduction

The transition from secondary to higher education is a challenge for every adolescent and success rates in the general student's population are found to be considerably low. Tuckman and Kennedy (2011), for example, report a dropout rate of 25% in American universities and up to 50% for Colleges. In a Belgian study success rate for first-year bachelor students varies from 45% for Colleges and 50% for Universities (Declercq & Verboven, 2010). Additional challenges are faced by students who enter higher education with a disability such as dyslexia. However, despite the extra strain for these specific students, a positive trend is noticeable worldwide -for it seems that students with dyslexia are registering in higher education in larger numbers than a few years back. As a result of this increase, literature on the topic has augmented tremendously in the last decade and information on the cognitive profile of individuals with dyslexia in higher education is now relatively widespread. It is the responsibility of institutions that organize and offer programs for higher education to try to meet the needs of these students at a reasonable level. A considerable amount of money and resources are invested in trying to provide facilities and compensatory means for students with disabilities to optimize their chances of succeeding. The question rises whether the current setting is sufficient for students with dyslexia to succeed in higher education equally well as their peers.

Because of the considerable economic and social impact, research on academic success and dropout in higher education been done. The main finding is that a number of factors are important in normal functioning students in higher education. Van Den Berg and Hofman (2005) concluded that student factors explain 95 % of the variance in study progress whereas only 5% is due to course factors. The fact that characteristics at the student level show the most significant and direct influence on study outcome, has been confirmed on other occasions as well (Loyens, Rikers, & Schmidt, 2007; Robbins et al., 2004). These characteristics are situated at different levels, namely familial and social background related, preschool experience, personality, intelligence and metacognitive study skills.

Background factors linked to academic achievement are parental socio-economic status (SES), gender, age and preschool experience. Most frequently, socio-economical status refers to the financial situation, the educational level and occupation of the parents (Bradley & Corwyn, 2002). According to Bourdieu (1986), the educational level of the parents is of special importance for the academic success of their children. Students who have higher educated parents are more likely to succeed (Lacante et al., 2001; Steinmayr, Dinger, & Spinath, 2010) than those who have parents with a lower academic attainment.

This correlation is said to be mediated by the influence of the parents' educational level on the intelligence and personality of their offspring (Steinmayr et al., 2010).

In studies predicting study outcome, gender also matters. Women have higher chances of succeeding (Declercq & Verboven, 2010; Lacante et al., 2001), are less likely to drop out, receive higher grades and graduate at a higher rate than their male colleagues (Buchmann & DiPrete, 2006). Age has also been assigned as an important factor but due to the restricted age group in our study we will not elaborate on this variable. As for preschool experience, students coming from grammar schools are the most promising in higher education in contrast to those coming from professional, technical or art programs (see further) (Goovaerts, 2011; Lacante et al., 2001) and are less likely to fall out. It has been said that former education is a meaningful determinant of an individual's orientation to learning (Duff, Boyle, Dunleavy, & Ferguson, 2004).

Studies on academic success also typically include measures of personality and intelligence for they have proven their impact on academic success. Intelligence has been said to exert not only a direct influence on study success (Busato, Prins, Elshout, & Hamaker, 2000) but also indirectly through its relation with study skills (Chamorro-Premuzic & Furnham, 2008). Rosander and Backstrom (2012) found that IQ was the most effective predictor of academic achievement although the correlation between IQ-scores and academic performance decreases with age, going from 0.6 in elementary school to 0.4 in higher education (Chamorro-Premuzic & Furnham, 2005). Other studies were, however, unable to replicate this correlation and discarded intelligence as a good predictor of academic achievement at a post-secondary level (O'Connor & Paunonen, 2007). It has been suggested that because in higher education a selection based on intelligence has already taken place, variables such as personality and motivation are more likely to have an impact on academic success. Several studies have confirmed this idea and reported that -when controlled for IQ- personality accounts for a substantial part of the variance in academic performance and that personality has a higher predictive power than IQ in higher education (Kappe & van der Flier, 2012; Poropat, 2009).

Studies on the impact of personality on academic attainment typically use the Five-factor model or the Big Five model. This model is based on the fact that when using these 5 factors (neuroticism, extraversion, openness, agreeableness and conscientiousness) most of the individual differences in behavioral patterns can be accounted for. Across studies, on four of the five personality factors the results are somewhat contradictory but conscientiousness has consistently been found as a strong predictor of academic success (Chamorro-Premuzic & Furnham, 2008; Kappe & van der Flier, 2012;

Poropat, 2009). This relationship has been explained in terms of the self-discipline, the persistence and the orientation to achievement of highly conscientious students.

Finally -not surprisingly- study skills as part of the student factors, have been identified as important precursors of academic success. For example, in a meta-analytic study by Robbins et al. (2004) study skills are defined as a variety of behaviors and activities necessary to organize and complete schoolwork and to prepare and take tests such as note-taking, time management, motivation and using information resources. Here, academic self-efficacy and academic motivation were the best predictors of academic performance- operationalised as a grade point average- with contributions over and above those of SES and previous school experience. Rosander and Backstrom (2012) reported that learning approaches had the potential to explain additional variance differentiated for gender, when controlled for personality. In many studies on the identification of at-risk students in higher education, the Learning and Study Strategies Inventory (LASSI) is administered as a measure of study skills and learning strategies. Marrs, Sigler, and Hayes (2009) reported that the Motivation subscale correctly discriminated 71% of the successful students. This result was replicated in a similar Asian study, where Attitude and Motivation were identified as the two major factors in the discrimination of high achieving students (Yip, 2007). In a study on the performance of medical students, not Motivation but Time Management and Self-testing were crucial study skills in the prediction of academic success (West & Sadoski, 2011). As such, the LASSI has proven its value in the prediction of academic success (Carson, 2011; Marrs et al., 2009; West & Sadoski, 2011; Yip, 2007).

We do not pretend the above list of factors affecting academic performance to be exhaustive but the variables discussed seem to be the most essential variables and have proven their individual contribution in the prediction of success for normal functioning students.

Many healthy students have trouble succeeding in higher education and things get even more complicated for students with dyslexia as a specific learning disorder. Despite this extra burden, the fact remains that -internationally- a rise in the numbers of students registering for higher education can be observed (Hadjikakou & Hartas, 2008; Hatcher et al., 2002; Madriaga et al., 2010). Vogel et al. (1998) postulate several reasons, such as the fact that aspirations and expectations of students with a learning disability (LD) now go beyond secondary school. Other reasons are the increase in self-knowledge and self-advocacy in these students with a more effective planning as a result, the implementation of regulations that give them access to reasonable adjustments in higher education, and an increased awareness in professionals and postsecondary institutions due to more scientific publications on the topic of what these students require. Prevalence rates for dyslexia in the general population vary a great deal - largely depending on the language and the applied cut-off rates- but a prevalence of about 5 to 10% is a commonly accepted estimation (Jimenez et al., 2009; Plume & Warnke, 2007; Snowling, 2000). As for the prevalence of dyslexia in higher education, less information is available. In a Dutch study by Broeninck and Gorter (2001) on a total of 478 000 students 2 to 3% were dyslexic. In the US, a study from 1998 reports a prevalence going from 0.5% to 10% depending on the institution (Vogel et al., 1998). More precise numbers are at hand from the UK because here every student that applying for a Disabled Student Allowance is registered. In 2003-2004, a prevalence of 2,22% was noted. Still, students are not obliged to make their disability public so the number could be an underestimation of the exact rate.

The core problems of people with dyslexia are reading and spelling difficulties. Due to the importance of these skills in combination with a higher work load in higher education, they are likely to have an impact on the academic functioning, and indirectly influence other important academic skills. Furthermore, several other coinciding cognitive deficits that could have an effect on academic performance have been reported in students with dyslexia in higher education. For one, the presence of persistent phonological problems in adulthood is undisputed (Callens et al., 2012; Hatcher et al., 2002; Johnson, Humphrey, Mellard, Woods, & Swanson, 2010; Reid et al., 2007). Many studies also describe deficits in lexical retrieval and naming (Lindgren & Laine, 2011; Shaywitz & Shaywitz, 2005), verbal memory (Johnson et al., 2010; Wolf et al., 2010), vocabulary and math (Callens et al., 2012; Swanson & Hsieh, 2009).

Every one of these impairments can have an additional impact on skills necessary for efficient functioning in an academic context. When we look into the specific academic related difficulties these students with dyslexia encounter in higher education, the findings are mostly based on self reports. In a qualitative study at the University of Leuven (Defranc, 2008) university students were interviewed about the specific problems related to their disability they encounter in their studies. Compared to their peers, these students reported they had to invest more time in reading and structuring their courses, mainly because comprehension was hampered due to the time invested in the technical part of reading. Course materials provided in a different language than their mother tongue also form an obstacle. The students encounter difficulties with note taking during classes, even more so for unstructured classes and in noisy surroundings. Note taking is a very complex skill with a heavy load on working memory and is affected by several factors such as listening comprehension, information processing, writing and organization. Writing papers and essays is perceived as problematic because of the difficulties students with dyslexia have formulating ideas and identifying errors in their grammar and spelling (proofreading). Memorizing facts and names and learning courses that are unstructured and deprived of logical coherence are found to be difficult. Finally, problems with time management due to a poor concept of time or the inability to estimate how long tasks will take are an extra cause of stress. These findings correspond to those reported by Du Prez, Gilroy, and Miles (2008), MCLoughlin, Leather, and Stringer (2003) and Mortimore and Crozier (2006). It goes without saying that considering their cognitive deficits and the reported problems in higher education, these students are potentially more burdened than the average student in an academic context.

To help these students with learning disabilities to overcome these difficulties related to their disability, they are entitled to so called "reasonable adjustments" or in more common terms "compensatory means". In the Dutch speaking part of Belgium, the legislation on the right to reasonable adjustments is described in the Flemish Decree for Equal Chances of July 2008 and in the UN Convention on the Rights of Persons with Disabilities that was ratified in Belgium in July 2009. In the Flemish Decree for Equal Chances reasonable adjustments are described as all measures of a(n) (im)materialistic nature, that neutralize the problems encountered by a disabled individual when trying to participate in an unadapted environment. A refusal of such adaptation is viewed as discrimination. In the UN convention learning disorders such as dyslexia fall within the category of disabilities on the grounds of it being a permanent cognitive impairment that hinders an individual to participate in educational settings in the same way as normal individuals. In article 24 of this convention it is clearly stated that a person with a disability has a right to reasonable adjustments in the educational setting, so that the person can participate on equal grounds and without discrimination. In both legislations adjustments are considered reasonable when they do not cause any disproportional inconveniences for the authority that should provide them and when they are not covered by another adjustment. So, in practice every institution providing education in Belgium is obliged to grant these compensatory means to students with dyslexia to make participation possible. The final decision is in the hands of the institution, but a rejection for a certain adjustment requires a justification of its disproportionallity and should result in an active search for alternative solutions. Common compensatory measures for students with dyslexia are study or exam related, such as providing digital versions of courses (so speech software can be used), overlooking spelling or syntactical errors in written materials, giving more time for written exams and more preparation time for oral exams, reading questions out loud and granting a wider spread of exams in time.

To acquire compensatory measures in Belgium, the student needs to be in the possession of a founded attestation for dyslexia that meets the 3 criteria of the definition of dyslexia of the Stichting Dyslexie Nederland (2008) [Foundation Dyslexia Netherlands]. First of all, the level of reading and/or writing should be significantly lower than what can be expected on the basis of one's educational level and age (below percentile 10 on a standardized instrument). Secondly, a resistance to instruction (low scores should remain present despite some form of remedial teaching) should be demonstrated. Finally, external and/or individual factors such as socio-economic status, cultural background or intelligence should not be the cause of the reading and writing impairment. Once these measures are granted, it is up to the students to use them or not.

However, even with these current adjustments it is not unlikely that students with dyslexia are more at risk for failure and dropout than normally functioning students. In our study, by comparing two matched groups of first-year bachelor students (dyslexia and controls) we want to see whether students with dyslexia are more prone to dropout and whether having a learning disability plays a role in academic success. In comparison to the general literature available on academic performance in higher education, far less has been written on the success rates of learning disabled students and the factors that have an impact on their academic success.

Some studies have shown that students with learning disabilities can attain normal levels of academic performance with the assistance of adequate academic support. Within an educational context as in the US and the UK, where strict admission criteria are applied, outcomes seem quite positive for students with learning disabilities (LD). In a large American longitudinal study, no differences were found in annual dropout and graduation-time for students with LD compared to control students (Wessel, Jones, Markle, & Westfall, 2009). These findings are similar to the ones reported by Adelman and Vogel (1990), Vogel and Adelman (1992), Trainin and Swanson (2005), McGuire, Hall, and Litt (1991) and Richardson (2009). In the study by Adelman and Vogel (1990) the LD group graduated at about the same rate as the control group and academic failure rates were almost identical on both groups. In another study, the group of LD students even outperformed the control students in academic performance and the number of grades obtained (Vogel & Adelman, 1992). Trainin and Swanson (2005) also found a non significant difference in achievement in a small sample (N=20) of learning disabled students compared to peers. However, some of the above reported studies report on learning disabilities as a group without further specifications or subdivisions possibly resulting in large group heterogeneity. Richardson (2009) identified the differences in educational attainment between students with and without dyslexia in the

UK as confounded with effects of demographic and institutional variables. However, for all the above studies the following can be said. Due to the strict entrance criteria in institutions for higher education, these students are likely to be a very select, highly motivated group for they already managed to get through the selection procedures. Furthermore, differences in cut-off scores used for the diagnosis of dyslexia and the lack in consensus on dyslexia in the US can also lead to a large variation in results. For example, in the study by Trainin and Swanson (2005) a cut-off score of percentile 25 on phonological processing was used for the definition of LD. As a group, these students did exhibit deficit in word reading but large individual variations cannot be excluded based on the available data. A literature review by Hughes and Smith (1990) clearly demonstrates this problem for in their discussion of limitations they themselves acknowledge that "identification procedures vary across programs". Sparks and Lovett (2009) further reinforce this finding. In an up-to-date review on the literature on postsecondary students with LD they state that only 30% on a total of 400 studies reported empirical data and a wide range of criteria was used for classification means of LD. A final reflection relating to the generalization of the findings from the UK and the US is that in several European countries higher education is mainly supported by the government, making the tuition considerably smaller and as a result higher education more accessible to a wide range of students.

For all the above reasons, the reported findings in the Anglo-Saxon system cannot be generalized to other educational settings and one may wonder how students with dyslexia perform when no pre-entry criteria are imposed. Additionally, considering the enormous amount of research on academic achievement in normal functioning students and the factors that predict success, it is remarkable how little information is available for this specific subgroup. One study focusing on factors potentially influencing academic growth in learning disabilities was published by Patrikakou (1996). Here, parental expectations were found to be essential in raising the academic achievement in adolescents with LD. Factors included in the above study, that reappear in the above mentioned studies on academic performance students without LD are background related (gender, prior achievement and SES) or measure individual academic expectations. Within this framework, prior achievement and academic expectations turned out to be highly correlated to current achievement in both groups. Results in this study indicated that the same factors are at hand in both groups, so findings from a normal student population possibly apply to students with a learning disability as well. In a second study by Murray and Wren (2003) only FIQ and procrastination accounted for a small amount of variance in Grade Point Average (GPA) in a sample of learning disabled students in a large private university. However, in this study only intelligence measures and a survey on study habits and attitude were inserted in the analysis.

The authors concluded that other measures besides cognitive and academic skills are relevant in academic performance in higher education. Again, the same objections can be postulated as for the general studies on academic achievement in dyslexia.

The lack of information of individually influential factors on study outcome and academic performance in dyslexic students is very unfortunate for it is highly relevant for student support centers with respect to e.g. study choices and career decisions. For example, it could be that motivation and study skills are even more relevant contributors to academic success in students with dyslexia than for their peers. Or it could be that higher cognitive abilities aid in overcoming their difficulties leading to better academic performance.

The present study was conducted to answer the following research questions:

1. How does dyslexia influence study outcome in a free admission higher educational context?
2. What individual factors contribute to success in students with dyslexia in higher education within these settings (and are these different from the normal population)?

Method

Educational system in Flanders

A quick overview of the educational system in Flanders seems appropriate to comprehend the context and the data collected in the study.

Typically, students enter secondary school at the age of 12 after completing a 6-year program in primary school (preceded by three years in kindergarten which are not compulsory). When primary school is completed successfully, children enter the A-stream of the first grade of secondary school (first two years of secondary education). After completion of the first grade, students can enter any type of second grade educational form (four subsequent years) they choose, namely general secondary education (GSE), technical secondary education (TSE), arts secondary education (ASE) or professional secondary education (PSE). However, when no primary school diploma was obtained or when the student is confronted with learning difficulties or considered unsuited for general education, B-stream first grade education is advised. After one year in B-stream education a transition to the first year A-stream is still possible but after a second year in B-stream only a transition to PSE is possible for the second grade. So, in second grade students usually have to make a choice between four types of secondary education: GSE, TSE, ASE or PSE. Unfortunately, they are not altogether considered as equal. A cascading effect is often observed, were instead of focusing on the interests of the student TSE, ASE and PSE are only considered when failing in GSE. In GSE pupils aim at a general acquisition of knowledge in a wide range of subjects such as languages, sciences, math, history and geography as a preparation for higher education. Students can choose between a large set of programs that each have a specific emphasis (e.g. math, languages, or sciences). In TSE, theoretical, practical or combined programs are organized which prepare for either a specific profession (practical and combined programs) or a transition to higher education (theoretical and combined programs). ASE constitutes of programs in three areas of expertise namely ballet, stage arts and plastic arts. Some aim at a transition to higher education and are more theoretical in nature, while others are more applied and lead to a specific profession. Finally, PSE is a very practical form of education where theoretical courses are purely meant to back up the practical courses and trainings. An additional specialization year is needed to go to in higher education.

After signing the Bologna Declaration[1], the Bachelor-Master structure (BaMa) for higher education was introduced in Flanders in 2004. In accordance with this declaration the higher educational system now consists of professional bachelor degrees, academic bachelor degrees and master degrees, potentially followed by a doctoral degree. Professional bachelor degrees typically prepare students for specific professions in a wide range of areas such as health care, education, social work and technology. These programs include courses that are practice-oriented and involve internships and many practical training sessions. These bachelor programs are exclusively organized in so called university colleges. As for the academic bachelor programs, these are provided by either a university or a university college in association with university (from 2013-2014 on these will all be incorporated in university). Academic bachelor programs are aimed at the acquisition of academic skills and are usually followed by a master degree. A credit accumulation system of study progress (CAS) based on ECTS (European Credit Transfer System) is operational in all forms of higher education. One credit represents 25 to 30 hours of a students' work load. Usually, each course counts for at least 3 credits, with a maximum of 12 courses per 60 credits. Students are responsible for their own study program and can choose between three options (diploma contract, credit contract and exam contract). Students are also free to decide how many credits they want to include and attempt to earn in their annual program. In this study, all

[1] Flanders is the Dutch speaking Northern half of Belgium

students were engaged in a traditional diploma contract aimed at the acquisition of a diploma[2]. Each academic year consists of about 60 ECTS credits. A bachelor degree can be obtained when 180 ECTS (a full bachelor program) are accumulated, which in a model trajectory takes three years. In practice, institutions have individual regulations for deviations or tolerances on the number of obtained credits in order to obtain a degree (on the certificate of qualification credits that were not obtained are mentioned as such).

Participants

The study protocol was approved by the ethical committee of Ghent University, meaning that students gave a written informed consent and were informed that they could stop at any time if they felt they were treated incorrectly.

This study is a longitudinal follow-up study of the students who participated in the general study on dyslexia in higher education (Callens et al., 2012). A broad scale of cognitive tasks, reading and spelling tasks, a learning strategy instrument, and a personality test were administered to 200 young adults (a group of 100 students with dyslexia and a control group). All individuals participating in the study were first year bachelor students (professional or academic) within the Association Ghent. They all had Dutch as their mother tongue and had normal or corrected-to-normal vision. The group of 100 students with dyslexia was recruited with the assistance of Cursief, a non-profit institution responsible for the attestation and follow-up of students with disabilities within the Association Ghent. Every first year bachelor student applying for special educational measures related to dyslexia was asked to participate until a total of 100 were reached (only few declined). Most students with dyslexia reported having a history of reading and/or spelling problems throughout their school career, either from primary school (N=96) on or starting in secondary school (N=3). For two participants this is not clear. Ninety-eight students reported having been diagnosed prior to the study by trained diagnosticians (such as a speech language pathologist or a psychologist). From two students this data was unavailable. Most students with dyslexia reported having received individual tutoring in primary or secondary education (N=87) for a period of minimum 6 months by either a speech-therapist or a remedial teacher. Eight students received extra tutoring in primary school. One participant started primary school in an institution for special education and from two students this information is unavailable. Only two students did not receive any specific training. Based on the results on the reading and writing tests, it was clear that the

[2] A few students ($N_{controles}$= 4; $N_{dyslexia}$= 4) registered for an extracurricular course on the basis of an exam contract. However, due to the limited number of students doing this, we decided to leave these out of the analyses.

group met the three criteria (see above) for dyslexia put forward by the Foundation Dyslexia Netherlands (Nederland, 2008). A control group of 100 first year bachelor students was recruited - matching the dyslexia group on gender and field of study- using the social networks of the students, student coaches and electronic learning platforms. None of the members of the control group had any known neurological or functional disorders. To avoid confounds based on previous experiences in higher education and to compare trajectories of pure first year bachelor students we decided to only use the generation[3] students. This resulted in the omission of 10 students from the control group and one from the dyslexia group. Additionally, from one student of the control group we could not collect data on academic performance. This resulted in a final control group of 89 students and a group of 99 students with dyslexia in this longitudinal study. From each participant the presence of any comorbid disorders (for dyslexia group), the use of compensatory means (for the dyslexia group), the highest obtained educational level of both parents, the type of diploma obtained in secondary school (GSE, TSE, ASE, PSE) and the type of bachelor program were registered. For the parents' educational levels a different partition for higher education was applied than for the participants due to the fact that the BaMa structure was not yet effective at the time of their graduation. Colleges provided three or four year programs with a more applied nature, the standard university program at that time consisted of a minimal four year program, academic in nature. Educational attainment (SES) is therefore divided in first grade and second grade secondary school, non-university college, and university. For this variable, 7 data points for the father and 6 for the mother were missing. To avoid elimination of these 7 participants, we applied a hot deck imputation. This is an often used method for handling missing data in which each missing value is replaced with an observed response from a "similar" unit. As for the institutions, all students came from 4 different colleges (all within the Association Ghent) and 1 university. Artevelde and Ghent College are quite large and together with the Catholique College Saint-Lieven (which is smaller) they have a large overlap in program. Saint-Lucas School of Arts has a focus on art directed programs. Concerning the field of study, we decided to group programs (independent of their professional or academic status) because of the large disparity relative to the number of students. We grouped fields of study in 8 categories based on a division postulated by the Ministry of Education namely Health care (e.g. nurse, pharmacy, occupational therapy), Business sciences (business engineer, office management, applied economical sciences), Human sciences (psychology, pedagogy, social work), Law and criminology, Education (kindergarten teacher, teacher in primary and secondary school), Art and history, Politics and sociology and Industry and Technology (chemistry, bio engineering, wood

[3] Generation students are all students that are inscribed for the first time in a bachelor program.

technology, electro-mechanics). The reported comorbidities in the dyslexia group entailed attention deficit (hyperactivity) disorders, dyscalculia and combinations of these disorders but because of the relative low frequencies of these comorbidities when separated they were grouped as a whole.

Study outcome

A full bachelor program is usually spread over three years; therefore data on academic performance was collected at the end of the academic year 2011-2012 (October 2012). At the beginning of the general cognitive study all participants signed a consent form, giving their educational institution permission to transfer their study results to us. The administrative services from all institutions provided us with the following data: dropout per year, the number of credits the student registered for per year, the number of credits obtained per year and whether or not the student obtained a bachelor degree after three years. In relation to dropout the following needs to be taken into account. The term dropout refers to the termination of a study before formal graduation. However, the student still has several options. They can switch to another program at the same or a different level or not continue an educational career at all. When a student did not continue a program, we did not have access to quantitative data from any subsequent program. Therefore, participants who dropped out during or after the first year were contacted during the second year by phone and email to inform us on their current occupation. These results will be described qualitatively.

Instruments

The data used in this study was collected in a large study on dyslexia in higher education by Callens et al. (2012) (see Chapter 2). Personality and learning and study strategies were also assessed but these results were not reported in that study because of its focus on the cognitive profile of students with dyslexia in higher education. These are described below.

Learning and Study Strategies Inventory (LASSI).

To assess if students are aware of learning and study strategies and how to apply them, a validated Dutch version (Lacante & Lens, 2005) of the Learning and Study Strategies Inventory (LASSI) (Weinstein, Schulte, & Palmer, 1987) was administered. This Dutch instrument has been used frequently in scientific studies (de Bilde, Vansteenkiste, & Lens, 2011; Vansteenkiste et al., 2012; Vansteenkiste et al., 2010). Each of the ten scales contains eight items to be rated on a 5-point Likert scale ranging from 1 (not at all typical) to 5 (very typical for me), except for the “Selecting main ideas”, which only contains 5 items. For the different scales alpha Cronbach's reliability scores range from .63 to .83 (Lacante et al., 2001). The *Information processing* scale represents how well a student makes use of imagery, organization skills and reasoning skills when processing new information and uses skills to connect this to what they already know. The ability to identify crucial information amongst details and less important information is reflected in the *Selecting main ideas* scale. Next, in the *Time management* scale an idea is given on how well a student uses time management strategies in academic situations. The *Concentration* scale assesses how a student is capable of directing and maintaining attention on academic tasks. The *Anxiety* scale examines to which degree a student worries about his academic performance. The interest and orientation on education and academic achievement is tested with the *Attitude* scale. The *Motivation* scale relates to exerted self-discipline and effort necessary for success in an academic context. In the *Study aids* scale an inventory is made on how well a student uses support and resources to help him in studying. The use of reviewing and comprehension monitoring techniques to assess their level of processing the information is evaluated in the *Self testing* scale. Finally, in the *Test strategies* scale an evaluation is made on how the student prepares for tests. Usually the LASSI is made on paper, but to make administration easier this inventory was presented in form of a power point slideshow with 1 question per sheet. The answer applicable to them had to be clicked. The scoring was made manually by the test leader, resulting in total scores for all 10 scales. For items that are negatively formulated, a reverse scoring rule was used. Therefore high scores result in a good score.

NEO-PI-R

The Dutch NEO-PI-R measures the 5 most important dimensions in personality, as stated in the Big Five model and is based on the original Revised NEO Personality Inventory by Costa and McCrae (1992). Each dimension (Neuroticism, Agreeableness, Extraversion, Openness to experience, and Conscientiousness) is subdivided into 6 facets, each represented by 8 items, thus resulting in a total of 240 items. For the 5 dimensions Cronbach's alpha varies between .68 and .86. The digital version was applied for administration and scoring on all 200 students. Participants were seated in front of the computer, the test administrator filled in all relevant information (such as date of birth, gender) needed for computerized scoring. Next, to ensure a correct use of the instrument the test administrator read out the instructions displayed on the screen and stayed with the participant for the first couple of questions. Once it was clear that the participant was sufficiently familiarized with the administration, participants filled in the remaining items. The test administrator stayed in the room for backup if needed. After termination, a detailed scoring sheet was available. Scores for all 30 facets and the 5 dimensions were available for all 200 participants.

Data analysis

The topic of our analysis, study progress, can be characterized in several ways. One can contrast the number of dropouts, students still working on their program and students who have obtained their degree. Alternatively, one can count the number of obtained credits. This measure has the advantage of begin a continuous variable, but visual inspection of the data revealed that this variable was nowhere near normally distributed. As can be seen in Figure 1, students who had obtained their degree scored close to the maximum (90-100% of obtained credits), students who dropped out scored close to the minimum (0-25%) and students who were still in their bachelor program scored in between. Therefore, we chose to analyze study progress as a categorical variable. In a first analysis, the number of students who dropped out (Dropout) was the dependent variable. In a second analysis, of the remaining group, the number of students who obtained their degree (Degree obtained) was the dependent variable.

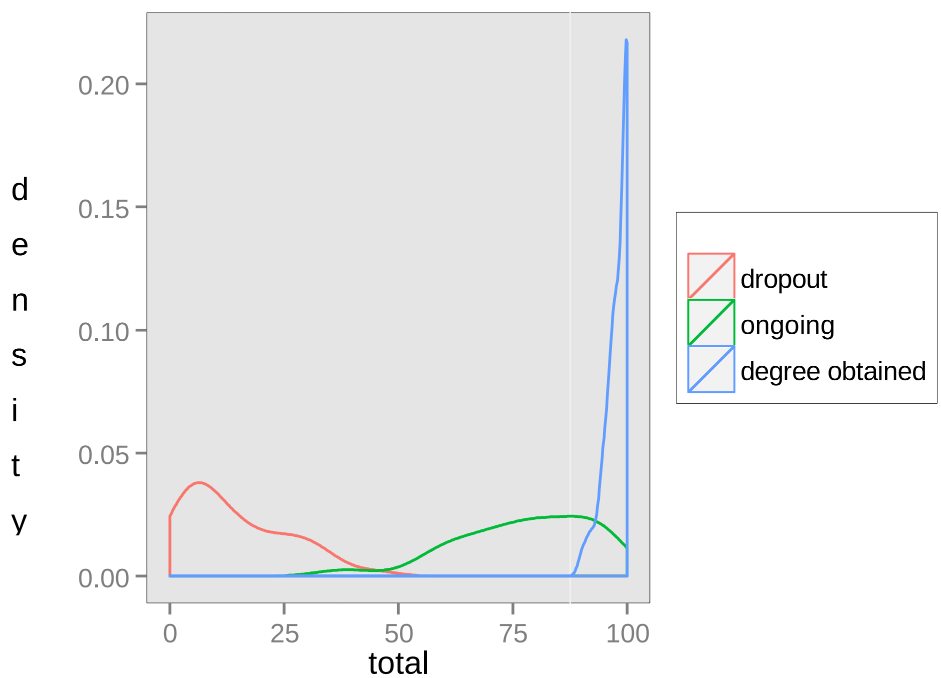

Figure 1. Density plot of the percentage of degrees obtained, split up by group.

Our analyses contained a rather large number of possibly highly correlated predictors. Therefore, we first describe the bivariate relationship of each predictor with Dropout and Degree Obtained, and the interactions with dyslexia. This allows us to identify the predictors that can be included in the further models. To further alleviate possible multicollinarity problems, the LASSI subscales were reduced to three components using Principal Components Analysis. Then, three model building strategies were compared.

In a first analysis, post-diction models were built manually, selecting the predictors in three steps. First, separate models were fitted per group of predictors (background, NEO-PI-R and LASSI). From these models, we selected the significant predictors and these were entered in the full model. In the final step non-significant predictors were removed. These models however are only valid for the data upon which they are based. In such an analysis authors first administer a series of tests and then examine how well the scores allow them to classify the participants. In this type of analysis the more test scores one has the better the prediction becomes, because the test scores are combined in such a way that they optimally account for the pattern of performances observed in the specific group tested. The drawback of this procedure is that it tends to overestimate the percentage of systematic variance, because sample-specific variance (noise) is used for model fitting. As a result, using the same criteria for a new group of participants is likely to result in significantly worse assessment.

So, we also wanted to build models that perform well on new data too. In the present study we will select variables based on prediction results rather than “postdiction” results (Gaugh, 2002). In such an analysis, one examines to what extent it is possible to use the scores of one group of participants (the training data) to predict the performance of another group (the test data). This avoids the problem of model overfitting. Both in a predictive and post-diction model the model fit increases over the first few predictors included. However, whereas in a post-diction model the fit keeps on increasing (because of overfitting), in a predictive model the fit starts to decrease after a few variables have been entered, a phenomenon which Gaugh (2002) called “Ockham’s hill”. The reason for the decrease in performance is that after a certain point the model starts to explain noise in the group tested rather than variables systematically affecting performance. Therefore, the number of significant variables in a predictive model usually is lower than the number in a post-hoc analysis. Models with few parameters may be underfitting reality, but models with additional parameters tend to overfit spurious noise (Gauch, 2002).

Two sets of prediction models were built. The first set of models was build using recursive feature elimination as implemented in the R package caret (Kuhn, 2008). This automated selection procedure is highly similar to stepwise regression with backward elimination: first, a full model is fitted and the predictors are ranked according to their importance as measured by the absolute t-value. The least important one is then removed from the model. A new model is fitted and again the least important predictor is removed. This is repeated until no predictors are left in the model. The difference with stepwise regression is that this process is repeated many times (100 in our analysis) on subsets of the data. In each step, prediction accuracy of the model is computed on the hold-out sample. This prediction accuracy is then used to select the optimal size of the model and the optimal set of predictors in the model. Then, the final model is fitted on the full dataset using this optimal set of predictors.

Recursive feature elimination will lead to better prediction accuracy than post-diction models, but there is still a drawback. In the presence of highly correlated predictors that are both related to the dependent variable, the solution may become unstable: on one subset of the data, the first predictor may win over the second, whereas in a second subset of the data the second predictor may win. A slight change to the data might reverse this again. This instability is caused by the all-or-none nature of the selection mechanism: both predictors try to explain the same variance, but once this variance is explained by one predictor, there is no need for the other predictor to explain it a second time. The third model building approach we used circumvents this problem by shrinking the regression weights of correlated predictors: instead of selecting one predictor over the other, they both stay in the model, each having a smaller (shrunken) regression weight compared to the situation where only one of them would be in the model.

This shrinkage strategy is implemented by adding a multiple of the sum of the regression weights to the loss function of the linear model. The sum can be either the sum of the absolute values, the sum of the squared values or a mixture of both. The first is called lasso regression, the second ridge regression and the third is the elastic net (Friedman, Hastie, & Tibshirani, 2010). This leads to a two-dimensional set of solutions of the regression model. One dimension spans the range between pure lasso and pure ridge regression. On this dimension we chose the lasso regression, as this method will not only shrink the weight of variables, but also remove the ones that are completely unnecessary. The second dimension varies the penalty on the size of the regression weights and spans the range between no penalty at all (all regression weights are identical to the standard regression solution) and an infinite penalty (all regression weights become zero). We determined the optimal size of the penalty parameter by looking at the prediction accuracy on our hold-out sample. One drawback of the shrinkage methods is that they are completely focused on prediction: the outcome of the analysis is an optimal subset of predictors and regression weights, but no p values are associated with the predictors.

Our hope is that the combination of the three techniques gives us a list of ‘common’ predictors that survive all selection strategies.

Results

How does dyslexia influence study performance in a free admission higher educational context?

Univariate analysis

a. Background data

Detailed information on the participants can be consulted in Table 1. Originally the two groups (N= 200) were matched on gender and field of study but due to the loss of certain participants a comparison of groups on these characteristics seems appropriate. The participants in the two groups did not differ in gender [$\chi^2_{(1)}$ = 0.12; p=0.73], FIQ [t (186) =1.19; p=0.23] nor in age at entrance [t (186) =-1.768; p= 0.08]. For means and standard deviations see Table 1. Also, the educational level of the father [$\chi^2_{(3)}$ = 2.15; p= 0.54] and mother [$\chi^2_{(3)}$ = 6.28; p =0.1]) was not significantly different between groups. The type of secondary education of the participants is significantly different between groups [$\chi^2_{(3)}$ =7.81; p=0.05]. To further analyze this difference, we compared the number of students with a GSE level degree ($N_{control}$= 60, $N_{dyslexia}$= 49) to the number of students at the other levels (TSE, ASE, PSE) combined for both groups ($N_{control}$= 29, $N_{dyslexia}$= 50). More students with dyslexia came from a technical, art or professional type of secondary education [$\chi^2_{(1)}$ = 5.46; p=0.02] than the control group.

Table 1
Characteristics of the First Generation Students within the Control Group and the Dyslexia group Expressed in Number and Percentage within Groups.

		Control group	Dyslexia group
Gender	Male	40 (44.95%)	41 (41.41%)
	Female	49 (55.05 %)	58 (58.59%)
Mean age		19.02 (SD=0.61)	19.23 (SD=1.00)
Comorbid disorders			21 (21.21%)
Use of compensatory means			74 (74.7%)
SES father	First grade secondary	3 (3.37%)	7 (7.07%)
	Second grade secondary	37 (41.57%)	36 (36.36%)
	College	27 (30.34%)	30 (30.30%)
	University	15 (16.85%)	22 (22.22%)
	Missing	7 (7.87%)	4 (4.04%)
SES mother	Lower secondary	4 (4.49%)	4 (4.04%)
	Higher secondary	32 (35.96%)	35 (35.35%)
	College	41 (46.07%)	40 (40.40%)
	University	5 (5.62%)	18 (18.18%)
	Missing	7 (7.86%)	2 (2.02%)
Secondary education (SE)	GSE	60 (67.42%)	49 (49.49%)
	TSE	26 (29.21%)	40 (40.40%)
	ASE	1 (1.12%)	6 (6.06%)
	PSE	2 (2.25%)	4 (4.04%)
Type of Bachelor	Professional	52 (58.43%)	62 (62.62%)
	Academic	37 (41.57%)	37 (37.37%)

Table 2
Means and Standard Deviations for the NEO-PI-R and LASSI for the Control Group (N=89) and the Dyslexia Group (N=99).

	Control group		Dyslexia group		
	Mean	SD	Mean	SD	*p*
NEO-Extraversion	167.89	20.17	165.36	18.70	n.s.
NEO-Neuroticism	149.92	19.50	147.00	19.78	n.s.
NEO-Agreeableness	165.07	14.93	165.62	19.63	n.s.
NEO-Openness	167.96	17.24	167.86	16.73	n.s.
NEO-Conscientiousness	151.08	20.65	152.23	20.36	n.s.
LASSI-Information Processing	27.70	4.62	29.12	4.45	0.033
LASSI-Selecting Main Ideas	17.34	3.37	16.86	3.11	n.s.
LASSI-Time Management	22.94	5.47	23.05	5.41	n.s.
LASSI-Concentration	24.64	5.15	24.82	4.86	n.s.
LASSI-Anxiety	26.27	5.63	24.71	5.06	0.046
LASSI-Attitude	32.20	3.76	30.96	4.26	0.036
LASSI-Motivation	26.91	4.29	27.01	4.99	n.s.
LASSI-Study Aids	25.70	4.15	24.96	4.39	n.s.
LASSI-Self Testing	23.97	4.57	24.09	3.75	n.s.
LASSI-Test Strategies	29.47	4.22	26.73	4.25	> 0.0001

b. NEO-PI-R and LASSI

The results for the NEO-PI-R and LASSI are presented in Table 2. For personality, no differences were found. Four subscales of the LASSI resulted in significant differences namely Information processing, Anxiety, Attitude and Test strategies.

c. Principal component analysis of the LASSI

The LASSI results in a total of 10 subscale scores. We had no specific hypotheses regarding these different subscale scores so we chose to reduce this large number using principal component analysis (PCA). This also eliminates a possible influence of high correlations between subscales in the logistic regression models. A principal component analysis with a promax rotation was applied. The Kaiser-Guttman rule was used to determine the number of components. This rule states that only components with eigenvalues larger than 1 were withheld. This was the case for three of the 10 components. The model seemed to fit the data reasonably well [Goodness-of-fit index (GFI) = .93]. The standardized loadings based upon the correlation matrix, the communalities, the uniqueness of the variables and the amount of explained variance can be consulted in Table 3.

These results are identical to the PCA performed on the LASSI by Cano (2006)[4]. Therefore -in analogy with Cano (2006) - the component scores of the three extracted component were used for further analysis. The variables Attitude, Motivation, Time management and Concentration loaded high on the first component -now referred to as *Affective strategies.* Anxiety, Selecting main ideas and Test strategies loaded high on factor two: *Goal strategies.* The remaining three subscales (Information, Study Aids and Test strategies) loaded high on the third component: *Comprehension monitoring*.

[4] This PCA was performed on the data of all generation students. PCA analysis on the subgroups separately (dyslexia-controls) resulted in the same three component structure.

Table 3
Loadings, Communalities and Uniqueness for the LASSI Subscales on the Three Components.

Subscale	PC1	PC2	PC3	Communalities	Uniqueness
Attitude	0.49	0.26	0.03	0.38	0.62
Motivation	0.84	-0.14	0.15	0.76	0.24
Time management	0.87	-0.07	0.04	0.75	0.25
Anxiety	-0.04	0.78	-0.29	0.64	0.36
Concentration	0.81	0.20	-0.08	0.75	0.25
Information	-0.10	0.32	0.68	0.55	0.45
Selecting main ideas	-0.18	0.79	0.29	0.68	0.32
Study aids	-0.04	-0.02	0.78	0.58	0.42
Self testing	0.22	-0.22	0.76	0.73	0.27
Test strategies	0.27	0.75	-0.06	0.73	0.27
Proportion variance	0.26	0.21	0.19		
Cumulative variance	0.26	0.47	0.66		

Number of Dropouts and Degrees obtained after three years for the two groups

a. Dropout

To evaluate the study continuance of the group of dyslexic students compared to the control group, we compared the number of drop outs (premature termination of the study program they registered for in the academic year 2009-2010) in each group. As stated before, dropout does not necessarily imply that the student stops higher education altogether. In general, considerably more students with dyslexia [*N*= 34; 34%] dropped out of their study their registered for in 2009-2010 compared to the number of control students who dropped out [*N*=15; 17%] [$\chi^2_{(1,N=188)}$= 7.434; *p*= 0.005]. When looking more in detail, we see that from the 89 control students, 12 dropped out during or after their first-year bachelor year. In the group of students with dyslexia [N=99], the number was 25. A comparison of these number results in a significant difference between groups [$\chi^2_{(1, N=188)}$ = 4.12; *p*= 0.032]. The difference was mainly due to the higher number of students with dyslexia who aborted their studies during the academic year [*p*=0.039] and not due to the number of dropouts at the end of the first year [*p*=0.152].

Table 4
Number of Dropout Students in the Control Group (N=89) and the Dyslexia Group (N=99) in the First Academic Year.

	Control group	Dyslexia group	Total
During year 1	0 (0%)	5 (5.05%)	5 (2.66%)
At the end of year 1	12 (13.48%)	20 (20.20%)	32 (17.02%)
Total	12 (13.48%)	25 (25.25%)	37 (19.68%)

As for the second year, from the control students who continued after the first year (N= 77), 3 did not go through to their third year. In the group of 74 second bachelor year students with dyslexia, 9 terminated their bachelor program after their second year. This did not result in a significant difference in the number of dropouts after year two [$\chi^2_{(1,N=151)}$=3.53; p= 0.056].

We do not have quantitative data on study results after dropout, but we did contact the students and questioned them on their occupation in the academic year after they dropped out (after this point we no longer have longitudinal data about these students).

Table 5
Description of Occupation for First and Second year Dropouts for the Control Group (N=89) and the Dyslexia Group (N=99).

	Control group	Dyslexia group	Total
Stopped higher education	2 (13.3%)	4 (11.8%)	6
Identical program in a different institution	0 (0%)	2 (5.9%)	2
Switch to a different AcBa	1 (6.7%)	5 (14.7%)	6
Switch from AcBa to a ProBa	7 (46.7%)	10 (29.4%)	17
Switch to a different ProBa	4 (26.7%)	10 (29.4%)	14
Different type of education	0 (0%)	2 (5.9%)	2
Missings	1 (6.6%)	1 (2.9%)	2
Total	15	34	49

Note: AcBa: academic bachelor; ProBa: professional bachelor

b. Degree obtained

So, from the generation students 74 control students and 65 dyslexic students did continue their studies. The difference in the number of students who obtained their degree after a model trajectory of three years is not statistically significant [$\chi^2_{(1)}$ =2.677; *p*= 0.072] between groups but a trend is noticeable. Fewer students with dyslexia tended to obtain their degree. On the positive side nearly 60% of the students with dyslexia that did not quit, did obtain their degree.

Table 6
Success Rate after 3 Years of Bachelor studies in the Control Group and the Dyslexia Group for continuing students.

	Control group	Dyslexia group	Total
Degree obtained	52 (70%)	37 (57%)	89
Degree not obtained	22 (30%)	28 (43%)	50
Total	74	65	139

Interaction-effects of background, personality and learning strategies with dyslexia

Before examining whether dyslexia is a significant predictor for dropout and degree obtained, we wanted to identify potential interaction effects between dyslexia and the background data, personality and learning strategies. To evaluate this, the difference in predictive value of the variables between groups was calculated. In Table 7 chi-squares and p-values for these differences are reported.

Table 7
Difference in effects between groups for Background Variables, Personality and Learning Strategies

Variable	Chi		df	p	
	Dropout	Degree obtained		Dropout	Degree obtained
Gender	0.723	0.257	1	.395	.612
SES father	1.755	3.146	3	.625	.370
SES mother	2.185	5.548	3	.535	.136
Type of bachelor	0.271	0.142	1	.603	.706
SE (GSE versus TSE/ASE/PSE)	0.166	3.726	1	.684	**.054**
CIQ[5]	0.010	0.080	1	.921	.777
FIQ	2.568	0.005	1	.109	.946
TIQ	1.182	0.077	1	.277	.781
Neuroticism	0.996	0.030	1	.318	.862
Extraversion	0.007	6.226	1	.932	**.013**
Openness	0.108	0.111	1	.742	.739
Agreeableness	0.040	0.401	1	.842	.526
Conscientiousness	0.674	0.841	1	.412	.359
Affective strategies	2.162	0.016	1	.141	.899
Goal strategies	1.828	2.063	1	.176	.151
Comprehension monitoring	0.111	0.635	1	.739	.425

For Dropout, none of the interactions with dyslexia were statistically significant, so none will be inserted in the models as predictors.

For Degree obtained, the interaction with the type of secondary education degree was marginally significant; the one with extraversion was significant. These interactions will be taken up in the post-diction and predictive models for Degree obtained.

Logistic models

For the following models the background data, personality subscales and LASSI components were entered as predictors. In every step, dyslexia is inserted as a predictor as well.

In the following tables the estimates and p-values are reported for the different logistic models namely the bivariate model, the post-diction model that was constructed based on the bivariate predictions, the

[5] CIQ, FIQ and TIQ data were extracted from the first study. Because our study group is a subsample from the initial sample, adjusted data is reported here. The CIQ from the control group (M=111.48 ; SD=9.09) and the dyslexia group (M=106.66 ; SD=8.15) is significantly different (p<.001); as is the TIQ (M= 110.27; SD= 9.33;M=106.57 ; SD= 8.79; p< .001). The FIQ from the control group (M=107.38 ; SD 10.43) and the dyslexia group (M=105.51 ; SD= 11.00) is not significantly different (p=.23).

prediction model with a stepwise approach and the predictive model using LASSO (see method section) for dropout and degree obtained.

a. Dropout

Table 8 gives the regression weights and p-values for all the variables for each of the three models for the prediction of Dropout.

Table 8
Regression Weights and p-values for Bivariate, Post-diction, Stepwise Prediction and Prediction with LASSO models with Dropout as dependent variable.

Variable	Bivariate		Post-diction		Prediction (stepwise)		Prediction (LASSO)
	β	p	β	p	β	p	β
Intercept	N.A.	N.A.	-1.298	<.001	-0.348	<.001	-1.225
Gender	0.005	.970			0.177	.452	0.008
Dyslexia	0.336	**.004**	0.486	.01	0.507	.026	0.406
SES father	-0.282	**.003**	-0.548	.004	-0.524	.019	-0.415
SES mother	-0.158	.094			-0.356	.095	-0.226
Type of bachelor	0.156	.206			0.518	.047	0.313
SE (GSE versus TSE/ASE/PSE)	0.017	.891			0.046	.857	
CIQ	-0.074	.459					
FIQ	0.051	.616					
TIQ	-0.005	.962					
Neuroticism	-0.021	.825			-0.394	.142	-0.211
Extraversion	0.162	.095			0.373	.149	0.242
Openness	0.069	.479			-0.121	.621	
Agreeableness	-0.112	.247					-0.029
Conscientiousness	-0.327	**.000**			-0.327	.193	-0.251
Affective strategies	-0.378	**.000**	-0.740	<.001	-0.537	.055	-0.391
Goal strategies	-0.280	**.002**			-0.565	.024	-0.410
Comprehension monitoring	-0.191	**.004**			-0.188	.411	-0.140

For the post-diction model (Dyslexia, SES father, Affective strategies) with dropout as dependent variable, the average prediction accuracy on the test data was 77.7% (95% CI [71.0, 83.4]), sensitivity was 93.5% and specificity was 32.7%. See also Table 9.

Table 9
Classification Table for Dropout Based on the Post-diction model.

		Prediction	
		Dropout	No dropout
Reference	Dropout	16	33
	No dropout	9	130

For the prediction model using the stepwise approach (Gender, Dyslexia, SES father and mother, Type of bachelor, SE, Neuroticism, Extraversion, Openness, Conscientiousness, Affective Strategies, Goal strategies, Comprehension monitoring) the average prediction accuracy on the test data was 80.3% (95% CI [73.9, 85.7]), sensitivity was 92.1 % and specificity was 46.9 %. See also Table 10.

Table 10
Classification Table for Dropout Based on the Predictive Model with a stepwise approach.

		Prediction	
		Dropout	No dropout
Reference	Dropout	23	26
	No dropout	11	128

For the prediction model applying the LASSO technique (Gender, Dyslexia, SES father and mother, Type of bachelor, Neuroticism, Extraversion, Agreeableness, Conscientiousness, Affective Strategies, Goal strategies, Comprehension monitoring) the average prediction accuracy on the test data was 79.3% (95% CI [72.8, 84.8]), sensitivity was 95 % and specificity was 34.7 %. See also Table 11.

Table 11
Classification Table for Dropout Based on the Predictive Model with LASSO.

		Prediction	
		Dropout	No dropout
Reference	Dropout	17	32
	No dropout	7	132

b. Degree obtained

Table 12 gives the regression weights and p-values for all the variables for each of the three models for the prediction of Degree obtained.

Table 12
Regression Weights and p-values for Bivariate, Post-diction, Stepwise Prediction and Prediction with LASSO models with Degree obtained as dependent variable.

Variable	Bivariate		Post-diction		Prediction (stepwise)		Prediction (LASSO)
	β	p	β	p	β	p	β
Intercept	N.A.	N.A.	0.700	.002	0.685	.004	0.582
Gender	0.216	.105					
Dyslexia	-0.221	.095	-0.323	.144	-0.655	.007	-0.306
SES father	-0.016	.890					
SES mother	-0.001	.992					
Type of bachelor	-0.130	.343			-0.356	0.127	-0.133
SE (GSE versus TSE/ASE/PSE)	-0.052	.704	0.052	.812			
SE x dyslexia			-0.434	.048	.497	.035	0.233
CIQ	0.046	.674					
FIQ	0.185	.080					
TIQ	0.146	.174					
Neuroticism	0.053	.626					
Extraversion	0.011	.919	0.185	.455			
Extraversion x dyslexia			0.814	.002	0.913	<.001	0.534
Openness	-0.040	.718					-0.001
Agreeableness	0.271	**.010**			0.350	0.156	0.146
Conscientiousness	0.361	**<.001**					0.182
Affective strategies	0.494	**<.001**	1.192	<.001	1.377	<.001	0.797
Goal strategies	-0.093	.403			-0.572	.016	-0.250
Comprehension monitoring	0.267	**.009**			0.685	0.016	0.321

For the post-diction model with degree obtained as dependent variable (Dyslexia, SE, SE x dyslexia, Extraversion, SE x Extraversion, Affective strategies) the average prediction accuracy on the test data was 77.0% (95% CI [69.1, 83.7]), sensitivity 56 % was and specificity was 88.8 %. See also Table 13.

Table 13
Classification Table for Degree Obtained Based on the Post-diction model.

		Prediction	
		Degree obtained	Degree not obtained
Reference	Degree obtained	79	10
	Degree not obtained	22	28

For the prediction model using the stepwise approach (Dyslexia, Type of bachelor, SE x dyslexia, Extraversion x dyslexia, Agreeableness, Affective strategies, Goal strategies, Comprehension monitoring) the average prediction accuracy on the test data was 77% (95% CI [69.1, 83.7]), sensitivity was 60 % and specificity was 86.5 %. See also Table 14.

Table 14
Classification Table for Degree Obtained Based on the Predictive Model with a stepwise approach.

		Prediction	
		Degree obtained	Degree not obtained
Reference	Degree obtained	77	12
	Degree not obtained	20	30

For the prediction model applying the LASSO technique (Dyslexia, Type of bachelor, SE x dyslexia, Extraversion x dyslexia, Agreeableness, Conscientiousness, Openness, Affective strategies, Goal strategies, Comprehension monitoring), the average prediction accuracy on the test data was 77% (95% CI [69.1, 83.7]), sensitivity was 56 % and specificity was 88.8 %. See also Table 15.

Table 15
Classification Table for Degree Obtained Based on the Predictive Model with LASSO.

		Prediction	
		Degree obtained	Degree not obtained
Reference	Degree obtained	79	10
	Degree not obtained	22	28

What individual factors contribute to success in students with dyslexia in higher education and are these different from the normal population?

For this research question the dyslexia group and control group were examined separately to compare the models obtained in the two groups. Dyslexia was thus no longer included as a predictor. All variables that have been suggested to be of relevance in the prediction of success in a normal student population were entered in both analyses (background, personality and learning strategies).

Logistic models for the dyslexia group

The initial idea was to compare models for controls with models for dyslexia to see whether these were alike. However, when performing these analyses on the control group this resulted in models with very few to no predictors (the obtained models also had very poor specificity). For dropout only Affective strategies had any predictive value in de post-diction model and the prediction model with the stepwise approach. In the models with degree obtained as dependent variable, only conscientiousness (post-diction and prediction with LASSO) and Affective strategies (stepwise prediction and prediction with LASSO) seemed to contribute something. Due to the low number of predictors in combination with low model quality, comparisons between groups seem inappropriate. Therefore, only the results for the dyslexia group will be reported here.

a. Dropout

Table 16 gives the regression weights and p-values for all the variables for each of the three models for the prediction of Dropout in the Dyslexia group.

Table 16

Regression Weights and p-values for Bivariate, Post-diction, Stepwise Prediction and Prediction with LASSO models with Dropout as dependent variable in the Dyslexia Group.

Variable	Bivariate		Post-diction		Prediction (stepwise)		Prediction (LASSO)
	β	p	β	p	β	p	β
Intercept	N.A.	N.A.	-0.782	.001	.1.577	.003	-0.667
Use of compensatory means	-0.206	.226					
Comorbid disorder	-0.173	.346			-0.382	.312	
Gender	0.054	.740			0.477	.143	
SES father	-0.376	**.001**	-0.722	.004	-0.735	.017	-0.227
SES mother	-0.234	.054			-0.339	.248	
Type of bachelor	0.206	.196			0.540	.066	
SE (GSE versus TSE/ASE/PSE)	-0.014	.929					
CIQ	.008	.949					
FIQ	.197	.125					
TIQ	0.140	.284					
Neuroticism	-0.071	.573			-0.491	.139	
Extraversion	0.174	.167			0.375	.223	
Openness	0.050	.701					
Agreeableness	-0.142	.258			-0.453	.122	
Conscientiousness	-0.404	**<.001**	-0.812	.002	-0.756	.017	-0.336
Affective strategies	-0.300	**.013**					
Goal strategies	-0.122	.335			-0.430	.203	
Comprehension monitoring	-0.248	**.045**					

For the post-diction model with dropout as dependent variable (SES father, Conscientiousness) the average prediction accuracy on the test data was 73.7% (95% CI [63.9, 82.1]), sensitivity was 86.2% and specificity was 50.0 %. See also Table 17.

Table 17
Classification Table for Dropout Based on the Post-diction Model in the Dyslexia Group.

		Prediction	
		Dropout	No dropout
Reference	Dropout	17	17
	No dropout	9	56

For the prediction model using the stepwise approach (Comorbid disorder, Gender, SES father, SES mother, Type of bachelor, Neuroticism, Extraversion, Agreeableness, Conscientiousness, Goal strategies) the average prediction accuracy on the test data was 77.8 (95% CI [68.3, 85.5]), sensitivity was 87.7 % and specificity was 58.8 %. See also Table 18.

Table 18
Classification Table for Dropout Based on the Predictive Model with a stepwise approach in the Dyslexia Group.

		Prediction	
		Dropout	No dropout
Reference	Dropout	20	14
	No dropout	8	57

For the prediction model applying the LASSO technique (SES father, Conscientiousness) the average prediction accuracy on the test data was 69.7% (95% CI [59.6, 78.5]), sensitivity was 98.5% and specificity was 14.7 %. See also Table 19.

Table 19
Classification Table for Dropout Based on the Predictive Model with LASSO in the Dyslexia group.

		Prediction	
		Dropout	No dropout
Reference	Dropout	5	29
	No dropout	1	64

b. Degree obtained

Table 20 gives the regression weights and p-values for all the variables for each of the three models for the prediction of Degree obtained in the Dyslexia group.

Table 20

Regression Weights and p-values for Bivariate, Post-diction, Stepwise Prediction and Prediction with LASSO models with Degree obtained as dependent variable in the Dyslexia Group.

Variable	Bivariate		Post-diction		Prediction (stepwise)		Prediction (LASSO)
	β	**p**	**β**	**p**	**β**	**p**	**β**
Intercept	N.A.	N.A.	0.217	0.490	-0.737	.105	0.071
Use of compensatory means	0.227	.276			0.467	.189	0.018
Comorbid disorder	-0.211	.293			-0.891	.018	-0.148
Gender	0.278	.135			0.453	.117	
SES father	0.067	.665			0.510	.110	
SES mother	0.088	.570					0.067
Type of bachelor	-0.011	.956					
SE (GSE versus TSE/ASE/PSE)	-0.244	.191					-0.060
CIQ	0.038	.811					
FIQ	0.141	.354					
TIQ	0.155	.457					
Neuroticism	0.031	.845					
Extraversion	0.288	**.051**	1.234	0.012			0.403
Openness	-0.004	.981					
Agreeableness	0.396	**.009**					0.020
Conscientiousness	0.290	**.042**					
Affective strategies	0.503	**<.001**	1.479	.001			0.688
Goal strategies	-0.285	.059	-1.066	.01			-0.495
Comprehension monitoring	0.355	**.012**			0.986	.015	0.320

For the post-diction model with degree obtained as dependent variable (Extraversion, Affective strategies, Goal strategies) the average prediction accuracy on the test data was 76.9% (95% CI [64.8, 86.5]), sensitivity was 67.9% and specificity was 83.8 %. See also Table 21.

Table 21
Classification Table for Degree Obtained Based on the Post-diction Model in the Dyslexia Group.

		Prediction	
		Degree obtained	Degree not obtained
Reference	Degree obtained	31	6
	Degree not obtained	9	19

For the prediction model using the stepwise approach (Use of compensatory means, Comorbid disorders, Gender, SES father, Comprehension monitoring) the average prediction accuracy on the test data was 81.5% (95% CI [70.0, 90.1]), sensitivity was 67.9 % and specificity was 91.9 %. See also Table 22.

Table 22
Classification Table for Degree Obtained Based on the Predictive Model with a stepwise approach in the Dyslexia Group.

		Prediction	
		Degree obtained	Degree not obtained
Reference	Degree obtained	34	3
	Degree not obtained	9	19

For the prediction model applying the LASSO technique (Use of compensatory means, Comorbid disorders, SES mother, SE, Extraversion, Agreeableness, Affective strategies, Goal strategies, Comprehension monitoring) the average prediction accuracy on the test data was 80.0% (95% CI [68.2, 88.9]), sensitivity was 67.9% and specificity was 89.2 %. See also Table 23.

Table 23
Classification Table for Degree Obtained Based on the Predictive Model with LASSO in the Dyslexia Group.

		Prediction	
		Degree obtained	Degree not obtained
Reference	Degree obtained	33	4
	Degree not obtained	9	19

Discussion

An increase in the number of students with dyslexia in higher education can be observed worldwide. However, information on how these students perform at this level is scarce. The information at hand comes primarily from Anglo-Saxon countries where a master-apprentice model is applied (selection at the beginning and commitment to positive outcome once admitted) and within these settings the results are quite positive. For various reasons a generalization of these conclusions to other educational models (e.g. the admission free model in Flanders) seems precarious. Therefore, we compared study continuance and study success between 99 students with dyslexia with 89 control students matched on gender and field of study. The number of students who dropped out versus those who obtained their degree after a model trajectory of three years was compared between groups. The influence of being dyslexic on the chance of dropping out and obtaining a degree was evaluated with both post-diction and prediction models. Other factors that are said to have an influence on academic performance such as background information, personality and learning strategies were also included in the prediction models. Finally, to identify potential differences between groups in the predictive values of influential factors, logistic models between groups were compared.

Background information revealed that compared to their peers, relatively fewer students with dyslexia came from general secondary education and they were more inclined to register for a professional program. Groups did not differ in personality, but differences could be noted in learning strategies. Using the LASSI as a self-report test, students with dyslexia seemed to apply fewer skills to build bridges between previously acquired knowledge and new information and used fewer reasoning skill to retain information. They worried more about school and their academic performance, were less interested in achieving academic success and applied fewer strategies to assess their level of comprehension. When applying a principal component analysis on the 10 LASSI subscales, we obtained the same 3 component structure as Cano (2006). The component Affective Strategies included affective and support learning strategies, whereas Goal Strategies and Comprehension Monitoring Strategies are a mixture of strategies to both interact directly with the learning material and provide metacognitive and affective support for learning.

In contrast to most studies performed in a master-apprentice model for higher education (Adelman & Vogel, 1990; McGuire et al., 1991; Richardson, 2009; Vogel & Adelman, 1992; Wessel et al., 2009), in an admission free context students with dyslexia did not perform as well as their peers. Dyslexia turned out to be an important predictor for study continuance in all post-diction and prediction models. The dropout rate in the dyslexia group (34%) was significantly higher than in the control (15.5 %), specifically during their first year. However, a positive observation is that from all dropout students with dyslexia only 12.5% of them stopped studying altogether. Although the reasons for dropout are unknown these numbers suggest that students with dyslexia would benefit from more guidance in their transition from secondary to higher education.

Dyslexia also has an impact on study duration. Although the difference in the proportions of students who obtained a degree after three years in both groups was not statistically significant, dyslexia did turn up as a relevant predictor in every logistic model even in the presence of other factors that are said to influence success rate. These diverging results between educational contexts (master-apprentice/admission free) could be due to the selection procedure that takes place within the master-apprentice model. A selection based on intelligence within the master/apprentice model is unlikely to be the cause of these observed differences since IQ was not found to add any predictive value to success in our study. Possibly the differences in success rate between settings are due to a selection based on personality factors and learning strategies since these have a large impact on success in dyslexic students. To make firm conclusions on this matter, comparable methods should be used in the two setting.

As for the other findings in the mixed models, we cannot say much about the other predictors that turned up as significant. After all, there is no way of knowing whether the findings can be generalized to both groups and whether they are mainly driven by one group. An indication in this direction is the observations that in an attempt to compare models between groups those for the control group separately produced few to no predictors in models with low accuracy rates. The fact that the results for the dyslexia group and the mixed groups were very much alike reinforces the idea that the logistic models found in the mixed analysis were mainly driven by the variation in the dyslexia group. However, one would expect to find interactions between dyslexia and the other relevant predictors but there could be a lack of power due to the number of subjects (reduced to half of the original number) relative to the number of predictors. Important to mention are the two interaction effects that turned up as significant predictors in the mixed group models on degree obtained. Students with dyslexia benefit more than control students from being extravert and from having a general secondary education degree. A possible explanation could be that students who are extraverts have larger social networks which they can benefit from during their studies or that they are more energetic and confident to face their problems. This could be an important message to give to students in helping them cope in higher education. Having a degree in general secondary education which is intended to prepare adolescents for a transition to higher education, is even slightly more beneficial for students with dyslexia. Duff et al. (2004) observed that prior education is likely to influence a student's orientation to learning. An important implication is that students with dyslexia who have aspirations to take the step to higher education are better off with a general educational degree. We should point out that this is a somewhat tricky generalization. It is likely that for some bachelor programs (wood technology) a TSE is more appropriate. In our study, splitting up the data in specific programs would result in a power problem due to the sample size.

In line with findings in normal student populations coming from a master-apprentice model of education, instruments on personality and learning strategies and background information seem to be valuable tools for the all round prediction of success in higher education. Although we cannot come to firm conclusions about the general population in an admission free context based on the results from the control group, well developed affective strategies (for study continuance and study success) and a high level of conscientiousness (for study success) seem to have positive predictive power. Cano (2006) reported both Affective Strategies and Goal Strategies to contribute to the regression equation on academic performance in a normal population of students in higher education. Marrs et al. (2009) and Yip (2007) identified motivational aspects and attitude (part of the AS component) as two major factors differentiating high academic achieving students from low academic achieving students. The finding that the level of conscientiousness acts as an important predictor in the general students' performance is consistent with the literature (Chamorro-Premuzic & Furnham, 2008; Kappe & van der Flier, 2012; Poropat, 2009). Intelligence does not seem to exert an influence on academic performance, neither for the control group nor for the dyslexia group which is contradictory to some literature found (Busato et al., 2000). Our findings are more in line with the idea of Rosander and Backstrom (2012) that the influence of IQ decreases with age or that students select an appropriate study for their level of intelligence.

Within the dyslexia population, some factors have an influence on both study continuance and study success. The educational attainment of both father and mother (although less so) turned up as important influential factors. Students with dyslexia with parents with higher levels of attainment had less chance of dropping out of their bachelor program and more chance of obtaining a degree after three years when they did continue their programs. These results indirectly confirm what little information is available on factors that have an impact on study success in students with dyslexia. Patrikakou (1996) found that parental expectations were instrumental in raising academic performance in students with learning disabilities. Magnuson (2007) points out in her paper that parents who are higher educated are likely to attach more value to a higher educational attainment and harbor higher expectations. Inversely, students with lower educated parents are less likely to persist because less importance is attached to a degree in higher education. This agrees with literature an academic performance in a normal student population within a master/apprentice model (Steinmayr et al., 2010). The influence of gender affects drop out and study success in opposite directions. For dropout, female students tend to quit more -which is contradictory to the results of Lacante et al. (2001) and Declercq and Verboven (2010) in a normal population in the same educational setting. Female students with dyslexia that do continue have more chance of obtaining a degree after three years than their male colleagues. This last finding is consistent with the general literature. Maybe the gender difference is mediated by personality. It has been suggested that females have higher levels of neuroticism and maybe that is why they are more likely to abandon their studies.

Agreeableness and Extraversion are two personality traits that have an impact on both dropout and study success. Dropout risk is lower for students with dyslexia who are more agreeable. However, the impact of agreeableness on obtaining a degree is minimal. As for extraversion, the more extravert a student with dyslexia is the more chances he has of dropping out. When persisting with the studies, being extravert has a positive influence on study success. While self assurance or a more adventurous life style possibly causes more dropout they could contribute to creating larger social networks, as described above. More detailed analysis on the subscales could provide us with more suggestions as to the reasons why agreeableness and extraversion have an influence on dropout in dyslexia.

Remarkably, the presence of a comorbid disorder decreases the chance to drop out. Possibly these students have more experience with academic failure which they attribute to their impairments and therefore are more at peace with the situation. Contrarily, having multiple disorders makes it harder for students to finish their program in three years than their peers without comorbid disorders.

As for learning strategies, only the component Goal strategies exerts an influence on both study continuance and study success. Low goal strategies tend to increase the chances of dropping out in students with dyslexia. However, good goal strategies are also negatively related to the chance of obtaining a degree after three years. This is somewhat puzzling. More anxiety and poor study skills (such as selecting main ideas and test strategies) are usually linked to worse academic performance in higher education. This would suggest an opposite effect for students with dyslexia within an admission free context. Post-hoc analyses were done on the different subscales of this component for the two groups separately to investigate this remarkable finding. For the control group the three subscales (Anxiety, Selecting main ideas and Test strategies) and the component individually had a positive influence on the chance to obtaining a degree. As for the dyslexic group, the subscales of mainly Anxiety and to some extent Selecting main ideas strangely point in the opposite direction. Test strategies had little to no impact on study success. It would appear that for dyslexics being more anxious drives them to better results.

Some factors only have an impact on dropout. For example, students with dyslexia are more likely to drop out of an academic program then out of a professional bachelor program. Academic programs are known to have more dropouts in the normal population, so this finding is consistent for dyslexic students (Declercq & Verboven, 2010). Secondly, some personality aspects of students with dyslexia seem to affect only dropout. For one, being conscientious has a positive impact on study continuance. Murray and Wren (2003) identified avoidance as a relevant predictor for study outcome in a sample of learning disabled students in higher education. Conscientious people are organized, reliable and self-disciplined and therefore less likely to exhibit avoidance behavior. Secondly, students with dyslexia who are more neurotic have more chances of dropping out. Students who are more impulsive, who experience more anxiety and are emotionally unstable –characteristics related to a neurotic personality- are also more likely to drop out as demonstrated in the general Flemish students population (Lacante et al., 2001). So this trait seems to affect both normal functioning students and dyslexic students.

The factors that are only of influence on the prediction of obtaining a degree within the designated time are the following. Good affective strategies, *low* goal strategies (maybe driven by the anxiety subscale) and good comprehension monitoring strategies are most related to a positive outcome after three years. So, students with dyslexia -and other students for that matter- could really benefit from workshops on the development of good learning strategies. Up until now, this kind of students support is limited. The use of compensatory means and the absence of any comorbid disorder have a positive predictive value on study outcome. On itself, the use of these means is not enough to make students with dyslexia get their degree in three years time but it can tip the balance. This has been reported by Mull, Sitlington, and Alper (2001) as well. This should encourage students with dyslexia to take up their rights and use the means that are set out for them. In any case, institutions will be happy to hear that the investment of resources and time made to help these students, are not without result. In our study, this variable was coded in only two levels (0 or 1), so it does not give specific information on the efficiency of individual compensatory means. More detailed research could help optimize the facilities.

The maximum quality of the models in this study was an average prediction accuracy of about 80%. This implies that besides background, personality and study skills, additional factors are important in determining academic performance in students with dyslexia. For example, course related variables, instructional variations or personal circumstances could also have an impact on academic success rates. Lacante et al. (2001) demonstrated that students, who are unsure of their study choice, tend to dropout more in their first year. Others have pinpointed specific motivational aspects as key factors in predicting success in higher education (Kusurkar, Ten Cate, Vos, Westers, & Croiset, 2013). As you can see, several other factors -that were not included in this study- are still potential candidates to increase the predictive power of our models on academic performance.

Some limitations to the study should be mentioned. For one, as stated before, dropping out of a program not necessarily means that the student in question will never obtain a diploma in higher education. As the qualitative inventory indicates, only a few students actually stop studying after quitting a program. However, success rate in a subsequent program can only be inventorized after minimally three years of registration. Also, students who continued their studies but did not manage to obtain their degree after three year are still likely to succeed in subsequent years. A follow-up study could provide us with the necessary data to have a full picture of study success of students with dyslexia in higher education compared to their peers.

When looking back at the recruitment procedure, some issues should be raised. For one, we recruited the students with dyslexia in the order that they applied for compensatory means. Maybe these students have more severe or pronounced reading and/or writing problems or maybe they are more affected by their disability compared to students who apply for measures later in the academic year (or not at all). This should be taken into account when looking at the results. Ideally, the sample should consist of all students with dyslexia whether they apply for facilities or not. Due to the fact that some students with dyslexia prefer not to divulge their disability this specific subgroups is not likely to respond to participant calls for research. This could potentially influence the results since disability disclosure has been reported to be positively related to the academic experience and performance of students with disabilities in postsecondary school (Mull et al., 2001). Secondly, recruitment of the control students started somewhat later in the year sampling from a somewhat smaller pool excluding students that dropped out early during the year. In ideal circumstances, recruitment should have started at the same time as the dyslexia group. Due to the large number of students to be tested, this was hard to accomplish. This could potentially underestimate the dropout rate in the control group. Considering the large difference between groups, however chances are small that this effect can be completely attributed to the selection procedure.

This study was one of the first to investigate study success in students with dyslexia and to identify factors relevant for academic success for these students in Flanders. This study gives direction to more elaborate research on the topic. The essential question for students with dyslexia in higher education is what their chances are of obtaining a degree compared to their peers and not so much how high their course grades are. However, the level of measurement of the dependent variables (dropout and degree obtained) that were used in the study could have influenced the outcome and stability of the obtained models. Using grade point averages, as is often done in studies on academic performance, could provide more variability. As mentioned throughout the discussion, possibilities are endless for research on academic success of students with dyslexia in higher education.

Although the general picture is predominantly a negative one, we would like to emphasize the positive finding of our study. Students with dyslexia do indeed drop out (or change program) more often than their peers and preliminary results suggest that they do tend to take longer to graduate, but a considerable number of them still obtain their degree and the reported percentages are an underestimation of the total number. The fact that compensatory means are beneficial is good news. This means that the efforts taken are indeed effective and that students who do not use them can still benefit from using them. The results also indicate that there is a lot to gain in the development of better learning strategies in students with dyslexia.

References

Adelman, P. B., & Vogel, S. A. (1990). College graduates with learning-disabilities - Employment attainment and career patterns. *Learning Disability Quarterly, 13*(3), 154-166. doi: 10.2307/1510698

Ahissar, M. (2007). Dyslexia and the anchoring-deficit hypothesis. [Review]. *Trends in Cognitive Sciences, 11*(11), 458-465. doi: 10.1016/j.tics.2007.08.015

Bishop, D. V. M. (2006). Dyslexia: what's the problem? *Developmental Science, 9*(3), 256-257. doi: 10.1111/j.1467-7687.2006.00484.x

Blomert, L., & Willems, G. (2010). Is There a Causal Link from a Phonological Awareness Deficit to Reading Failure in Children at Familial Risk for Dyslexia? *Dyslexia, 16*(4), 300-317. doi: 10.1002/dys.405

Bourdieu, P. (1986). The forms of capital. *Handbook of theory and research for the sociology of education* (pp. 241-258). New York: Greenwood Press.

Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology, 53*, 371-399. doi: 10.1146/annurev.psych.53.100901.135233

Broeninck, N., & Gorter, K. (2001). *Studeren met een handicap. Belemmeringen die studenten met een lichamelijke beperking, psychische klachten of dyslexie in het hoger onderwijs ondervinden*. Verwey-Jonker Instituut.

Brus, B., & Voeten, M. (1991). *Een-minuut-test vorm A en B, schoolvorderingstest voor de technische leesvaardigheid bestemd voor groep 4 tot en met 8 van het basisonderwijs. Verantwoording en handleiding*. Lisse, The Nederlands: Swets & Zeitlinger.

Buchmann, C., & DiPrete, T. A. (2006). The growing female advantage in college completion: The role of family background and academic achievement. *American Sociological Review, 71*(4), 515-541.

Busato, V. V., Prins, F. J., Elshout, J. J., & Hamaker, C. (2000). Intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. *Personality and Individual Differences, 29*(6), 1057-1068. doi: 10.1016/s0191-8869(99)00253-6

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive profile of students who enter higher education with an indication of dyslexia. *PLos One, 7*(6). doi: 10.1371/journal.pone.0038081

Cano, F. (2006). An In-Depth Analysis of the Learning and Study Strategies Inventory (LASSI). *Educational and Psychological Measurement, 66*(6), 1023-1038. doi: 10.1177/0013164406288167

Carson, A. D. (2011). Predicting student success from the LASSI for learning online (LLO). *Journal of Educational Computing Research, 45*(4), 399-414. doi: 10.2190/EC.45.4.b

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition, 91*(1), 77-111. doi: 10.1016/S0010-0277(03)00164-1

Chamorro-Premuzic, T., & Furnham, A. (2005). *Personality and intellectual competence*. Mahwah, NJ: Lawrence Erblaum.

Chamorro-Premuzic, T., & Furnham, A. (2008). Personality, intelligence and approaches to learning as predictors of academic performance. *Personality and Individual Differences, 44*(7), 1596-1603. doi: 10.1016/j.paid.2008.01.003

Costa, P. T., & McCrae, R. R. (1992). *Revised NEO Personality Inventory (NEO-PI-R) and the Five Factor Inventory (NEO-FFI): Professional Manual*. Odessa, Florida: Psychological Assessment Resources.

de Bilde, J., Vansteenkiste, M., & Lens, W. (2011). Understanding the association between future time perspective and self-regulated learning through the lens of self-determination theory. *Learning and Instruction, 21*(3), 332-344. doi: 10.1016/j.learninstruc.2010.03.002

De Pessemier, P., & Andries, C. (2009). *GL&SCHR Dyslexie bij +16-jarigen. Test voor Gevorderd Lezen en Schrijven*. Antwerpen, Belgium: Garant.

de Vos, T. (1992). *Tempo Test Rekenen*. Amsterdam: Pearson Education.

Declercq, K., & Verboven, F. (2010). Slaagkansen aan Vlaamse Universiteiten: tijd om het beleid bij te sturen? [Succes rate at Flemish universities: time for policy changes?] Retrieved March 15 2013, from http://www.deredactie.be/polopoly_fs/1.871925!file/20100927declercq_verboven.pdf

Defranc, E. (2008). *De begeleidingsbehoeften van universiteitstudenten met dyslexie [Guidance needs of university students with dyslexia]*. Unpublished thesis. Catholic University Leuven.

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Nunes, G., Jobert, A., . . . Cohen, L. (2010). How Learning to Read Changes the Cortical Networks for Vision and Language. *Science, 330*(6009), 1359-1364. doi: 10.1126/science.1194140

Dekker, R., Dekker, P. H., & Mulder, J. L. (2004). *Kaufman Adolescent and Adult Intelligence Test - Nederlandstalige versie: Handleiding*. Leiden, The Nederlands: PITS.

Dekker, R., Dekker, P. H., & Mulder, J. L. (2007). *De ontwikkeling van vijf nieuwe Nederlandstalige tests*. Leiden: PITS.

Du Prez, L., Gilroy, D. E., & Miles, T. (2008). *Dyslexia at college*. London and New York: Routledge.

Duff, A., Boyle, E., Dunleavy, K., & Ferguson, J. (2004). The relationship between personality, approach to learning and academic performance. *Personality and Individual Differences, 36*(8), 1907-1920. doi: 10.1016/j.paid.2003.08.020

Elbro, C., Nielsen, I., & Petersen, D. K. (1994). Dyslexia in Adults - Evidence for Deficits in Non-Word Reading and in the Phonological Representation of Lexical Items. *Annals of Dyslexia, 44*, 205-226.

Friedman, J. H., Hastie, T., & Tibshirani, R. (2010). Regularization Paths for Generalized Linear Models via Coordinate Descent. *Journal of Statisical Software, 33*(1), 1-22.

Gaugh, G. H. (2002). *Scientific Method in Practice*. Cambridge: United Kingdom: Cambridge University Press.

Ghesquière, P. (1998). *Algemene toets gevorderde spelling van het Nederlands (AT-GSN): verantwoording en handleiding. Rapport van een specialisatiejaar: onderzoek At-GSN-dictee.*: Unpublished bachelor thesis, University Leuven, Leuven, Belgium.

Ghesquiere, P., Boets, B., Gadeyne, E., & Vandewalle, E. (2012). Dyslexie: Een beknopt wetenschappelijk overzicht. In A. Geudens, D. Baeyens, K. Schraeyen, K. Maetens, J. De Brauwer & M. Loncke (Eds.), *Jongvolwassenen met dyslexie.Diagnostiek en begeleiding in wetenschap en praktijk.* (pp. 41-54). Leuven/ Den Haag: Acco.

Gilroy, D. E., & Miles, R. (2001). *Dyslexia at College (2nd ed.), London: Routlegde*.

Goovaerts, M. (2011). *Wie overleeft het eerste bachelorjaar niet? Een onderzoek naar drop-out in het hoger onderwijs [Who doesn't survive the first bachelor year? A study on drop-out in higher education].* Master thesis, University of Antwerp.

Goswami, U. (2008). Reading, dyslexia and the brain. *Educational Research, 50*(2), 135-148. doi: 10.1090/00131880802082625

Hadjikakou, K., & Hartas, D. (2008). Higher education provision for students with disabilities in Cyprus. *Higher Education, 55*(1), 103-119. doi: 10.1007/s10734-007-9070-8

Harrison, A. G., & Nichols, E. (2005). A validation of the Dyslexia Adult Screening Test (DAST) in a post-secondary population. *Journal of Research in reading, 28*(4), 423-434. doi: 10.1111/j.1467-9817.2005.00280.x

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology, 72*, 119-133. doi: 10.1348/000709902158801

Heim, S., Tschierse, J., Amunts, K., Wilms, M., Vossel, S., Willmes, K., . . . Huber, W. (2008). Cognitive subtypes of dyslexia. *Acta Neurobiologiae Experimentalis, 68*(1), 73-82.

Henneman, K., Kleijnen, R., & Smits, A. (2004). *Protocol Dyslexie Voortgezet Onderwijs: Deel 2- Signalering, diagnose en begeleiding.* : KPC Groep, Expertisecentrum Nederlands, Werkverband Opleidingen Speciaal Onderwijs.

Hoekstra, H. A., Ormel, J., & de Fruyt, F. (2007). *NEO-PI-R/NEO-FFI: Handleiding*. Amsterdam, The Netherlands: Hogrefe Uitgevers.

Hofmeester, N. (2002). *Studeren met dyslexie.* Apeldoorn, Nederland: Maklu Uitgevers nv.

Hughes, C. A., & Smith, J. O. (1990). Cognitive and academic - performance of college-students with learning disabilities - A synthesis of the literature. *Learning Disability Quarterly, 13*(1), 66-79. doi: 10.2307/1510393

Jimenez, J. E., Guzman, R., Rodriguez, C., & Artiles, C. (2009). Prevalence of specific learning disabilities: The case of dyslexia in Spain. *Anales De Psicologia, 25*(1), 78-85.

Johnson, E. S., Humphrey, M., Mellard, D. F., Woods, K., & Swanson, H. L. (2010). Cognitive processing deficits and students with specific learning disabilities: A selective meta-analysis of the literature. *Learning Disability Quarterly, 33*(1), 3-18.

Kappe, R., & van der Flier, H. (2012). Predicting academic success in higher education: what's more important than being smart? *European Journal of Psychology of Education, 27*(4), 605-619. doi: 10.1007/s10212-011-0099-9

Kleijnen, R., & Loerts, M. (2006). *Protocol Dyslexie Hoger Onderwijs*. Antwerpen/Apeldoorn: Garant.

Kusurkar, R. A., Ten Cate, T. J., Vos, C. M. P., Westers, P., & Croiset, G. (2013). How motivation affects academic performance: a structural equation modelling analysis. *Advances in Health Sciences Education, 18*(1), 57-69. doi: 10.1007/s10459-012-9354-3

Lacante, M., & Lens, W. (2005). *Nederlandse bewerking van de Weinstein-Palmer LASSI-scales [Dutch adaptation of the Weinstein-Palmer LASSI-scales]*. Unpublished research paper. University of Leuven, Department of Psychology. Leuven, Belgium.

Lacante, M., Lens, W., Van Ensbroek, R., de Metsenaere, M., De Coninck, T., De Jaeger, K., . . . Wenselaer, C. (2001). Drop-out in het hoger onderwijs: Onderzoek naar achtergronden en motieven van drop-out in het eerste jaar hoger onderwijs. In opdracht van de Vlaamse Minister voor Onderwijs en Vorming. [Drop-out in higher education: Study on motives and background of drop-out in higher education- In assignment of the Flemish Ministry of Education]. Brussel-Leuven: Vrije Universiteit Brussel/KULeuven.

Lefly, D., & Pennington, B. (1991). Spelling errors and reading fluency in compensated adult dyslexics. *Annals of Dyslexia, 41*(1), 141-162. doi: 10.1007/bf02648083

Legge, G. E., Mansfield, J. S., & Chung, S. T. L. (2001). Psychophysics of reading XX. Linking letter recognition to reading speed in central and peripheral vision. *Vision Research, 41*(6), 725-743. doi: 10.1016/s0042-6989(00)00295-9

Lewis, C., Hitch, G. J., & Walker, P. (1994). The Prevalence of Specific Arithmetic Difficulties and Specific Reading Difficulties in 9-Year-Old to 10-Year-Old Boys and Girls. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 35*(2), 283-292. doi: DOI 10.1111/j.1469-7610.1994.tb01162.x

Lindgren, S. A., & Laine, M. (2011). Cognitive linguistic Performances of Multilingual University Students Suspected of Dyslexia. *Dyslexia, 17*(2), 184-200. doi: 10.1002/dys.422

Loyens, S. M. M., Rikers, R., & Schmidt, H. G. (2007). The impact of students' conceptions of constructivist assumptions on academic achievement and drop-out. *Studies in Higher Education, 32*(5), 581-602. doi: 10.1080/03075070701573765

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia, 53*, 1-14. doi: 10.1007/s11881-003-0001-9

Madriaga, M., Hanson, K., Heaton, C., Kay, H., Newitt, S., & Walker, A. (2010). Confronting similar challenges? Disabled and non-disabled students' learning and assessment experiences. *Studies in Higher Education, 35*(6), 647-658. doi: 10.1080/03075070903222633

Magnuson, K. (2007). Maternal education and children's academic achievement during middle childhood. *Developmental Psychology, 43*(6), 1497-1512. doi: 10.1037/0012-1649.43.6.1497

Marrs, H., Sigler, E., & Hayes, K. (2009). Study Strategy Predictors of Performance in Introductory Psychology. *Journal of Instructional Psychology, 36*(2), 125-133.

McGuire, J. M., Hall, D., & Litt, A. V. (1991). A field based study of the direct service needs of college students with learning disabilities. *Journal of College Student Development, 32*(2), 101-108.

MCLoughlin, D., Leather, C., & Stringer, P. (2003). *The adult dyslexic. Interventions & outcomes*. London: Whurr Publishers Ltd.

Menghini, D., Finzi, A., Benassi, M., Bolzani, R., Facoetti, A., Giovagnoli, S., . . . Vicari, S. (2010). Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia, 48*(4), 863-872. doi: 10.1016/j.neuropsychologia.2009.11.003

Mortimore, T., & Crozier, W. R. (2006). Dyslexia and difficulties with study skills in higher education. [Article]. *Studies in Higher Education, 31*(2), 235-251. doi: 10.1080/03075070600572173

Mull, C., Sitlington, P. L., & Alper, S. (2001). Postsecondary education for students with learning disabilities: A synthesis of the literature. *Exceptional Children, 68*(1), 97-118.

Murray, C., & Wren, C. T. (2003). Cognitive, academic, and attitudinal predictors of the grade point averages of college students with learning disabilities. *J Learn Disabil, 36*(5), 407-415. doi: 10.1177/00222194030360050201

Nederland, S. D. (2008). *Diagnose dyslexie. Brochure van de Stichting Dyslexie Nederland. Herziene versie*. Bilthoven, The Nederlands: Stichting Dyslexie Nederland.

Nicolson, R. I., Fawcett, A. J., Berry, E. L., Jenkins, I. H., Dean, P., & Brooks, D. J. (1999). Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults. *Lancet, 353*(9165), 1662-1667. doi: 10.1016/s0140-6736(98)09165-x

O'Connor, M. C., & Paunonen, S. V. (2007). Big five personality predictors of post-secondary academic performance. *Personality and Individual Differences, 43*(5), 971-990. doi: 10.1016/j.paid.2007.03.017

Parrila, R., Georgiou, G., & Corkett, J. (2007). University students with a significant history of reading difficulties: What is and is not compensated? *Exceptionality Education Canada, 17*, 195-220.

Patrikakou, E. N. (1996). Investigating the academic achievement of adolescents with learning disabilities: A structural modeling approach. *Journal of Educational Psychology, 88*(3), 435-450. doi: 10.1037//0022-0663.88.3.435

Pennington, B. F., Vanorden, G. C., Smith, S. D., Green, P. A., & Haith, M. M. (1990). Phonological processing skills and deficits in adult dyslexics. *Child Development, 61*(6), 1753-1778. doi: 10.1111/j.1467-8624.1990.tb03564.x

Plume, E., & Warnke, A. (2007). Definition, symptoms, prevalence and diagnosis of dyslexia. *Monatsschrift Kinderheilkunde, 155*(4). doi: 10.1007/s00112-007-1480-2

Poropat, A. E. (2009). A Meta-Analysis of the Five-Factor Model of Personality and Academic Performance. *Psychological Bulletin, 135*(2), 322-338. doi: 10.1037/a0014996

Reid, A. A., Szczerbinski, M., Iskierka-Kasperek, E., & Hansen, P. (2007). Cognitive profiles of adult developmental dyslexics: Theoretical implications. *Dyslexia, 13*(1), 1-24. doi: 10.1002/Dys.321

Richardson, J. (2009). The academic attainment of students with disabilities in UK higher education. *Studies in Higher Education, 34*(2), 123-137. doi: 10.1080/03075070802596996

Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill, factors predict college outcomes? A meta-analysis. *Psychological Bulletin, 130*(2), 261-288. doi: 10.1037/0033-2909.130.2.261

Rosander, P., & Backstrom, M. (2012). The unique contribution of learning approaches to academic performance, after controlling for IQ and personality: Are there gender differences? *Learning and Individual Differences, 22*(6), 820-826. doi: 10.1016/j.lindif.2012.05.011

Shaywitz, S. E., & Shaywitz, B. A. (2005). Dyslexia (specific reading disability). *Biological Psychiatry, 57*(11), 1301-1309. doi: 10.1016/j.biopsych.2005.01.043

Singleton, C. H. (1999). *Dyslexie in Higher Education: Policy, provision and practice (Report of the National Working Party on Dyslexia in Higher Education).* . Hull: University of Hull, on behalf of the Higher Education Funding of England.

Snowling, M. (2000). *Dyslexia. Second Edition.* Oxford: Blackwell Publishers.

Sparks, R. L., & Lovett, B. J. (2009). College students with learning disability diagnoses: who are they and how do they perform? *J Learn Disabil, 42*(6), 494-510. doi: 10.1177/0022219409338746

Stanovich, K. E. (1988). Explaining the difference between the dyslexic and garden-variety poor readers: The phonological-core variable difference model. *J Learn Disabil, 21*(10), 590-&.

Stein, J., & Walsh, V. (1997). To see but not to read; The magnocellular theory of dyslexia. [Article]. *Trends in Neurosciences, 20*(4), 147-152. doi: 10.1016/s0166-2236(96)01005-3

Steinmayr, R., Dinger, F. C., & Spinath, B. (2010). Parents' Education and Children's Achievement: The Role of Personality. *European Journal of Personality, 24*(6), 535-550. doi: 10.1002/per.755

Sullivan, B. K., May, K., & Galbally, L. (2007). Symptom exaggeration by college adults in attention-deficit hyperactivity disorder and learning disorder assessments. *Applied Neuropsychology, 14*(3), 189-207. doi: 10.1080/09084280701509083.

Swanson, H. L., & Hsieh, C. J. (2009). Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. *Review of Educational Research, 79*(4), 1362-1390. doi: 10.3102/0034654309350931

Szenkovits, G., & Ramus, F. (2005). Exploring dyslexics' phonological deficit I: Lexical vs sub-lexical and input vs output processes. *Dyslexia, 11*(4), 253-268. doi: 10.1002/dys.308

Szmalec, A., Loncke, M., Page, M. P. A., & Duyck, W. (2011). Order or Disorder? Impaired Hebb Learning in Dyslexia. *Journal of Experimental Psychology-Learning Memory and Cognition, 37*(5), 1270-1279. doi: 10.1037/a0023820

Tops, W., Callens, M., Lammertyn, J., & Brysbaert, M. (2012). Identifying students with dyslexia in higher education. *Annals of Dyslexia, 62*(3), 186-203. doi: 10.1007/s11881-012-0072-6

Trainin, G., & Swanson, H. L. (2005). Cognition, metacognition and achievement of college students with learning disabilities. *Learning Disability Quarterly., 28*, 264-272.

Tuckman, B. W., & Kennedy, G. J. (2011). Teaching Learning Strategies to Increase Success of First-Term College Students. *Journal of Experimental Education, 79*(4), 478-504. doi: 10.1080/00220973.2010.512318

Van Den Berg, M. N., & Hofman, W. H. A. (2005). Student success in university education: A multi-measurement study of the impact of student and faculty factors on study progress. *Higher Education, 50*(3), 413-446. doi: 10.1007/s10734-004-6361-1

van den Bos, A., Spelberg, H., Scheepsma, A., & de Vries, J. (1999). *De Klepel vorm A en B: een test voor leesvaardigheid van pseudowoorden. Verantwoording, handleiding, diagnostiek en behandeling*. Lisse, The Nederlands: Swets & Zeitlinger.

Van der Leij, A., Bekebrede, J., Geudens, A., Schraeyen, K., G.M., S., Garst, H., . . . Schijf, T. J. (2012). *Interactieve Dyslexietest Amsterdam-Antwerpen: Handleiding.* Uithoorn.

Vansteenkiste, M., Sierens, E., Goossens, L., Soenens, B., Dochy, F., Mouratidis, A., . . . Beyers, W. (2012). Identifying configurations of perceived teacher autonomy support and structure: Associations with self-regulated learning, motivation and problem behavior. *Learning and Instruction, 22*(6), 431-439. doi: 10.1016/j.learninstruc.2012.04.002

Vansteenkiste, M., Smeets, S., Soenens, B., Lens, W., Matos, L., & Deci, E. L. (2010). Autonomous and controlled regulation of performance-approach goals: Their relations to perfectionism and educational outcomes. *Motivation and Emotion, 34*(4), 333-353. doi: 10.1007/s11031-010-9188-3

Vaughn, S., & Fuchs, L. S. (2003). Redefining learning disabilities as inadequate response to instruction: The promise and potential problems. *Learning Disabilities Research & Practice, 18*, 137-146.

Vogel, S. A., & Adelman, P. B. (1992). The succes of college-students with learning disabilities - Factors related to educational attainment. *J Learn Disabil, 25*(7), 430-441.

Vogel, S. A., Leonard, F., Scales, W., Hayeslip, P., Hermansen, J., & Donnells, L. (1998). The national learning disabilities postsecondary data bank: An overview. *J Learn Disabil, 31*(3), 234-247.

Vogel, S. A., Vogel, G., Sharoni, V., & Dahan, O. (2003). *Adults with learning disabilities in higher education and beyond: An international perspective*. Baltimore: MD: York Press. .

Weinstein, C. E., Schulte, A. C., & Palmer, D. R. (1987). *Learning and Study Strategies Inventory.* Clearwater, USA: H&H Publishing Company.

Wessel, R. D., Jones, J. A., Markle, L., & Westfall, C. (2009). Retention and graduation of students with disabilities: facilitating student success. *Journal of Postsecondary Education and Disability, 21*(3), 116-125.

West, C., & Sadoski, M. (2011). Do study strategies predict academic performance in medical school? *Med Educ, 45*(7), 696-703. doi: 10.1111/j.1365-2923.2011.03929.x

Whitney, C. (2001). How the brain encodes the order of letters in a printed word: The SERIOL model and selective literature review. *Psychonomic Bulletin & Review, 8*(2), 221-243.

Whitney, C., & Cornelissen, P. (2005). Letter-position encoding and dyslexia. *Journal of Research in reading, 28*(3), 274-301.

Wilkinson, G. S. (1993). *Wide Range Achievement test*. Lutz, Florida: PAR.

Wolf, R. C., Sambataro, F., Lohr, C., Steinbrink, C., Martin, C., & Vasic, N. (2010). Functional brain network abnormalities during verbal working memory performance in adolescents and young adults with dyslexia. *Neuropsychologia, 48*(1), 309-318. doi: 10.1016/j.neuropsychologia.2009.09.020

Wolff, U. (2009). Phonological and Surface Subtypes among University Students with Dyslexia. *International Journal of Disability Development and Education, 56*(1), 73-91. doi: 10.1080/10349120802682083

Yip, M. C. W. (2007). Differences in learning and study strategies between high and low achieving university students: A Hong Kong study. *Educational Psychology, 27*(5), 597-606. doi: 10.1080/01443410701309126

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*(1), 3-29. doi: 10.1037/0033-2909.131.1.3

No deficiency in left-to-right processing of words in dyslexia but evidence for enhanced visual crowding

Chapter 5

Chapter 5: No deficiency in left-to-right processing of words in dyslexia but evidence for enhanced visual crowding

Callens, M., Whitney, C., Tops, W., & Brysbaert, M. (2013).
No deficiency in left-to-right processing of words in dyslexia but evidence for enhanced visual crowding.
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Whitney and Cornelissen (2005) hypothesized that dyslexia may be the result of problems with the left-to-right processing of words, particularly in the part of the word between the word beginning and the reader's fixation position. To test this hypothesis, we tachistoscopically presented consonant trigrams in the left and the right visual field (LVF, RVF) to 20 undergraduate students with dyslexia and 20 matched controls. The trigrams were presented at different locations (from -2.5° to + 2.5°) in both visual half fields. Participants were asked to identify the letters and accuracy rates were compared. In line with the predictions of the SERIOL model of visual word recognition (Whitney, 2001), a typical U-shaped pattern was found at all retinal locations. Accuracy also decreased the further away the stimulus was from the fixation location, with a steeper decrease in the LVF than in the RVF. Contrary to the hypothesis, the students with dyslexia showed the same pattern of results as the control participants, also in the LVF, apart from a slightly lower accuracy rate, particularly for the central letter. The latter is in line with the possibility of enhanced crowding in dyslexia. In addition, in the dyslexia group but not in the control group the degree of crowding correlated significantly with the students' word reading scores. These findings suggest that lateral inhibition between letters is associated with word reading performance in students with dyslexia.

Introduction

Although advanced readers experience little difficulty deciphering words and text, reading is a complex process. It involves the rapid integration of orthographic, phonological, morphological, and semantic information. Problems with any of these elements may lead to a failure or a delay in the entire process. The complexity becomes particularly clear when we are confronted with children having difficulties in learning to read and/or write. When no sensory deficit can explain the reading and/or writing difficulties and when adequate tuition has been given but fails to result in an adequate level of performance, developmental dyslexia is diagnosed.

There is strong evidence that individuals with dyslexia have phonological difficulties (de Jong & van der Leij, 1999; Griffiths & Snowling, 2002; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wagner & Torgesen, 1987). These deficits have been described extensively in both children and adults with dyslexia (Bruck, 1992; Vellutino et al., 2004; Wilson & Lesaux, 2001; Wolff & Lundberg, 2003). There is discussion, however, on a number of fronts, including whether phonological deficits are the only problem, whether they are the basic cause of dyslexia or a symptom of other underlying deficits (see Bishop, 2006; Blomert & Willems, 2010; Castles & Coltheart, 2004; Dehaene et al., 2010; Ramus & Szenkovits, 2008 for more information). Various authors argue that a single cognitive level account of dyslexia cannot explain its heterogeneity (Heim et al., 2008), nor can it explain the fact that some children with dyslexia do not exhibit phonological impairments (Bosse, Tainturier, & Valdois, 2007; White et al., 2006).

Several authors have proposed models alternative to the phonological deficit hypothesis, and models containing more than one failing component. For example, Bishop (2006) set out a multifactorial view of dyslexia, in which several perceptual and cognitive impairments interact. Menghini et al. (2010) ran a study to test this multifactorial hypothesis and concluded that dyslexia is indeed a complex disorder that can be caused by multiple neuropsychological deficits. They observed that only 19% of the children with dyslexia in the sample they tested had a pure phonological deficit. Most of the children showed impairments at different levels such as executive functioning, visual-spatial perception, attention allocation, and combinations of the above. A similar conclusion was reached by Ramus et al. (2003) who observed that many participants with dyslexia had sensory and motor problems in addition to a phonological impairment.

There is some evidence to suggest differences in the earliest stages of visual word processing in people with dyslexia. Using MEG technology, Helenius, Tarkiainen, Cornelissen, Hansen, and Salmelin (1999) observed that the divergence in cortical activation between normal and dyslexic readers is apparent in the earliest brain signals specific to words: 80% of the dyslexic readers did not show the typical left hemisphere infero-temporal activation 150 ms post-stimulus when confronted with letter strings (as opposed to other symbols or faces). This brain area is often referred to as the visual word form area (Cohen et al., 2000; Dehaene, Cohen, Sigman, & Vinckier, 2005; Warrington & Shallice, 1980). Taroyan and Nicolson (2009) also reported abnormal brain activity in the visual word form area when participants with dyslexia were confronted with words and pseudowords. One cause of these abnormalities may be a deficit in the visual attention span of individuals with dyslexia (Bosse et al., 2007; Lobier, Zoubrinetzky, & Valdois, 2012). A second cause may be enhanced lateral masking (reduced performance on target identification when flanked by nearby stimuli), as proposed by several authors (Bouma & Legein, 1977; Martelli, Di Filippo, Spinelli, & Zoccolotti, 2009; Pernet, Andersson, Paulesu, & Demonet, 2009). Indeed, there is evidence that increased spacing of letters may be beneficial to readers with dyslexia (Perea, Panadero, Moret-Tatay, & Gomez, 2012; Zorzi et al., 2012).

Whitney and Cornelissen (2005) formulated another reason why early visual processes could be the core deficit in dyslexia, based on the SERIOL model of visual word recognition. This SERIOL (Sequential Encoding Regulated by Inputs to Oscillations within Letter Units) model is a detailed model of word processing, describing how the visual signals from the retina are converted into abstract representations that can activate lexical representations (Whitney, 2001; Whitney & Cornelissen, 2005). Such conversion must explain two aspects of visual word recognition: (1) how words are recognized independent of their position in the visual field (and the retina), and (2) how letter positions within words are retained. In the SERIOL model this is achieved by means of five hierarchical layers. For a full account of the SERIOL model, see Whitney (2001). We focus on those aspects that are related to the proposed impairment in dyslexia.

How can the SERIOL model contribute to the understanding of dyslexia? To understand this, it is necessary to know that the SERIOL model postulates a left-to-right word recognition process at the highest level, the lexical level. The letters of the words are encoded in such a way that the signals of the first letter fire before those of the second letter, which in turn fire before those related to the third letter, and so on, resulting in a letter activation pattern from left to right, adequate for lexical retrieval. The left-to-right firing of letters is called the location gradient. When a word is fixated at the first letter or presented in the right visual field (RVF), the location gradient is in line with the signals coming from the retina (called the acuity gradient). Indeed, it is well documented that stimuli require more time to be processed the further they are from the centre of the visual field, because visual acuity drops steeply away from the fixation point (Brysbaert & Nazir, 2005). The increase in processing time can already be observed for letters presented one or two positions away from the fixation location. The right part of Figure 1 shows the correspondence between the acuity gradient and the location gradient when a word is presented in the RVF.

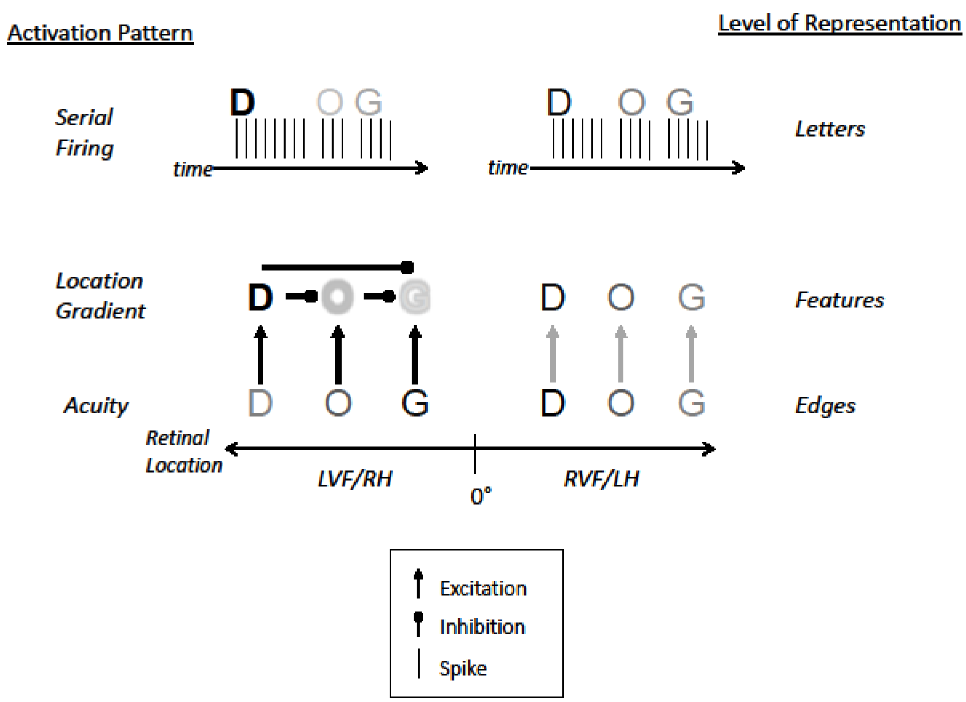


Figure 1. This figure portrays the activation patterns (left side) at the different levels of representation (right side) of the letters of the word "DOG" in each visual field, from retinal representation to activation at letter level. Darker letters represent higher activation levels, darker arrows represent stronger excitation. At the edge level, activation is based on acuity from fixation point (acuity gradient). At feature level, these levels of activation are transformed in a location gradient in the LVF due to stronger edge-to-feature excitation in the LVF/RH, and the left-to-right inhibition in the LVF/RH (blurriness of the letters). At the next level of representation -the letter level- the serial firing of the letters is represented as a spiking pattern. Each group of spikes represents the spiking duration for the letter above and the darkness of the letter (activation level) is in line the number of spikes for that letter. Based on the feature-level activity, the predictions for normal reading are that an initial letter should be recognized better in the LVF than the RVF, and an initial letter should have a stronger advantage over non-initial letters in the LVF than the RVF.

When the word is fixated at the last letter or presented in the left visual field (LVF), the acuity gradient is in contradiction with the location gradient, because under these circumstances the retinal signal is clearest/fastest for the last letter of the word, less so for the second-last letter, and so on. To reverse the acuity gradient into the location gradient, an inhibition process is postulated, such that the signals of the letters are inhibited until the signals of the preceding letters have fired. The left part of Figure 1 shows how the acuity gradient of a word presented in the LVF is reversed into the appropriate location gradient.

Further factors taken into account by the SERIOL model are that the retinal signals not only depend on the distance from fixation, but also on whether they come from letters on the outside of a word or from inner letters. The signals from exterior letters are stronger/faster because they are not fully surrounded by other letters. In addition, the firing of the last letter is not terminated by a subsequent letter.

A strong aspect of the SERIOL model is that it is mathematically formulated, so that it makes precise predictions about the chances of identifying the letters of tachistoscopically presented letter strings in both hemifields[1]. In the LVF, strong left to right inhibition is needed to turn the acuity gradient into the location gradient. In addition, there are the stronger signals from the exterior letters. Together these factors predict that the first letter of a word presented in the LVF will have the highest activation (even though it is furthest away from fixation), followed by the last letter, and the inner letters. There are two factors that influence the predictions on identification patterns in the RVF, namely the presence of the acuity gradient and the higher activation levels for the exterior letters. Because the acuity gradient is less steep than the serial inhibition in the LVF, the pattern of results is expected to be more symmetric.

The predictions from the SERIOL model were confirmed in a tachistoscopic trigram identification experiment performed by Legge, Mansfield, and Chung (2001). These authors observed that in the LVF the first letter of the trigram had a much higher chance of being identified than the third letter, which in turn was identified more often than the middle letter. In the RVF, there was less difference between the accuracies for the first and the last letter, and both were better than the middle letter. The asymmetry between LVF and RVF is a function of the reading direction and reverses for languages read from right to left (Adamson & Hellige, 2006; Eviatar, 1999).

[1] We restrict ourselves to the predictions made for small eccentricities, within -5°/5° of fixation, as these pertain to the present study. The letter perceptibility weights are slightly different for larger eccentricities.

Because the conversion from the acuity gradient to the location gradient (for letters presented to the left of fixation) is a process specific to reading, Whitney and Cornelissen (2005) hypothesized that problems with its acquisition would lead to deficits very similar to those observed in dyslexia. More specifically, if people with dyslexia have a deficient location gradient, they would only be able to process the letters of the words in the right order when they are fixating on the first letter. Given that most words in reading are fixated towards the middle, the order of the letters to the left of fixation would be jumbled up and they would interfere with the processing of the letters to the right of fixation.

In summary, Whitney and Cornelissen (2005) hypothesized that the reading problems of individuals with dyslexia could be caused by a deficiency in the formation of the location gradient. Some empirical evidence consistent with this hypothesis was published by Pitchford, Ledgeway, and Masterson (2009). In a visual search task they reported that dyslexics reacted more slowly than skilled readers to target letters located on the left of the stimulus array. This could be interpreted as evidence for a deficient conversion of the acuity gradient to the location gradient in the LVF. In the present paper, we performed a more direct test of the hypothesis by comparing the performance of students with and without dyslexia on Legge et al. (2001) trigram recognition study. If the location gradient formation is indeed underdeveloped in students with dyslexia, the SERIOL model makes a straightforward prediction of how the pattern of results will differ in readers with dyslexia, as shown in Figure 2. Given that the acuity gradient agrees with the location gradient in the RVF and no inversion is needed, dyslexic readers should perform very similar to normal readers here, with better performance for the first and the last letter than for the middle letter. In contrast, given the importance of the location gradient formation in the LVF, the performance of the dyslexic readers should differ from that of the controls. In particular, they are not expected to show the strong advantage for the first letter of the trigram. Because of the acuity gradient we even predict that the last letter will be indentified more often than the other two letters.

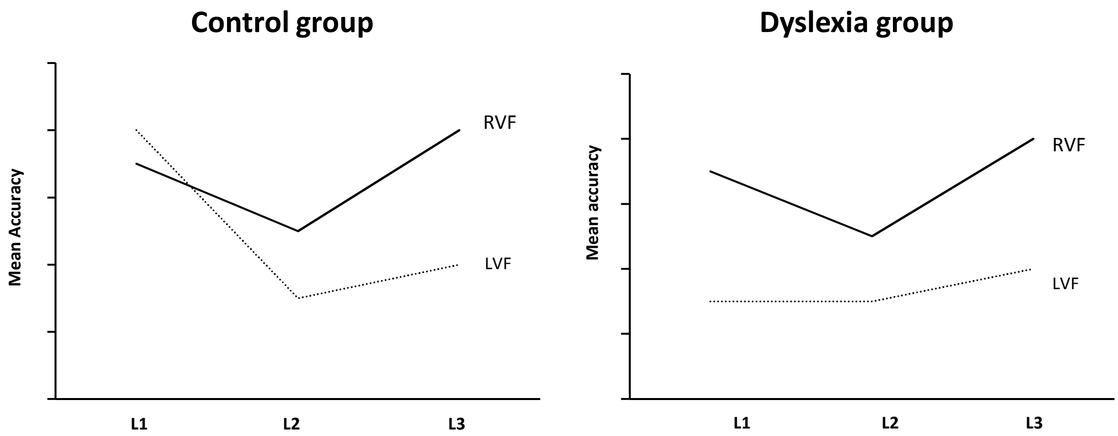


Figure 2. Expected mean accuracy rates in the right and left visual field for each group with a clear right visual field advantage for the last letter and a left field advantage for the first letter in normal readers. In readers with dyslexia the SERIOL model predicts an absence of this left field advantage for the first letter.

We tested the prediction outlined in Figure 2 by comparing the performance of a sample of 20 first-year bachelor students with dyslexia to a sample of 20 control students. We used the paradigm of Legge et al. (2001), in which trigrams of consonants were presented tachistoscopically at various positions in the LVF or the RVF. Participants had to identify as many letters as possible.

Method

Participants

Forty students in higher education (from the Association of Higher Education Ghent) received a small financial compensation for their participation in the experiment. All had normal or corrected-to normal vision and were native speakers of Dutch. They were first year students of either an academic bachelor (university and some academic colleges for higher education) or a professional bachelor (other colleges for higher education with less theory-driven teaching). The group consisted of 20 students diagnosed with dyslexia and a control group of 20 students with no known neurological impairments. All students were selected from the participants of a large scale study on dyslexia in higher education conducted at Ghent University, in which 100 students with dyslexia were compared to 100 matched control students on a battery of tests (Callens, Tops, & Brysbaert, 2012). Diagnoses of dyslexia were based on three criteria which are used by the Stichting Dyslexie Nederland (2008) [Foundation Dyslexia Netherlands]:

(1) reading and/or spelling abilities are significantly below the level of performance expected for their age; (2) resistance to instruction despite effective teaching; (3) impairment cannot be explained by extraneous factors, such as sensory deficits. Table 1 shows the main characteristics of the groups. They were matched for age [t (38) = - 0.32, p = .75] and intelligence [t (38) = 1.03, p =.75] as measured with the Kaufmann Adult Intelligence Test (Dekker, Dekker, & Mulder, 2004). Reading skills were assessed with a word reading and a pseudoword reading test. The word reading test was the Dutch One Minute Test (Brus & Voeten, 1991). A list of 116 Dutch words of increasing difficulty is presented in four columns. Participants have to accurately read as many words as possible in one minute. The pseudoword reading test was the Klepel (van den Bos, Spelberg, Scheepsma, & de Vries, 1999). The principle is the same as in the One Minute Test but instead of words pseudowords are presented. Writing skills were assessed with a standardized word spelling test for adolescents and adults, comprising of 30 words (De Pessemier & Andries, 2009). On all three tests the control group obtained scores within the normal range, whereas the students with dyslexia on average had scores more than 1.5 standard deviations below this level (see the effect sizes in Table 1).[2] Of the 20 students with dyslexia, two had a comorbid hyperactivity disorder.

[2] Five students from the group with dyslexia performed significantly worse on the spelling test than on the reading tests. To make sure that our findings were not distorted by this subgroup, we repeated the analyses with the scores of the remaining 15 dyslexic participants. The results were the same as the ones reported here.

Table 1
Characteristics of the 20 Control Students and the 20 Students with Dyslexia

		Control students	Dyslexia students	
Gender	Male	8	7	
	Female	12	13	
Institution	University	13	9	
	College	7	11	
Handedness	Right	19	14	
	Left	1	6	
		Mean (SD)	**Mean (SD)**	**Effect size (d)**
Age		19.20 (0.69)	19.20 (0.79)	NA
TIQ		110.75 (9.70)	109.85 (7.88)	0.10
OMT		59.2 (28.12)	18.22 (21.47)	-1.70
Klepel		57.34 (30.28)	17.09 (19.43)	-1.61
Word dictation		59.75 (27.00)	17.6 (18.90)	-1.65

Note. TIQ= Total IQ score; OMT= Dutch word reading, calculated from centile scores of the number of words read correctly in 1 minute time; Klepel= pseudoword reading, calculated from centile scores of the number of pseudowords read correctly in 1 minute time. Effect size calculated according to Cohen's d.

Design and stimuli

The stimuli consisted of consonant trigrams typed in upper case Courier New Font, size 24, composed of 3 consonants (see the appendix). The trigrams never contained two of the same consonants and no two visually similar consonants were juxtaposed. By using trigrams, we minimized top-down contributions from phonology, lexicality, or semantics, so that the results maximally reflect the contribution of orthographic (visual) processing. The stimuli were presented at 11 horizontal retinal locations going from 5 letter positions to the left of fixation to 5 letter positions to the right of fixation (distances measured to the letter in the middle of the trigram). Participants were sitting at a distance of 60 cm from the screen, so that each letter subtended 0.5° of visual angle and the stimuli were presented from -3.0° in the LVF (the first letter of the most leftward stimulus location) to +3.0° in the RVF (the last letter of the most rightward stimulus location). The stimuli were presented briefly and participants were asked to type in the letters they perceived. Because interactions are difficult to interpret in the presence of large main effects (Loftus, 1978), we decided to work with individually adjusted stimulus presentation times. This also avoided ceiling and floor effects (Adamson & Hellige, 2006). The experiment began with practice blocks, each consisting of 18 trials. Trials in the first block used a stimulus duration equivalent to one refresh cycle of the monitor, namely 14 ms. After each block, the stimulus duration was increased by one refresh cycle until an accuracy rate of 70 % was reached. Once the threshold was acquired, the experiment started, using this presentation duration. Two blocks of 90 trials were presented. Per participant, the mean accuracy per letter and location was calculated.

Procedure

Participants completed the experiment individually in a quiet, well-lit room. They were seated in front of a computer screen at a distance of 60 cm. Detailed instructions were given on three subsequent screens. The participants were asked to concentrate on the fixation location, indicated by a flashing fixation cross ("+"). This fixation cross was obtained by six times presenting a "+" for 90 ms followed by a blank interval of 90 ms. The trigram stimulus was presented after the last blank interval, followed by a string of hash marks to mask the stimulus. The mask remained on the screen until the participant responded. The task of the participants was to type in the letters they had perceived. They were told that the speed of the response and the order of letters were unimportant. After the response was entered, there was a one second interval before the next trial was presented. Whenever the participants wanted to take a rest, they could pause the block.

Results

Presentation duration

For each participant, the presentation duration needed to obtain an accuracy level of 70% during the practice trials was noted. To compare the presentation times (expressed in milliseconds) of the groups, the data was first tested for normality using a Kolmogorov-Smirnov test expressed with the test statistic D. Data distributions for the control group [M = 70.6 ms, SD = 17.3 ms; $D(20) = .301$, $p < .01$,] and the group of participants with dyslexia [M = 78.2 ms, SD = 13.4 ms; $D(20) = .27$, $p < .01$] were significantly non-normal, so we used the non-parametric Mann-Whitney-U test for data analysis. The presentation durations between the two groups needed to reach 70% levels of accuracy were not significantly different [$U = 243$, $p = .244$].[3]

Results for the main hypothesis

To test the main hypothesis of this study - namely that readers with dyslexia have a different letter identification pattern in the LVF due to impaired inversion of the acuity gradient into the location gradient - we ran an ANOVA with letter position (initial letter L1, middle letter L2, final letter L3) and trigram location (Location 1 to Location 9: Loc1 to Loc9) as repeated measures variables and group (normal, dyslexic) as a between subjects factor on the mean percentage correct scores. The assumption of homogeneity of variance was found valid on the basis of the Levene test. Our hypothesis predicted an interaction between letter position, trigram location, and group, but this effect was not significant [$F(16, 23) = 1.290$; $p = .282$].

To better test the prediction outlined in Figure 2, we averaged the data per visual field. For the LVF we calculated the mean accuracies of trigram locations 1 to 4; for the RVF we grouped the trigram locations 6 to 9. An ANOVA on this new variable was run with visual half field (RVF, LVF) and letter position (initial letter L1, middle letter L2, final letter L3) as repeated measures and group (normal, dyslexic) as a between subjects variable. As can be seen in Figure 3, the performance of the participants with dyslexia was very similar to that of the control participants, both in the LVF and the RVF. In particular, the participants with dyslexia did not perform less well on the first letter (L1) in the LVF, as expected on the basis of Whitney and Cornelissen (2005). The interaction group x visual half field x letter position was not significant [$F(2, 37) = 0.252$, $p = .78$] and a likelihood ratio test (Dixon, 2003) confirmed that a model with the interaction of letter position x VF x group was as likely as a model without this interaction ($L = 1.02$; only values above 10 would point to a contribution of the interaction).

[3] In the next sections it will become clear that our procedure did not completely succeed in getting equivalent levels of performance in the group with dyslexia and the controls. If full equivalence is required, it may be better to adjust the stimulus duration as a function of the accuracy level throughout the entire experiment. Another way to better match the performance levels may be to use a screen with a higher refresh rate than the presently used 70 Hz, so that finer adjustments can be made. Our adjustments were inspired by the consideration that large differences in overall performance would make the interpretation of interaction effects difficult, and we succeeded in the objective of avoidance them.

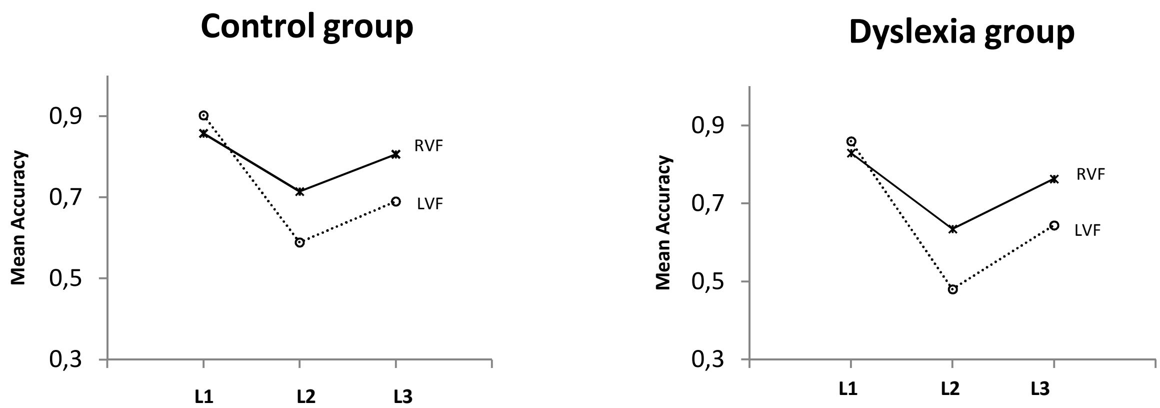


Figure 3. Mean accuracy for the three trigram letters for the left visual field and right visual field presentation for the two groups. The figure shows the lower accuracy level for all letters in the dyslexic group compared to the control group. As mentioned in the results, the graphs also illustrate the RVF advantage for L2 and L3 in both groups. In L1 this pattern is reversed for both groups. Most importantly, however, the dyslexia group did not show the drop in performance for L1 in LVF, as predicted in figure 2.

Other main and interaction effects

The ANOVA with letter position, ***trigram location***, and group revealed a significant main effect of group [F (1, 38) = 6.984; p =.012]. Participants with dyslexia overall had lower accuracy scores than normal readers (73% (*SD*=1.4) versus 78% (*SD*=1.4)). The ANOVA also yielded main effects of letter position [F (2, 37) = 279.88; $p < .001$] and trigram location [F (8, 31) = 99.19, $p < .001$]. As can be seen in Figure 4, the main effect of letter position showed the typical U-shaped pattern at almost all retinal locations in both groups. With respect to the main effect of trigram location, we found the expected increase in accuracy when stimuli were presented close to the fixation location. The decrease in performance as a function of eccentricity was steeper in the LVF than in the RVF. Turning to the main effect of letter position, performance was better on L1 than on L2 [t (39) = 22.012; $p < .001$], on L3 than on L2 [t (39) =8.470; $p < .001$] and on L1 than on L3 [t (39) = 15.06; $p < .001$].

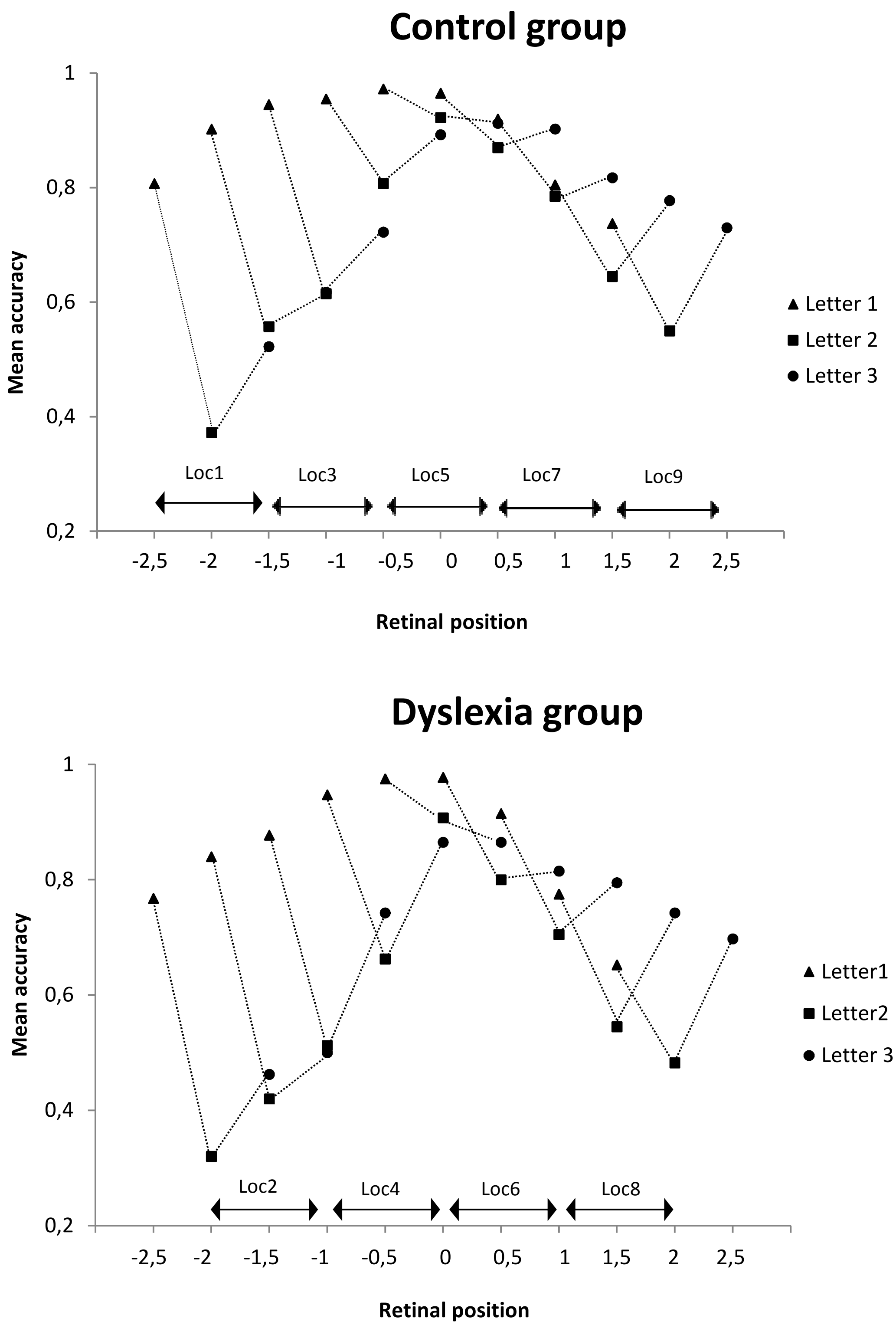


Figure 4. Mean accuracy of each of the three trigram letters at different locations from -2.5° to 2.5° of fixation point.

In addition to these main effects, there were two significant interaction effects: letter position x group [*F* (2, 37) = 4.168; *p* = .023] and trigram location x letter position [*F* (16, 23) = 20.818; *p*<.001]. The letter position x group interaction was explored with follow-up ANOVAS; these indicated that performance between the groups did not differ on L1 [*t* (38) = 1.679; *p*=.101, *d* = .5], was marginally worse on L3 [*t* (38) = 2.120; *p* = .041, *d* = .6], but differed significantly on L2 [*t* (38) = 3.539; *p* = .001, *d* = 1.4]. Because the observed trigram location x letter position interaction [*F* (16, 23) = 20,818; *p* < .001] is in line with the SERIOL predictions and is not of particular interest to the idea tested in this paper, we do not present a detailed description.

The ANOVA with letter position, ***visual half field***, and group replicated the main effect of group [*F* (1, 38) = 7.153; *p*= .01]. It further revealed a clear RVF advantage [*F* (1, 38) = 58.609; *p* < .001], which was present in both groups as the interaction group x visual field (VF) was not significant [*F* (1, 38) =0 .728; *p* = .399]. A RVF advantage for letter perception has been reported several times before (e.g., Hellige, Taylor, and Eng (1989); Hellige, Cowin, and Eng (1995)) and is related to the typical left hemisphere dominance for language processing (Hunter & Brysbaert, 2008). There was a main effect of letter position [*F* (2, 37) = 291.21; *p* < .001], which interacted with visual half field [*F* (2, 37) = 46.02; *p* < .001] and with group [*F* (2, 37) = 4.52; *p*= .017]. The interaction between letter position and visual half field was caused by the fact that the RVF advantage was only present for L2 [*t* (39) = - 8.852; *p* < .001] and L3 [*t* (39) = - 7.213; *p* < .001]. For L1, there was a reversed visual field advantage: the first letters of the trigrams were reported more accurately in the LVF than in the RVF [*t* (39) = 2.773; *p* = .008]. The interaction between letter position and group was due to the relatively worse performance on L2 in the dyslexic group. This finding is further examined in the next section.

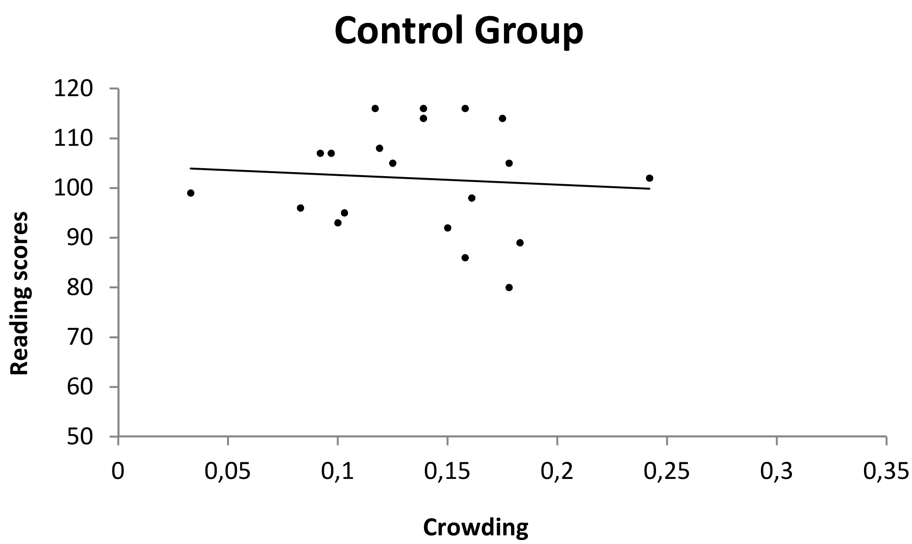
The crowding effect

To further examine the worse performance on L2 in the dyslexic group and the crowding to which it could point, a new variable was constructed to express how much worse L2 was identified compared to L1 and L3. This was calculated per participant by subtracting the overall accuracy on L2 from the average accuracies on L1 and L3 across all stimulus locations [i.e., crowding= $(L1_{\text{mean accuracy}} + L3_{\text{mean accuracy}})/2 - L2_{\text{mean accuracy}}$]. As expected on the basis of the previous ANOVAs, a t-test on this crowding variable showed a larger difference between performance on the inner letter and the outer letters in the dyslexia group [*M*=0.18, *SD* =0.05] than in the control group [*M*=0.14, *SD*= .05; *t*(38)= -2.602; *p*=.013]. To gauge the potential importance of the difference, we calculated a Cohen's d effect size, which equalled to $d = 0.8$, so potentially a large effect (although one has to take into account the large confidence interval, given the small numbers of participants involved in the between-group comparison). The same variable was calculated for the two visual fields separately, and showed a larger crowding effect in the LVF (locations 1 to 4) than in the RVF (locations 6 to 9) [$F(1,38)= 41.311$; $p<.001$]. The larger crowding effect in the LVF was found for both groups (as the interaction with participant group was not significant [$F(1, 38) = 0.441$; $p = .511$.

Correlations and linear regressions with reading scores

To see whether the enhanced crowding was connected to the reading skills in general, Pearson correlations were calculated between the crowding variable and the scores on the One Minute Test (word reading), the Klepel (pseudoword reading), and the word dictation test for the 40 participants. These revealed significant correlations with crowding for the reading tests (OMT: $r= -.507$, $N= 40$, $p= .001$; Klepel: $r= -.393$, $N= 40$, $p=.012$; word dictation: $r=-.23$, $N = 40$, $p=.151$). Further multiple regression analysis on the data from the dyslexia group with the scores on the OMT, the Klepel, and word dictation as predictors, indicated that only the OMT was a significant independent predictor of crowding in this group [$\beta = -0.002$, *CI95%* lower bound = -0.003, *CI95%* upper bound = -0.0001, $p = .001$].[4] The scores on the Klepel did not provide a significant increase in prediction precision [$\beta=0.136$, $p=.452$], nor did the scores on the word dictation test [$\beta=-0.105$, $p=.582$]. The overall model fit was $R^2 = .257$. A similar analysis on the data of the control group did not provide a significant predictor. Figure 5 illustrates the difference between the two groups.

[4] To make sure that the correlation with OMT could be interpreted as the outcome of crowding, we additionally looked at the correlations between OMT and performance on each of the letter positions. This analysis conformed that the correlation OMT performance and L2 accuracy in the dyslexic group was significantly larger than the correlation between OMT performance and L1 accuracy (p=.006, Hotelling-Williams test, see (Steiger, 1980)) or the correlation between OMT and L3 accuracy (p=.059).



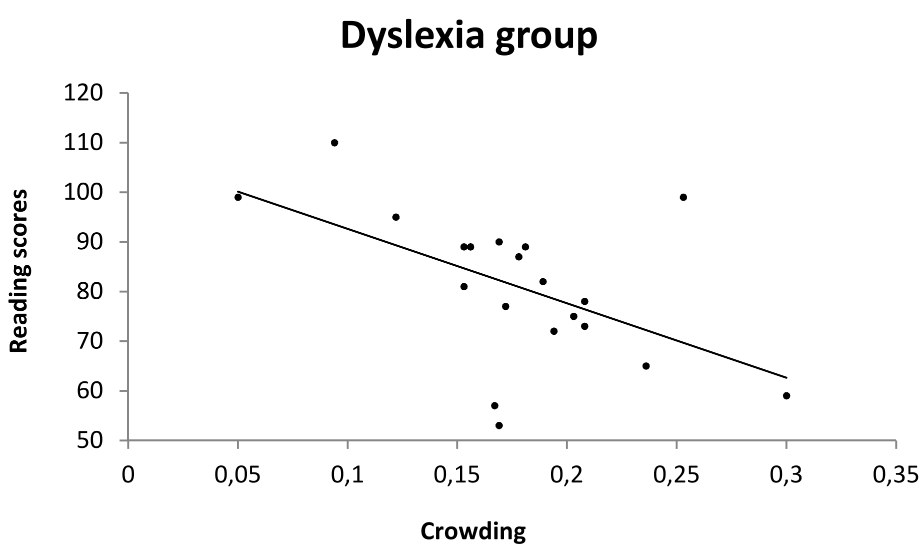


Figure 5. Scatter plots of the control group and the dyslexia group with on the X-axis the crowding effect and on the Y-axis the scores on the One Minute Test (Brus & Voeten, 1991). A linear trend line was added.

To further check whether problems with the formation of the location gradient could be a factor in the worst performing participants, we also calculated the correlations between a location variable defined as L1–L3 in the LVF (i.e., on stimulus locations 1-4) and the reading and writing scores. If the absence of the L1 advantage is the origin of reading problems, we should find that the difference between L1 and L3 is particularly small for poor readers. In other words, for the dyslexics we should find a positive correlation between reading skill and the difference between L1 and L3 in the LVF. No such correlation was found. As a matter of fact, the correlations trended in the opposite direction, with a slightly smaller difference for good readers than for poor readers, although the correlations were not significant (correlation between OMT and L1-L3 difference: $r = -.30$, $p = .197$, $N = 20$; Klepel: $r = -.17$, $p = .391$; word dictation: $r = -.06$, $p = .474$).

Discussion

In this paper we tested a hypothesis about the origin of dyslexia put forward by Whitney and Cornelissen (2005) on the basis of the SERIOL model of visual word recognition. According to the SERIOL model, visual word recognition involves a reading-specific skill (the inversion of the acuity gradient into the location gradient for letters presented to the left of fixation). Whitney and Cornelissen hypothesized that failure in acquiring this skill could be the true origin of reading problems (and the accompanying phonological deficits). To test this proposal, we repeated a study of Legge et al. (2001), in which consonant trigrams presented in the LVF and the RVF produced a pattern of results that was in line with simulations of the SERIOL model. Whitney and Cornelissen's (2005) hypothesis predicted a crucial difference between participants with dyslexia and controls for this particular task, as participants with dyslexia were expected not to show the high identification rate for the first letter in the LVF. For the rest, the performances were expected to be very similar (see the predictions laid out in Figure 2).

To test the hypothesis, two groups of participants were examined: one with normal reading/writing skills, and one with deficient reading/writing skills (Table 1). We were able to replicate the findings of Legge et al. (2001) in the group with normal skills (first part of Figure 3), providing evidence for the SERIOL model as a model of visual word recognition. However, contrary to the predictions of Whitney and Cornelissen (2005) we obtained very much the same pattern of results in the group with dyslexia (second part of Figure 3), suggesting that for the group of dyslexics we tested problems with the formation of the location gradient were not the origin of the reading problems. This is different from the finding with the visual search task reported by Pitchford et al. (2009), which pointed in the direction of reduced performance in the LVF for dyslexic readers.

The only significant difference we found between the dyslexic and the control group was worse performance on the middle letters of the trigrams (L2), suggesting an enhanced crowding effect in poor readers. Bouma (1970) was amongst the first to report inferior identification of embedded letters compared to letters in isolation, a phenomenon referred to as lateral masking or crowding (Bouma, 1973; Brysbaert & Nazir, 2005; Huckauf, Heller, & Nazir, 1999; Huckauf & Nazir, 2007; Massaro & Cohen, 1994; Pelli et al., 2007). Lateral masking is thought to occur at the first stages of visual processing before the letters are identified (Huckauf et al., 1999; Huckauf & Nazir, 2007). The extent of lateral masking is influenced by three factors: (1) the distance of the stimulus from fixation, (2) the distance between adjacent letters, and (3) the similarity between letters. Lateral masking is largest when the stimulus is far from fixation; the letters are close to each other and similar to one another. Bouma and Legein (1977) further reported an enhanced crowding effect in readers with dyslexia, a finding replicated by several authors (Goolkasian & King, 1990; Klein, Berry, Briand, Dentremont, & Farmer, 1990; Martelli et al., 2009; Pernet, Valdois, Celsis, & Demonet, 2006). Moores, Cassim, and Talcott (2011) argued that the enhanced crowding effect in dyslexia could be due to a deficit in attention allocation or to an unusually high lateral inhibition. For an alternative hypothesis of crowding in terms of letter position encoding see also Collis, Kohnen, and Kinoshita (2012).

An obvious next step was to correlate the crowding effect of the participants to their reading and writing scores as measured with a word reading test (OMT), a nonword reading test (the Klepel), and a word dictation test. We indeed observed in our dyslexic students (but not in controls; Figure 5) that enhanced crowding correlated with word reading performance (more than with nonword reading performance and word dictation), further suggesting a link between both variables, in line with the recent demonstration that increased letter spacing helps children with dyslexia more than control children (Perea et al., 2012; Zorzi et al., 2012). Further analyses confirmed that the correlation was limited to the crowding effect, as the correlation between word reading performance and accuracy scores on the middle letter in the dyslexic group was significantly larger than the correlation between word reading performance and accuracy on the first letter and last letter. Thus performance on the middle letter correlated best with the reading scores.

Although it is tempting to interpret the correlation between dyslexia and degree of crowding as suggesting that crowding is the cause of dyslexia, it is important to keep in mind that this interpretation may not be correct. Grainger, Tydgat, and Issele (2010) reported a larger crowding effect for symbols than for letters in normal readers and hypothesized that the smaller crowding effect for letters is letter-specific and the consequence of a specialized system acquired as part of learning to read. On the basis of this finding, a plausible, alternative interpretation of the larger crowding effect for dyslexics in our experiment may be that it is a consequence of less reading experience, rather than a cause of the reading problem.

Returning to the main question addressed in this study, we were unable to find evidence for Whitney and Cornelissen's (2005) hypothesis that the reading problem in dyslexia is due to a deficit in the left-to-right processing of words. There was no indication that students with dyslexia were less efficient at inversing the acuity gradient in the LVF than the controls. As a result we can conclude that problems with the location gradient are *not the only* cause of dyslexia. Whether we should conclude that it plays no role at all depends on the extent to which the participants we tested are representative of all people with dyslexia. Our sample performed considerably below expected levels on tests of reading and spelling, and all had a confirmed diagnosis of dyslexia. Nevertheless, they were a relatively high-achieving group, having compensated sufficiently to have started undergraduate studies. In terms of a multifactorial view of dyslexia, it remains possible that for some people, an impairment in the ability to inverse an acuity gradient into a location gradient for letters to the left of fixation is a possible cause of their dyslexia. As this might be associated with more severe reading difficulties, future studies should repeat our test with younger people with dyslexia, to see whether they all show the normal pattern, as seen in the adults with dyslexia in this experiment, and if not, to monitor the reading progress in children showing a deviant pattern.

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References

Adamson, M. M., & Hellige, J. B. (2006). Hemispheric differences for identification of words and nonwords in Urdu-English bilinguals. *Neuropsychology, 20*(2), 232-248. doi: 10.1037/0894-4105.20.2.232

Bishop, D. V. M. (2006). Dyslexia: what's the problem? *Developmental Science, 9*(3), 256-257. doi: 10.1111/j.1467-7687.2006.00484.x

Blomert, L., & Willems, G. (2010). Is There a Causal Link from a Phonological Awareness Deficit to Reading Failure in Children at Familial Risk for Dyslexia? *Dyslexia, 16*(4), 300-317. doi: 10.1002/dys.405

Bosse, M. L., Tainturier, M. J., & Valdois, S. (2007). Developmental dyslexia: The visual attention span deficit hypothesis. *Cognition, 104*(2), 198-230. doi: 10.1016/j.cognition.2006.05.009

Bouma, H. (1970). Interaction effects in parafoveal letter recognition. *Nature, 226*(5241), 177-178. doi: 10.1038/226177a0

Bouma, H. (1973). Visual interference in parafoveal recognition of initial and final letters of words. *Vision Research, 13*(4), 767-782. doi: 10.1016/0042-6989(73)90041-2

Bouma, H., & Legein, C. P. (1977). Foveal and parafoveal recognition of letters and words by dyslexics and by average readers. *Neuropsychologia, 15*(1), 69-80. doi: 10.1016/0028-3932(77)90116-6

Bruck, M. (1992). Persistence of dyslexics phonological awareness deficits. *Developmental Psychology, 28*(5), 874-886. doi: 10.1037/0012-1649.28.5.874

Brus, B., & Voeten, M. (1991). *Een-minuut-test vorm A en B, schoolvorderingstest voor de technische leesvaardigheid bestemd voor groep 4 tot en met 8 van het basisonderwijs. Verantwoording en handleiding*. Lisse, The Nederlands: Swets & Zeitlinger.

Brysbaert, M., & Nazir, T. (2005). Visual constraints in written word recognition: evidence from the optimal viewing-position effect. *Journal of Research in reading, 28*(3), 216-228. doi: 10.1111/j.1467-9817.2005.00266.x

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive profile of students who enter higher education with an indication of dyslexia. *PLos One, 7*(6). doi: 10.1371/journal.pone.0038081

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition, 91*(1), 77-111. doi: 10.1016/S0010-0277(03)00164-1

Cohen, L., Dehaene, S., Naccache, L., Lehericy, S., Dehaene-Lambertz, G., Henaff, M. A., & Michel, F. (2000). The visual word form area - Spatial and temporal characterization of an initial stage of reading in normal subjects and posterior split-brain patients. *Brain, 123*, 291-307.

Collis, N. L., Kohnen, S., & Kinoshita, S. (2012). The role of visual spatial attention in adult developmental dyslexia. *The Quarterly Journal of Experimental Psychology, 66*(2), 245-260. doi: 10.1080/17470218.2012.705305

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology, 91*(3), 450-476. doi: 10.1037/0022-0663.91.3.450

De Pessemier, P., & Andries, C. (2009). *GL&SCHR Dyslexie bij +16-jarigen. Test voor Gevorderd Lezen en Schrijven*. Antwerpen, Belgium: Garant.

Dehaene, S., Cohen, L., Sigman, M., & Vinckier, F. (2005). The neural code for written words: a proposal. *Trends in Cognitive Sciences, 9*(7), 335-341. doi: 10.1016/j.tics.2005.05.004

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Nunes, G., Jobert, A., . . . Cohen, L. (2010). How Learning to Read Changes the Cortical Networks for Vision and Language. *Science, 330*(6009), 1359-1364. doi: 10.1126/science.1194140

Dekker, R., Dekker, P. H., & Mulder, J. L. (2004). *Kaufman Adolescent and Adult Intelligence Test - Nederlandstalige versie: Handleiding*. Leiden, The Nederlands: PITS.

Dixon, P. (2003). The p-value fallacy and how to avoid it. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale, 57*(3), 189-202. doi: 10.1037/h0087425

Eviatar, Z. (1999). Cross-language tests of hemispheric strategies in reading nonwords. *Neuropsychology, 13*(4), 498-515. doi: 10.1037//0894-4105.13.4.498

Goolkasian, P., & King, J. (1990). Letter identification and lateral masking in dyslexic and average readers. *American Journal of Psychology, 103*(4), 519-538. doi: 10.2307/1423322

Grainger, J., Tydgat, I., & Issele, J. (2010). Crowding Affects Letters and Symbols Differently. *Journal of Experimental Psychology-Human Perception and Performance, 36*(3), 673-688. doi: 10.1037/a0016888

Griffiths, Y. M., & Snowling, M. J. (2002). Predictors of exception word and nonword reading in dyslexic children: The severity hypothesis. *Journal of Educational Psychology, 94*(1), 34-43. doi: 10.1037//0022-0663.94.1.34

Heim, S., Tschierse, J., Amunts, K., Wilms, M., Vossel, S., Willmes, K., . . . Huber, W. (2008). Cognitive subtypes of dyslexia. *Acta Neurobiologiae Experimentalis, 68*(1), 73-82.

Helenius, P., Tarkiainen, A., Cornelissen, P., Hansen, P. C., & Salmelin, R. (1999). Dissociation of normal feature analysis and deficient processing of letter-strings in dyslexic adults. *Cerebral Cortex, 9*(5), 476-483. doi: 10.1093/cercor/9.5.476

Hellige, J. B., Cowin, E. L., & Eng, T. L. (1995). Recognition of CVC syllables from LVF, RVF, and central locations - hemispheric differences and interhemispheric interaction. *Journal of Cognitive Neuroscience, 7*(2), 258-266. doi: 10.1162/jocn.1995.7.2.258

Hellige, J. B., Taylor, A. K., & Eng, T. L. (1989). Interhemispheric Interaction When Both Hemispheres Have Access to the Same Stimulus Information. *Journal of Experimental Psychology-Human Perception and Performance, 15*(4), 711-722.

Huckauf, A., Heller, D., & Nazir, T. A. (1999). Lateral masking: Limitations of the feature interaction account. *Perception & Psychophysics, 61*(1), 177-189. doi: 10.3758/bf03211958

Huckauf, A., & Nazir, T. A. (2007). How odgcrnwi becomes crowding: Stimulus-specific learning reduces crowding. *Journal of Vision, 7*(2). doi: 10.1167/7.2.18

Hunter, Z. R., & Brysbaert, M. (2008). Visual half-field experiments are a good measure of cerebral language dominance if used properly: Evidence from fMR1. *Neuropsychologia, 46*(1), 316-325. doi: 10.1016/j.neuropsychologia.2007.07.007

Klein, R., Berry, G., Briand, K., Dentremont, B., & Farmer, M. (1990). Letter identification declines with increasing retinal eccentricity at the same rate for normal and dyslexic readers. *Perception & Psychophysics, 47*(6), 601-606. doi: 10.3758/bf03203112

Legge, G. E., Mansfield, J. S., & Chung, S. T. L. (2001). Psychophysics of reading XX. Linking letter recognition to reading speed in central and peripheral vision. *Vision Research, 41*(6), 725-743. doi: 10.1016/s0042-6989(00)00295-9

Lobier, M., Zoubrinetzky, R., & Valdois, S. (2012). The visual attention span deficit in dyslexia is visual and not verbal. *Cortex, 48*(6), 768-773. doi: 10.1016/j.cortex.2011.09.003

Loftus, G. R. (1978). Interpretation of interactions. *Memory & Cognition, 6*(3), 312-319. doi: 10.3758/bf03197461

Martelli, M., Di Filippo, G., Spinelli, D., & Zoccolotti, P. (2009). Crowding, reading, and developmental dyslexia. *Journal of Vision, 9*(4), 1-18. doi: 10.1167/9.4.14

Massaro, D. W., & Cohen, M. M. (1994). Visual, orthographic, phonological and lexical influences in reading. *Journal of Experimental Psychology-Human Perception and Performance, 20*(6), 1107-1128. doi: 10.1037/0096-1523.20.6.1107

Menghini, D., Finzi, A., Benassi, M., Bolzani, R., Facoetti, A., Giovagnoli, S., . . . Vicari, S. (2010). Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia, 48*(4), 863-872. doi: 10.1016/j.neuropsychologia.2009.11.003

Moores, E., Cassim, R., & Talcott, J. B. (2011). Adults with dyslexia exhibit large effects of crowding, increased dependence on cues, and detrimental effects of distractors in visual search tasks. *Neuropsychologia, 49*(14), 3881-3890. doi: 10.1016/j.neuropsychologia.2011.10.005

Nederland, S. D. (2008). *Diagnose dyslexie. Brochure van de Stichting Dyslexie Nederland. Herziene versie*. Bilthoven, The Nederlands: Stichting Dyslexie Nederland.

Pelli, D. G., Tillman, K. A., Freeman, J., Su, M., Berger, T. D., & Majaj, N. J. (2007). Crowding and eccentricity determine reading rate. *Journal of Vision, 7*(2), 1-36. doi: 10.1167/7.2.20

Perea, M., Panadero, V., Moret-Tatay, C., & Gomez, P. (2012). The effects of inter-letter spacing in visual-word recognition: Evidence with young normal readers and developmental dyslexics. *Learning and Instruction, 22*(6), 420-430. doi: DOI 10.1016/j.learninstruc.2012.04.001

Pernet, C., Andersson, J., Paulesu, E., & Demonet, J. F. (2009). When All Hypotheses are Right: A Multifocal Account of Dyslexia. *Human Brain Mapping, 30*(7), 2278-2292. doi: 10.1002/hbm.20670

Pernet, C., Valdois, S., Celsis, P., & Demonet, J. F. (2006). Lateral masking, levels of processing and stimulus category: A comparative study between normal and dyslexic readers. *Neuropsychologia, 44*(12), 2374-2385. doi: 10.1016/j.neuropsychologia.2006.05.003

Pitchford, N. J., Ledgeway, T., & Masterson, J. (2009). Reduced orthographic learning in dyslexic adult readers: Evidence from patterns of letter search. *Quarterly Journal of Experimental Psychology, 62*(1), 99-113. doi: 10.1080/17470210701823023

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain, 126*, 841-865. doi: 10.1093/brain/awg076

Ramus, F., & Szenkovits, G. (2008). What phonological deficit? *Quarterly Journal of Experimental Psychology, 61*(1), 129-141. doi: 10.1080/17470210701508822

Taroyan, N. A., & Nicolson, R. I. (2009). Reading words and pseudowords in dyslexia: ERP and behavioural tests in English-speaking adolescents. *International Journal of Psychophysiology, 74*(3), 199-208. doi: 10.1016/j.ijpsycho.2009.09.001

van den Bos, A., Spelberg, H., Scheepsma, A., & de Vries, J. (1999). *De Klepel vorm A en B: een test voor leesvaardigheid van pseudowoorden. Verantwoording, handleiding, diagnostiek en behandeling*. Lisse, The Nederlands: Swets & Zeitlinger.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*(1), 2-40. doi: 10.1046/j.0021-9630.2003.00305.x

Wagner, R. K., & Torgesen, J. K. (1987). The Nature of Phonological Processing and its Causal Role in the Acquisition of Reading Skills. *Psychological Bulletin, 101*(2), 192-212. doi: 10.1037//0033-2909.101.2.192

Warrington, E. K., & Shallice, T. (1980). Word-form dyslexia. *Brain, 103*(MAR), 99-112. doi: 10.1093/brain/103.1.99

White, S., Milne, E., Rosen, S., Hansen, P., Swettenham, J., Frith, U., & Ramus, F. (2006). The role of sensorimotor impairments in dyslexia: a multiple case study of dyslexic children. *Developmental Science, 9*(3), 237-255. doi: 10.1111/j.1467-7687.2006.00483.x

Whitney, C. (2001). How the brain encodes the order of letters in a printed word: The SERIOL model and selective literature review. *Psychonomic Bulletin & Review, 8*(2), 221-243.

Whitney, C., & Cornelissen, P. (2005). Letter-position encoding and dyslexia. *Journal of Research in reading, 28*(3), 274-301.

Wilson, A. M., & Lesaux, N. K. (2001). Persistence of phonological processing deficits in college students with dyslexia who have age-appropriate reading skills. *J Learn Disabil, 34*(5), 394-400. doi: 10.1177/002221940103400501

Wolff, U., & Lundberg, I. (2003). A technique for group screening of dyslexia among adults. *Annals of Dyslexia, 53*, 324-339.

Zorzi, M., Barbiero, C., Facoetti, A., Lonciari, I., Carrozzi, M., Montico, M., . . . Ziegler, J. C. (2012). Extra-large letter spacing improves reading in dyslexia. *Proceedings of the National Academy of Sciences of the United States of America, 109*(28), 11455-11459. doi: DOI 10.1073/pnas.1205566109

Appendix

Stimulus list

BCZ / CGV / DPW / GJN / HPS / JXB / LJH / MTJ / PMK / TFZ / BHP / CKT / DSC / GLZ / HRG/ KGV / LNS NFD / PVK / TXB / BHF / CSJ / DTG / GPF / HXS / KJM / LVZ / NGM /PZW / VGB/ BJZ / CVP / DWB ZMG / HXT / KLX / LTB / NHW / RGX / VKM / BSF / CXM / FBX / GSW /HXW / KRN / LWF / NJW / RHD WJD / BXM / DBX / FXN / GZH / JGN / KVR / MCN / NTJ /RKN / WTK / BZJ / DHM / GCZ / HCR / JMC LDJ / MGF / NVM / SKX / ZBS / BZK / DLC / GHB / HFR / JNB / LDN / MPD / PCJ / SWJ / XBV / CDB/ DNW / GHT / HMD / JPX / LHC / MRD / PDT / TBR / ZVC

General Discussion

Chapter 6

Chapter 6: General discussion

Conclusion and general discussion

This project was launched to meet a need for more scientific information on students with dyslexia who enter higher education in countries where English is not the mother tongue. In Anglo-Saxon countries a little more information was already available. For other languages and other educational contexts, however, information was scarce[1]. Various reasons have been voiced throughout the dissertation as to why a generalization of the findings in English is risky. As for the few studies that had been conducted in other languages at the time of the setup, these either reported small sample sizes or were very limited in the variety of skills that had been evaluated. In Flanders, information that was available was mainly practice-based coming from professionals who work with these students on a day to day base. The downside of this- however useful information- is that often a reference group is missing. As an addition to the field, we conducted a large scale study on 100 first-year bachelor students with dyslexia and a control group of equal size. For the setup we were mostly inspired by Hatcher, Snowling, and Griffiths (2002). After the launch of the study the metanalysis of Swanson and Hsieh (2009) became available. A wide variety of cognitive skills were evaluated using (mostly) validated Dutch instruments and performances were compared. This study is described in Chapter 2.

Based on our cognitive study a valid prediction model was constructed (Tops, Callens, Lammertyn, & Brysbaert, 2012). With the use of only 3 tests an average prediction accuracy of 90.9% was obtained. Sensitivity of the model was 91% and specificity 90%. However, this does not mean students only struggle on these tasks. This selection only relates to the diagnosis of dyslexia in higher education. Therefore one could wonder how all the administered tests are interrelated and how they are affected in the dyslexia group. So, in Chapter 3, an exploratory factor analysis (EFA) was used on all subtests reported in Chapter 2 (plus some additional ones). An EFA reduces the number of variables by searching for the latent variables that are assumed to drive the covariations between the variables. Here the EFA was used across groups in combination with effect sizes. Factors or latent variables with large effect sizes are then primarily driven by the difference between groups; factors with small effect sizes are mainly driven by the variance within groups. This gives an idea on how many factors are needed to

[1] Unfortunately, from our own experience we have come to think that studies in non-English languages are rare in the international literature, because the manuscripts are nearly all judged by reviewers who do not master these languages and who therefore do not see the need for this kind of articles.

extract a pattern of relationships between all the variables, which can help to set up a time efficient assessment protocol.

Entering higher education is one thing, actually graduating is yet another. A literature study revealed that virtually no information was available on how well students with dyslexia perform in higher education, specifically in non-Anglo-Saxon models of education. In the Anglo-Saxon setting, students with dyslexia seem to do quite well but due to the selection procedures little can be said for the free-admission equivalents. In Chapter 4, study results from the 200 students who participated in the first study were collected and compared across groups. Finally, regression models including background data, personality factors and learning skills were used to reveal factors that contribute most to study success in the dyslexia group.

Apart from the findings in the cognitive study, the EFA and the longitudinal study, the description of the participant group also revealed some interesting information. Almost every student with dyslexia who participated in the study experienced difficulties from the early stages of learning to read and write on and yet a quarter of them did not receive any form of remediation until secondary school. As for diagnostics, 60% of them received a diagnosis in primary school. At entrance in higher education for 46 students the diagnosis needed to be confirmed. So it would seem that some efforts are still required in that department. Possibly the students managed to slip through the mazes due to high compensatory efforts or some minor flaws in the system.

Comorbidity rates in our sample were 14 % for dyslexia and AD(H)D and 9% for dyslexia and dyscalculia. In the population, between 15% and 26% of the individuals with dyslexia also meet the criteria for AD(H)D (Willcutt et al., 2010) and 3.4% (Badian, 1999) to 7.6% (Dirks, Spyer, van Lieshout, & de Sonneville, 2008) do so for dyscalculia. So comorbidity rates in our sample of students in HE are quite similar to the proportions found in the general population.

First-year bachelor students with dyslexia seem to come more from technical, professional or art secondary education programs than their peers. General secondary education is mainly aimed at preparing for higher education. In addition, students with dyslexia seem to benefit slightly more from having a general secondary education degree than the control students. Students with dyslexia that register in higher education seem les tempted to take up an academic program and as Kleijnen and Loerts (2006) already observed they are more inclined towards technological programs. This is true for both our male and female group although females also take up more programs in human sciences. Clearly, for this subgroup dyslexia has an overall impact on their educational careers.

The results in Chapter 2 show that *"an average student with dyslexia entering higher education typically encounters problems with reading and spelling, has low phonological and orthographical skills, difficulties with mental calculations and rapid naming. Verbal skills such as lexical retrieval are likely to be impaired. FIQ is not affected by this learning disability."*

This confirms the traditional definition of dyslexia stating that someone with average to above average mental abilities can still exhibit pervasive problems with reading and spelling despite many years of instruction. We did not match the groups on IQ but fluid intelligence did not differ between groups. Yet reading and spelling remained impaired on many aspects. Snowling (2000) suggested that students in higher education have compensated (scores above percentile 25) for their difficulties in reading and writing. However our data and the data from others (Hatcher et al., 2002; Laasonen, Service, Lipsanen, & Virsu, 2012; Lindgren & Laine, 2011) do not seem to support this idea. The main expression of dyslexia in adulthood remains a deficit in reading and writing. This is also illustrated in the EFA where the Reading and Spelling factors arise as the two most affected latent variables. When looking at the effect sizes for the individual subtests, spelling seems to be more affected than reading. Strangely, the EFA reveals a different pattern. Here the factor with the largest effect size seems to be reading related. During the interviews the students were asked to define their impairment. Their definitions were mainly in line with this general profile (Bultinck, 2012). Fifteen percent report problems with reading only, 20 % report problems in spelling alone and 45% experience problems with both. Twenty percent describe dyslexia as a more general problem related to, for example a lack in the ability to automate skills or to a general language impairment.

Also in accordance with the SDN definition, these difficulties in reading and writing can be observed at the word level. Reading and writing skills at the sentence level do not seem to be more affected. In the EFA word and sentence level subtests did not load on different factors suggesting that the same functions lie at the basis of these skills. When we compare performances between normal readers and dyslexic readers, the suggestion of a specific non-word reading deficit in dyslexia does not seem to hold. Overall, effect sizes were larger for word reading than for nonword reading. This is in line with Van den Broeck and Geudens (2012) who argued that disabled readers do not show a specific problem with reading nonwords. Furthermore, the deficits in reading and writing do not seem to be more pronounced in English. Smaller effect sizes for comparable skills were obtained in a foreign language compared to the mother tongue. A possible explanation could be that different levels of print exposure in the mother tongue enlarge the gap in performance between groups. In a second language print exposure may differ less between groups. In the EFA, the English subtests did not group together but were more related to the general cognitive skill. This suggests that the communalities between the underlying cognitive skills are larger than the language relatedness.

Besides the core deficit of dyslexia, the effect sizes and the EFA revealed several associated problems in higher education students diagnosed with dyslexia. Phonological problems persist in HE which can be demonstrated using instruments that are sensitive enough. In the EFA, the phonology factor resulted in an effect size around 1. This can be viewed within the framework of the phonological deficit as a cause of dyslexia. However, researchers are now less sure of the nature of the relationship between the two skills. As a pillar in the phonological triad the rapid naming of letter, digits and colors was also found to be impaired in dyslexic students. In the EFA the four naming skills formed one distinct factor largely carried by letter and digit naming, to a lesser extent by color naming followed by object naming. Memory spans as measured with the tests we used, were similar between groups except for phonological short term memory. A final factor in the EFA that was impaired in dyslexic students was mental calculations.

Students with dyslexia have problems with lexical retrieval as shown by the rapid naming deficit. In the EFA a second factor related to lexical retrieval was slightly impaired namely the crystallized intelligence factor. Not only did this factor include the subtests of the KAIT measuring crystallized intelligence, but some additional tests on vocabulary and text comprehension loaded on this factor. There are several possible reasons as to why this factor results in a medium effect size. Either this is an additional weakness in dyslexia or it could be that it is a consequence of the fact that the information has been processed less often. The first possibility could be seen in the light of the overlap between dyslexia and specific language impairment. As mentioned before, some students looked at dyslexia as a specific language related impairment and problems with syntax and formulations are often reported (Bultinck, 2012). In my opinion, we cannot exclude the possibility that in our sample some students had a mild form of SLI that was left undiagnosed.

In general, the correspondence with previously mentioned English studies is impressive (Hatcher et al., 2002; Swanson & Hsieh, 2009). As such the cognitive profile of students with dyslexia in Flanders corresponds to the pattern of difficulties observed in dyslexic students in English speaking countries. Language and educational context do not seem to have a large influence on the cognitive profile of these students. Unfortunately, it does seem to have impact on study success. In Flanders, students with dyslexia tend to drop out more, and possibly take longer to obtain a degree while the picture in master-apprentice models is a more positive one. If at entrance their profiles are similar but their study results are not, the difference in educational context could be an influential factor. In a master-apprentice model institutions engage themselves to help students who get through the selection, succeed. Another possible cause related to this selection procedure is an initial difference in motivation and learning skills. Our results showed that these are of great importance in succeeding in HE. In an Anglo-Saxon model, students who get accepted in higher education are possibly more motivated. Of course we cannot draw firm conclusions based on the comparison of the available studies.

Although the dropout rate is higher for students with dyslexia, some additional qualitative research showed that only 12.5% of this group actually leaves HE. Others choose to register for a different degree. At present we cannot tell if these students actually prevailed after a change of program but it is a positive observation. Follow-up of these students would shed light on this issue. As for the factors that have an influence on study success in HE, we see much of the same relevant predictors as in the normal student population. The background level of the group, as measured by the educational attainment of both parents, affects academic success. Maybe the importance attached to getting a degree is higher for parents who themselves are educated; maybe they are more involved and give more support. Our data do not allow us to explain this relationship but it is certainly worth mentioning. There is also a gender effect on study performance in this group, although contradictory for dropout and graduating after three years. Female students with dyslexia have a higher chance of dropping out but those who continue do better than their male colleagues. What we did not include in the analysis -for interpretative and practical reasons- is the mediation of personality by gender. Females are reported to have higher levels of neuroticism and we showed that neuroticism negatively impacts study continuance for dyslexics so maybe an interaction effect is at the cause of this higher dropout. As for the fact that they eventually do better than their male peers with regards to time to graduation, this is a confirmation of a frequently reported observation in the general student population (Declercq & Verboven, 2010; Lacante et al., 2001).

Personality traits have been linked to academic performance and for students with dyslexia this is no different. Extraversion seems to negatively affect study continuance but positively impacts study success after three years. Compared to their non-dyslexic peers, students who are dyslexic seem to benefit even more from being extravert. To account for this finding some additional research should be done. A likely cause is that being extravert implies sociability, so maybe these students manage to create more elaborate social networks to rely upon. Assertiveness and optimism are also related to extraversion so maybe these traits also positively influence study success as well. Finally, an observation that has also been confirmed in the general population is that less conscientious people -and dyslexics- are more prone to dropout. Besides background and personality, learning skills seem to have the largest impact on study performance. Better developed learning skills helps to perform better in an academic context.

The above results summarize the results of the 3 studies that were more practical in nature. Working in a Department of Experimental Psychology (with a supervisor specialized in visual word recognition) provided me with the ideal surroundings to do some experimental research. In collaboration with Carol Whitney, author of the SERIOL model for visual word recognition, a possible deficiency in left to right processing in dyslexia was investigated. The result of this collaboration is presented in Chapter 5. To our knowledge this is the first study to investigate a possible existence of irregularities in left to right processing in individuals with dyslexia. In a trigram identification task performances of a group of readers with dyslexia were compared to those of skilled readers. Trigrams were presented at different locations in the two visual half fields, accuracy rates were compared between groups. The main results of the experiment provide evidence for the SERIOL model as a general model for normal visual word recognition. Its application to dyslexia as an expression of a failure to learn string specific left-to-right processing in the LVF could not be confirmed however. Individually adjusted presentation times were used to obtain equal overall mean accuracy levels. As a group, students with dyslexia had lower accuracy rates than students without reading difficulties but their pattern did not deviate as predicted by the SERIOL model. At the same time we noticed that students with dyslexia performed poorly on the middle letter. This is in agreement with recent claims of enhanced visual crowding in this group.

The phonological deficit has long been the leading theory in causal research on dyslexia. Nowadays researchers are less sure of the directionality of the relationship between phonological skills and literacy. The coexistence of these skills is not disputed. But the question remains whether phonological awareness is a necessary skill for reading development or whether these skills evolve together. Causal models of dyslexia are now shooting up like mushrooms after rainfall. Because reading is such a complex process, there are many candidates for possible causes of a failure in learning to read and/or write. Any causal model of dyslexia should be able to explain why it seems to affects reading and writing the most. Maybe the answer to the question of what causes dyslexia lies in what makes reading and writing so specific. So, in my opinion, further focusing on normal visual word recognition could lead to new insights in dyslexia research. Variations in performance levels in one or several components of visual word recognition could lead to the same deficit we call dyslexia. It is also in this multifactorial approach we could look for possible connections to disorders that are highly comorbid to dyslexia. Ideally, computational models for visual word recognition where all underlying processes are viewed as continuous variables and in which deficiencies in individual elements or combinations are introduced to various extents, could simulate the heterogeneity found in dyslexia. Reading ability could then also be seen as a continuous variable with dyslexics at the weakest end.

Practical implications for assessment

Starting from the theoretical findings in the different studies some suggestions and implications for assessment procedures can be put forward. In relation to a general assessment of reading and writing skills and a diagnostic protocol for dyslexia in HE, the following suggestions can be made.

Speed related measures seem to have higher discriminative power than accuracy related measures. Not only for tasks in which a time limit is imposed (EMT, OMT, Klepel, CDT) but also for tasks where there is none (phonological tasks, reading out loud), speed seems to result in higher effect sizes than accuracy within the same test. In the interviews, many dyslexic students reported that they need more time to finish certain tasks such as reading and writing. In transparent languages slowness rather than accuracy alone has been suggested as a primary marker of dyslexia. Of course, one can object that in these measures, speed is not really imposed and there is no way of telling whether participants perform at the best of their abilities. In any case this seems a cross linguistic finding (Leinonen et al., 2001; Serrano & Defior, 2008). Altogether, the present data support previous claims that reading latencies rather than errors are the more sensitive variable when comparing reading performance across languages (Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Korne, 2003).

The traditional, individually administered reading and writing tests that combine speed and accuracy (e.g. EMT, Klepel) remain very effective in discriminating groups at a higher educational level. When looking at the number of students in need of a valid attestation (see Chapter 2, Table 1), services responsible for these assessments would certainly benefit from a validated test battery that is less time-consuming. A computer based assessment has some advantages in this area. Thanks to self-administration and the fact that the results are available immediately, the administrative load and cost can be limited and delays avoided. To assess the diagnostic value of such an instrument (IDAA) in higher education the performance of a computerized diagnostic tool (IDAA) was compared to the classic paper and pencil protocol. The same cross validation method was used as in Tops et al. (2012). In this study it was demonstrated that with the use of only three tests (word reading, word dictation and a phonological task) 90.9% of the individuals could be correctly classified. Adding more predictors did not increase the prediction accuracy. To evaluate the efficiency of the IDAA, the 5 accuracy measures of the subtests were used in addition to the IDAA-quotient, as this is the score used in the manual of the test. This includes the four accuracy measures of the Flash typing tasks, corrected for the number of items. Using only the IDAA-quotient a mean prediction accuracy of 87.5% (95% CI [83.8, 91.2]) was obtained. A second model combining the IDAA-quotient and the Reversal task resulted in a mean prediction accuracy of 88.5% (95% CI [84.4, 92.6]). Thus, this computer based instrument performs almost as well as a classical test battery and can be considered a valid alternative for diagnostic purposes. This can also be seen in the EFA (with the flash tasks loading on the reading factor) where the IDAA closely related to the core of dyslexia. However, all flash tasks also loaded on a separate factor that does not seem to correlate to the core factors of dyslexia. Possibly the extra latent variable relates to a specific characteristic of the IDAA namely the use of brief stimulus presentation. To see whether the IDAA would improve the predictive power when combined with a classic pen and paper assessment, the seven most promising variables from Tops et al. (2012) (Dutch word spelling, Dutch word reading, spoonerism time, reversals time, mental calculation, writing speed, and verbal short term memory) and the five accuracy measures of the IDAA were used as predictors. Out of the 12 variables, seven had a significant predictive power resulting in a predictive accuracy of 92 % (95% CI [87.1, 96.9]). These variables were word dictation, word reading, classic Reversals (time), IDAA Reversals accuracy, Flash typing pseudowords accuracy, mental calculations, and the spoonerism task (time). Finally, the seven variables of Tops et al. (2012) were combined with the IDAA-quotient. This resulted in a prediction accuracy of 93% (95% CI [89.7, 96.3]) with word spelling, word reading, classic reversal task (time), mental calculation (mix) and the IDAA-Quotient as significant predictors. So a combination of a limited number of computer-based tests and classic paper and pencil tests may be better for diagnosis than each type of test alone.

For pure diagnostic purposes an assessment of reading and writing skills at the word level seems to suffice. However, reading and spelling assessment at the sentence level could provide additional information for remediation (if still required) and guidance. The goal of the assessment should be taken into account when deciding the level of testing. Also, the sentence dictation is quite time consuming. An idea would be to create a shorter version of this test.

Often the question is raised whether in higher education reading and writing instruments in foreign languages are more effective than their equivalents in the mother tongue. One could suggest that due to a relatively lower print exposure and experience with these languages the deficits would be more pronounced in a foreign language. We did not find any evidence –using a word dictation and word reading test in English- to confirm this idea. The tests at the word level in English did not have more discriminative power than those in Dutch. When one wants to have more information on actual language efficiency, a sentence comprehension test could then be more adequate. We chose not to include this in the test protocol because it was already quite extensive.

The results of the EFA can provide some additional directions for efficient testing. In the previous paragraphs suggestions for a diagnostic assessment were made. If one is interested in evaluating the associated problems of dyslexia or designing a skills matrix, the following issues can be taken into account. To assess phonological awareness an administration of a reversal task is sufficient. Reversals seem to discriminate the most (as shown by IDAA and GL&SCHR results) making the spoonerism task somewhat redundant. When evaluating rapid naming, the suggestion would be to administer only two forms of rapid naming. In this study a discreet version was used which seems to discriminate well between groups. Letter naming and digit naming are very similar in nature with equal effect sizes between groups and equal loadings on the RAN factor in the EFA. Object naming could provide some additional information based on the result from EFA and the idea that alphanumerical and non-alphanumerical naming task have different contributions to reading and reflect differences in sub-processes needed for execution. Administering a mental calculation task (the TTR in this case) gives information on a possible weakness in performing mental calculations, which is not unlikely to occur in dyslexia considering the effect sizes. An administration of for example multiplication, the mix and subtraction should be sufficient. After all, addition and division –like multiplication- also heavily rely on the verbal code, whereas subtraction does to a lesser extent. The difference for the mixed list is that it also involves a continuing shift between the 4 operations. Initially, the TTR was also included to screen for comorbid dyscalculia. However, as a group, students with dyslexia show a deficit in mental calculation either due to the overlap with dyscalculia or to the existence of an additional deficit. So, the TTR is very useful for the justification of the use of a calculator during exams (especially considering the high effect size for mental calculations) but is not efficient as a screening tool for dyscalculia in dyslexia. The same can be said for the Digit Crossing Test which was included as a measure of attention. From the 13 dyslexic participants who reported a comorbid attention (hyperactivity) deficit disorder only 6 scored subclinical on one or more subscores of the CDT. This instrument is therefore not reliable as a screening tool for ADHD.

The text comprehension subtest from the GL&SCHR could provide useful information in an assessment protocol with definite added value. For one, it does not seem to discriminate between groups that much which is good news. The combination of the visual and auditory presentation of the text possibly reduces the effect of the technical aspect of the reading impairment on text comprehension in dyslexic readers which makes it a useful assessment tool for pure text comprehension. Those who score low on this subtest could benefit from extra tutoring in text comprehension.

As for intelligence, the EFA showed that the instrument used in the study (KAIT) loaded on three different latent variables. An important implication of the results on the IQ measures is that one should be wary when applying an IQ-achievement discrepancy model in the diagnostic protocol of dyslexia. IQ tests traditionally contain some subtests that are more verbal in nature and some that focus on logical and deductive reasoning. The factor in the EFA grouping all subtests that tap on purely verbal skills clearly differentiates between the groups. Test administrators should therefore be careful with subtests that tap into verbal skills, as they are likely to disfavor students with dyslexia. As for the delayed reproduction tests, they did not form a separate construct but were closely related to their reference test (correlation for Symbol learning and the Delayed symbol learning test was .80, as for Auditory comprehension and the reproduction test it was .48) so one could question their added value when time is restricted in an assessment protocol. For an indication of fluid intelligence the Symbol learning test seems adequate because it obviously forms a distinct group and it does not -in any way- distinguish between groups. Subsequently, the assessment can be extended with additional tests on fluid intelligence in function of the available time and required information. Although the other subtests for fluid intelligence did load equally on one latent variable, the correlations between these three subtests are around .40. Choices should therefore be made based on the individual focus of each test. The same goes for the crystallized intelligence component. There seems to be a large overlap between Personalities from the KAIT and Vocabulary from the GL&SCHR (correlation .58 and equal loadings on factor) so an administration of both seems redundant. As for the other subtests of the crystallized intelligence test, they all have their own characteristics.

The NEO-PI-R and the LASSI have proven their value in the prediction of study success. The full NEO-PI-R battery -as administered in this research study- is possibly too elaborate and time consuming (about 45 minutes) but there exists a shorter version (NEO-FF) which takes about 20 minutes to administer. Another positive aspect of these tests is that a computer based administration and scoring system are available. Of course, the financial aspect should be taken into account but for populations that are more vulnerable in HE, a short personality analysis could give some indications for guidance. As for the LASSI, in many institutions this instrument is already available online, which is a good thing. For all students it is useful information but for dyslexic students who already have more difficulties with study skills, it is extra valuable. As for the LASSI, a suggestion to professionals would be to not focus too much on the traditional itemization in the three components as suggested in the manual (will, skill and self-regulation) because we found some evidence for a different structure. Using principal component analysis Cano (2006) found evidence for a different grouping of subtest namely Affective strategies, Goal strategies and Comprehension monitoring strategies. We found the same latent structure in our data and used these three subscales for further analysis. It seems a better reflection of the coherence between the 10 subscales.

In general this research could also be viewed as a starting point for the further optimization of the GL&SCHR. Based on experience and research findings some suggestions may be helpful. The battery consists of three main tests and seven additional tests. For the three main tests, the following can be said. The word dictation was found to be very effective and was one of the three predictors in the predictive model of Tops et al. (2012). Writing speed which is measured during this word dictation is less efficient for diagnostic purposes and the added value for guidance can be questioned. The text "Faalangst" that has to be read out loud, also resulted in high effect sizes for the variables reading time and substantial errors and was found to be very discriminative between groups. Scoring rules for the reading errors do, however, require some training. Maybe these could be simplified. The Proofreading task -as part of the core battery- had a high effect size but does not seem to have additional value in a diagnostic protocol. The task Morphology and syntax seems to be highly related to the spelling tasks and Proofreading, so one can wonder whether this really taps into knowledge of morphology and syntax. On the other hand, Furnham (2010) has highlighted the value of proofreading in HE and employment because of its relevance in these contexts where one is often required to proofread one's own or others' documents. So maybe we should look into the value of this test as predictor of success in HE. The vocabulary test seems to perform well. It has a high effect size and groups together in an EFA with other tests that measure lexical retrieval and vocabulary. The advantages of the text comprehension test have been addressed previously. As for the RAN, although the classical RAN was altered into a discreet computer administered version in this battery, it does discriminate well between groups as was expected. The same can be said for the phonological tasks. The rationale behind the Automation test had potential but it did not result in a high effect size and did not relate to any of the other variables. For the short term memory tasks some questions can be raised. For one, the phonological STM task did not relate to any of the other phonological tasks in the EFA and unexpectedly only had a medium ES. In the literature often a nonword repetition task is used to measure phonological STM. As for working memory, one can wonder whether this is an efficient measure of WM. At the end of each series, the complete letter and number lines (A to Z and 1 to 9) are presented which -to my opinion- significantly decreases the memory load. A correlation study with an experimental task could help unravel this.

Practical implications for guidance protocols and compensatory means

There is now theoretical and empirical evidence in Flanders for the justification of compensatory means and their usefulness in HE. Of course, using these compensatory means alone will not make a student with dyslexia pass but it does positively affect study success. As a general reflection I would like to add that these compensatory means should not be reduced to a standard package. An individual approach seems in place. What works for one student does not necessarily work for the next. Also, some means can be unjustified in certain contexts. For example, for students training to become a teacher dispensation for spelling errors all round would be unjust.

Exam related facilities that are often granted to students with dyslexia are extended time restrictions, the use of text-to-speech technology, the ability to elaborate orally on written answers, having access to a separate exam room, an appreciation of content instead of form in written exams (marks independent of spelling errors), and having questions read out loud.

Students with dyslexia in their first bachelor year very clearly still encounter large difficulties with reading and spelling. To compensate for their reading and spelling errors, the use of a computer can be helpful. For one, this could enable them to have the questions read out loud by means of speech software. The results from the text comprehension test thaught us that when text is presented visually and auditory, text comprehension is not impaired on group level. Interference of the technical aspect of reading can be reduced in this context. For the same reasoning having the questions read out loud by assistants or teachers can be justified.

Lexical retrieval is affected in some individuals with dyslexia. Some students also report having difficulties to express themselves and troubles with structuring their written output. Tops, Callens, Van

Cauwenberghe, Adriaens, and Brysbaert (in press) also found that written text from students with dyslexia is considered less structured and less pleasant to read by teachers, even after controlling for spelling errors and handwriting. Letting these students elaborate on their answers orally should prevent interference with exam results. More importantly, organizing workshop to help them train these skills would be very useful. As for the separate exam room, this can be helpful in case of a comorbid ADHD which is common in dyslexia.

As has been demonstrated, dyslexia seems to involve a general speed problem that goes beyond reading. In any case, reading goes considerably slower. Students with dyslexia are therefore disadvantaged in situations where time limits are imposed. Students with dyslexia also report being more relaxed and as a result being able to concentrate better due to this extended time limit during an exam (Bultinck, 2012). As such, granting them more time to finish an exam can be justified. Students who are not dyslexic would not benefit from this measure. In their case granting them more time is unlikely to result in higher scores. Of course, one could conjecture that as a general rule, exams should be setup so that even disadvantaged students are able to finish within the imposed time limit. This would make this individual adjustment redundant.

In our study, we also found evidence for some additional adjustments. For example, the LASSI showed that students with dyslexia apply fewer strategies to measure their level of comprehension. Introducing test exams would give them the opportunity to see if they master the course well enough to pass. Not only the students with dyslexia but all students would of course benefit from this. Also, as a group these students have difficulties with mental calculation, the use of a calculator in courses where this skill is critical (but not part of the content of the course), as in statistics, would help prevent unnecessary errors. Again, this is something every student would benefit from.

More general facilities are the use of text-to-speech and speech-to-text software, the use of spelling correctors and having courses in digital versions. Digital versions of syllabi enable students to use their speech-to-sound software on the texts to help them get through the large amounts of written material. Of course, not every student will appreciate and benefit from this. It remains a question of tuning in on the specific needs of the students. During classes, students get a lot of information. The teacher talks while slides are presented, and in the meantime students should make notes. When the slides are passed on before class, students with dyslexia can already prepare for the class by reading through the slides. As such, the slow reading pace does not obstruct them in following the class and taking notes.

Often the question is asked what letter type is most appropriate for students with dyslexia. New fonts are created claiming that this enhances reading performance in dyslexics. Blumberg (2007) suggested that for dyslexic people font determines the readability of a text. In the interview, we questioned the students with dyslexia on their preference and compared this to the control group. The group with dyslexia did not have a more pronounced preference for a specific font (Bultinck, 2012). Moreover, in the group of students who did have a clear preference, preferences did not differ between groups. Calibri followed by Arial were the most favored fonts. The most common remarks were that fonts with serif, italics and fonts that leave little space between letters are least appreciated in the dyslexia group. This can be viewed within the results of the experiment on visual word recognition which provided evidence for enhanced crowing in dyslexia: the closer letters, the more chance on crowding. As demonstrated by Perea, Panadero, Moret-Tatay, and Gomez (2012) and Zorzi et al. (2012) increasing letter space can enhance reading ability in dyslexia. This can be useful in practice, although further research is needed to find out whether this stills works for students in HE. Anyway, Sans Serif fonts seem to be more pleasant to read, in particular Calibri and Arial. Taking this into account, teachers and students may try to improve the readability of their syllabi and slides with only minor adjustments.

Besides these suggestions concerning assessment and compensatory means, students should be made aware of the challenges they are facing in HE. The profile that was obtained showed deficiencies in a wide range of skills. However, a significant proportion of students do graduate after three years. So the picture is not all negative! Dropout numbers in the first year clearly show that students with dyslexia, who make the step to higher education, should be supported better in the transition from secondary school to higher education. The fact that using the compensatory means can increase their chance of succeeding is a clear message for those who do not use them. What is also quite striking is that learning skills seem crucial for success in higher education while only 2 students reported having received training in this area. In general, more attention should be given to the development of these skills.

A final reflection on the guidance and support given to this subgroup of students is that we should be alert not to train helplessness. Granting compensatory means and supporting students in certain aspects is one thing, but it is also important that everyone remains the sole responsible for their own academic career. Maybe training the students in the ability to cope independently is the best help we can give them which will last them a lifetime.

Future research ideas

The data on study performance were collected three years after the initial study. At that point in time, 25 % of the students who had participated in this project had not yet completed their bachelor program. These students are likely to graduate in the coming years. Ideally, the data collection should be repeated until every student who participated finishes (or leaves) higher education. This way the picture will be more complete and comparisons between groups on study duration could be made. Additionally, students who dropped out of their bachelor program not necessarily quit higher education. Maybe these students found a different program that suited them better in which they will graduate eventually. Therefore, additional data on the subgroup that dropped out is also necessary to complete the picture. This will provide us with a full overview of how these students perform in higher education.

In the study on academic performance background data, personality and study skills were used as possible predictors. An interesting idea would be to use the data from the cognitive study as predictors for study success in both the control group and the dyslexia group and compare the models. Also worthwhile would be to follow these students further along their path and see how well they function in the job field and how their disability influences their performance on the work floor. Only few studies have investigated the effects of dyslexia in employment situations (Leather, Hogh, Seiss, & Everatt, 2011).

We started from the existing situation -meaning that we recruited students who already made the decision to enter higher education. Taking a step back and searching for what makes a students with dyslexia take the step to higher education, would also be useful. In the current socio-economic situation high importance is attached to having a degree in higher education which augments the pressure on adolescents. We have no idea of the proportion of students with dyslexia in secondary education who continue in higher education and what can be done to stimulate those who do not. More information on which factors contribute to the decision could lead to better insights and help finding ways to stimulate entrance in HE.

We were able to defend the allocation of the compensatory means often granted to students with dyslexia using the results of the cognitive study. In the fourth chapter, it has also been shown that using these compensatory means increases the chance of graduating after three years (bachelor degree) for students who do not drop out. However, the road does not end here. There is still a long way to go in the optimization of these compensatory means. For one, efficiency studies on specific means could tell us more about their usefulness. Qualitative research could supplement these findings by giving information on the experiences these students have with these tools and facilities.

In a paper by Trainin and Swanson (2005) it has been suggested that students who are successful in higher education (higher grade point averages) have developed better metacognitive skills such as learning strategies and help seeking. During this project additional self report questionnaires (BRIEF, PREF) that measure executive functions were administered to a subgroup of participants (Control group *N*= 62; dyslexia group *N*=55). Some first analyses indicate that students with dyslexia report having less developed metacognitive skills. Now that the longitudinal data are available it would be interesting to correlate these metacognitive skills with success in HE.

Up until now the main focus has been to report the results and findings relevant for international publications. Now the time is right to aim at a more local audience where these findings are most needed. The idea is to approach the results from a more practical view and translate this into a Dutch book on dyslexia in higher education in Flanders.

Together with some recent initiatives, this study provided some insights on the cognitive profile of students with dyslexia entering higher education in Flanders. One initiative is the information video and brochure developed by the Cell for Diversity and Gender at Ghent University in collaboration with Cursief and the collaborators of this PhD project. In addition, Geudens et al. (2011) published a book called “Young adults with dyslexia: Diagnostics and guidance in science and practice”. As a final general remark, I would like to add that the outcome of every study is a result of what you start out with. We do not claim to have been comprehensive in all aspects. Choices had to be made based on availability of test materials, relevance and the overall task load. I hope that the present project will be helpful to future researchers in this respect.

References

Badian, N. A. (1999). Persistent arithmetic, reading, or arithmetic and reading disability. *Annals of Dyslexia, 49*, 45-70.

Blumberg, S. L. (2007). Typefaces for dyslexia Retrieved 19/02/2012, from www.dyslexics.com/fonts

Bouma, H. (1973). Visual interference in parafoveal recognition of initial and final letters of words. *Vision Research, 13*(4), 767-782. doi: 10.1016/0042-6989(73)90041-2

Bultinck, E. (2012). *Begeleiding bij dyslexie doorheen de jaren: een kwalitatief onderzoek bij jongvolwassenen.* Master in pedagogical sciences. Unpublished thesis, Ghent University.

Cano, F. (2006). An In-Depth Analysis of the Learning and Study Strategies Inventory (LASSI). *Educational and Psychological Measurement, 66*(6), 1023-1038. doi: 10.1177/0013164406288167

De Pessemier, P., & Andries, C. (2009). *GL&SCHR Dyslexie bij +16-jarigen. Test voor Gevorderd Lezen en Schrijven*. Antwerpen, Belgium: Garant.

Declercq, K., & Verboven, F. (2010). Slaagkansen aan Vlaamse Universiteiten: tijd om het beleid bij te sturen? [Succes rate at Flemish universities: time for policy changes?] Retrieved March 15 2013, from http://www.deredactie.be/polopoly_fs/1.871925!file/20100927declercq_verboven.pdf

Dirks, E., Spyer, G., van Lieshout, E., & de Sonneville, L. (2008). Prevalence of Combined Reading and Arithmetic Disabilities. [Article]. *J Learn Disabil, 41*(5), 460-473. doi: 10.1177/0022219408321128

Estes, W. K., Allmeyer, D. H., & Reder, S. M. (1976). Serial position functions for letter identification at brief and extended exposure. *Perception & Psychophysics, 19*(1), 1-15. doi: 10.3758/bf03199379

Furnham, A. (2010). Proofreading as an index of crystallised intelligence. *Educational Psychology, 30*(6), 735-754. doi: 10.1080/01443410.2010.506005

Geudens, A., Baeyens, D., Schraeyen, K., Maetens, K., De Brauwer, J., & Loncke, M. (2011). *Jongvolwassenen met dyslexie. Diagnostiek en begeleiding in wetenschap en praktijk*. Leuven, België: Acco.

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology, 72*, 119-133. doi: 10.1348/000709902158801

Hellige, J. B., Cowin, E. L., & Eng, T. L. (1995). Recognition of CVC syllables from LVF, RVF, and central locations - hemispheric differences and interhemispheric interaction. *Journal of Cognitive Neuroscience, 7*(2), 258-266. doi: 10.1162/jocn.1995.7.2.258

Hellige, J. B., Taylor, A. K., & Eng, T. L. (1989). Interhemispheric Interaction When Both Hemispheres Have Access to the Same Stimulus Information. *Journal of Experimental Psychology-Human Perception and Performance, 15*(4), 711-722.

Jordan, T. R., Patching, G. R., & Thomas, S. M. (2003). Assessing the role of hemispheric specialisation, serial-position processing, and retinal eccentricity in lateralised word recognition. *Cognitive Neuropsychology, 20*(1), 49-71. doi: 10.1080/02643290244000185

Kleijnen, R., & Loerts, M. (2006). *Protocol Dyslexie Hoger Onderwijs*. Antwerpen/Apeldoorn: Garant.

Laasonen, M., Service, E., Lipsanen, J., & Virsu, V. (2012). Adult developmental dyslexia in a shallow orthography: Are there subgroups? *Reading and Writing, 25*(1), 71-108. doi: 10.1007/s11145-010-9248-9

Lacante, M., Lens, W., Van Ensbroek, R., de Metsenaere, M., De Coninck, T., De Jaeger, K., . . . Wenselaer, C. (2001). Drop-out in het hoger onderwijs: Onderzoek naar achtergronden en motieven van drop-out in het eerste jaar hoger onderwijs. In opdracht van de Vlaamse Minister voor Onderwijs en Vorming. [Drop-out in higher education: Study on motives and background of drop-out in higher education- In assignment of the Flemish Ministry of Education]. Brussel-Leuven: Vrije Universiteit Brussel/KULeuven.

Leather, C., Hogh, H., Seiss, E., & Everatt, J. (2011). Cognitive Functioning and Work Success in Adults with Dyslexia. *Dyslexia, 17*(4), 327-338. doi: 10.1002/dys.441

Legge, G. E., Mansfield, J. S., & Chung, S. T. L. (2001). Psychophysics of reading XX. Linking letter recognition to reading speed in central and peripheral vision. *Vision Research, 41*(6), 725-743. doi: 10.1016/s0042-6989(00)00295-9

Leinonen, S., Müller, K., Leppänen, P. H. T., Aro, M., Ahonen, T., & Lyytinen, H. (2001). Heterogeneity in adult dyslexic readers: Relating processing skills to the speed and accuracy of oral text reading. *Reading and Writing, 14*(3), 265-296. doi: 10.1023/a:1011117620895

Lindgren, S. A., & Laine, M. (2011). Cognitive linguistic Performances of Multilingual University Students Suspected of Dyslexia. *Dyslexia, 17*(2), 184-200. doi: 10.1002/dys.422

Martelli, M., Di Filippo, G., Spinelli, D., & Zoccolotti, P. (2009). Crowding, reading, and developmental dyslexia. *Journal of Vision, 9*(4), 1-18. doi: 10.1167/9.4.14

Meyler, A., & Breznitz, Z. (2005). Visual, auditory and cross-modal processing of linguistic and nonlinguistic temporal patterns among adult dyslexic readers. *Dyslexia, 11*(2), 93-115. doi: 10.1002/Dys.294

Moores, E., Cassim, R., & Talcott, J. B. (2011). Adults with dyslexia exhibit large effects of crowding, increased dependence on cues, and detrimental effects of distractors in visual search tasks. *Neuropsychologia, 49*(14), 3881-3890. doi: 10.1016/j.neuropsychologia.2011.10.005

Perea, M., Panadero, V., Moret-Tatay, C., & Gomez, P. (2012). The effects of inter-letter spacing in visual-word recognition: Evidence with young normal readers and developmental dyslexics. *Learning and Instruction, 22*(6), 420-430. doi: 10.1016/j.learninstruc.2012.04.001

Pernet, C., Valdois, S., Celsis, P., & Demonet, J. F. (2006). Lateral masking, levels of processing and stimulus category: A comparative study between normal and dyslexic readers. *Neuropsychologia, 44*(12), 2374-2385. doi: 10.1016/j.neuropsychologia.2006.05.003

Serrano, F., & Defior, S. (2008). Dyslexia speed problems in a transparent orthography. [Article]. *Annals of Dyslexia, 58*(1), 81-95. doi: 10.1007/s11881-008-0013-6

Snowling, M. (2000). *Dyslexia. Second Edition.* Oxford: Blackwell Publishers.

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. *Psychological Bulletin, 87*(2), 245-251. doi: 10.1037//0033-2909.87.2.245

Swanson, H. L., & Hsieh, C. J. (2009). Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. *Review of Educational Research, 79*(4), 1362-1390. doi: 10.3102/0034654309350931

Tops, W., Callens, M., Lammertyn, J., & Brysbaert, M. (2012). Identifying students with dyslexia in higher education. *Annals of Dyslexia, 62*(3), 186-203. doi: 10.1007/s11881-012-0072-6

Tops, W., Callens, M., Van Cauwenberghe, E., Adriaens, J., & Brysbaert, M. (in press). Beyond spelling: the writing skills of students with dyslexia in higher education. *Reading and Writing*. doi: 10.1007/s11145-012-9387-2

Trainin, G., & Swanson, H. L. (2005). Cognition, metacognition and achievement of college students with learning disabilities. *Learning Disability Quarterly., 28*, 264-272.

Van den Broeck, W., & Geudens, A. (2012). Old and new ways to study characteristics of reading disability: The case of the nonword-reading deficit. *Cognitive Psychology, 65*(3), 414-456. doi: 10.1016/j.cogpsych.2012.06.003

Van Ingelghem, M., van Wieringen, A., Wouters, J., Vandenbussche, E., Onghena, P., & Ghesquiere, P. (2001). Psychophysical evidence for a general temporal processing deficit in children with dyslexia. *Neuroreport, 12*(16), 3603-3607. doi: 10.1097/00001756-200111160-00046

Whitney, C., & Cornelissen, P. (2005). Letter-position encoding and dyslexia. *Journal of Research in reading, 28*(3), 274-301.

Willcutt, E. G., Betjemann, R. S., McGrath, L. M., Chhabildas, N. A., Olson, R. K., DeFries, J. C., & Pennington, B. F. (2010). Etiology and neuropsychology of comorbidity between RD and ADHD: The case for multiple-deficit models. *Cortex, 46*(10), 1345-1361. doi: 10.1016/j.cortex.2010.06.009

Ziegler, J. C., Perry, C., Ma-Wyatt, A., Ladner, D., & Schulte-Korne, G. (2003). Developmental dyslexia in different languages: Language-specific or universal? *Journal of Experimental Child Psychology, 86*(3), 169-193. doi: 10.1016/s0022-0965(03)00139-5

Zorzi, M., Barbiero, C., Facoetti, A., Lonciari, I., Carrozzi, M., Montico, M., . . . Ziegler, J. C. (2012). Extra-large letter spacing improves reading in dyslexia. *Proceedings of the National Academy of Sciences of the United States of America, 109*(28), 11455-11459. doi: DOI 10.1073/pnas.1205566109

Nederlandse samenvatting

Dyslexie

Dyslexie is een ontwikkelingsstoornis die meestal wordt gediagnosticeerd in de lagere of secundaire school maar die zich laat voelen tot in de volwassenheid (Callens, Tops, & Brysbaert, 2012; Hatcher, Snowling, & Griffiths, 2002; Swanson & Hsieh, 2009). De kern van dyslexie vormt het lees- en spellingsprobleem. Volgens de beschrijvende definitie van de Stichting Dyslexie Nederland (2008) is dyslexie immers "*een stoornis die gekenmerkt wordt door een hardnekkig probleem met het aanleren en/of vlot toepassen van het lezen en/of het spellen op woordniveau*". Verklarende definities voor dyslexie, verwerken een mogelijke oorzaak van dyslexie in hun formulering. Maar over wat aan de oorsprong ligt van deze leerstoornis, wordt nog steeds erg gediscussieerd. Aanhangers van de *phonological deficit hypothesis* stellen dat een verstoorde fonologische verwerking de lees- en spellingsproblemen volledig kunnen verklaren (Snowling, 2000; Stanovich, 1988). Het oorzakelijk verband tussen fonologische problemen en dyslexie wordt echter steeds meer in twijfel getrokken (Blomert & Willems, 2010; Castles & Coltheart, 2004). Zo wees een onderzoek van Dehaene et al. (2010) ook aan dat ongeletterden -net zoals individuen met dyslexie- een verminderde activatie vertonen in de auditieve cortex bij confrontatie met spraak. Een uitbreiding van de fonologische hypothese is de *double deficit theory* (Wolf & Bowers, 1999) waarvan de grondleggers vooropstellen dat naast een aanwezig fonologisch probleem, er ook sprake kan zijn van een opzichzelfstaand probleem met snel serieel benoemen (RAN). De *magnocellulaire theorie* stelt problemen met het verwerken van snelle temporele informatie voorop als oorzaak van dyslexie (Stein & Walsh, 1997). Andere theorieën zijn de *anchoring deficit theory* (Ahissar, 2007) en de *SOLID hypothesis* (Szmalec, Loncke, Page, & Duyck, 2011) waar een probleem met algemeen orde leren bij mensen met dyslexie wordt vooropgesteld. Echter, deze unitaire theorieën lijken de heterogeniteit van de stoornis niet te kunnen verklaren (Heim et al., 2008). Een multifactoriële visie op dyslexie, waar verschillende deficiten bij verschillende individuen tot dezelfde leesproblemen kan leiden, krijgt steeds meer aanhangers (Bishop, 2006; Menghini et al., 2010; Ramus et al., 2003). Ook het visuele aspect van lezen krijgt steeds meer aandacht als potentiële bijdrager tot leesproblemen. Helenius, Tarkiainen, Cornelissen, Hansen, and Salmelin (1999) en Taroyan and Nicolson (2009) toonden via visuele beeldvormingstechieken aan dat het eerste verschil tussen normale lezers en individuen met dyslexie merkzaam is op visueel vlak. In vergelijking met individuen zonder dyslexie vertonen zij verminderde of gewijzigde activatie in de "visual word form area", de infero-temporale regio in de hersenen ter hoogte van de visuele cortex. Oorzaken voor deze verschillen in corticale activatie worden gezocht bij fenomenen zoals moeite met het toewijzen van visuele aandacht (Bosse, Tainturier, & Valdois, 2007; Lobier, Zoubrinetzky, & Valdois, 2012), verhoogde laterale maskering (Martelli, Di Filippo, Spinelli, & Zoccolotti, 2009; Pernet, Valdois, Celsis, & Demonet, 2006) of verstoringen in de visuele verwerking van links naar rechts (Whitney & Cornelissen, 2005). Al deze verschillende theorieën geven in elk geval aan dat er heel wat geassocieerde problemen te bemerken zijn bij dyslexie als lees- en schrijfstoornis.

Prevalentie in het hoger onderwijs

Algemene prevalentiecijfers over dyslexie zijn erg uiteenlopend. Deze zijn in sterke mate taalafhankelijk en worden beïnvloed door de gehanteerde definitie met de daaraangekoppelde cut-off score (Ghesquiere, Boets, Gadeyne, & Vandewalle, 2012; Ziegler & Goswami, 2005). Hierdoor wordt soms melding gemaakt van een prevalentie oplopend tot 20%. Meestal wordt echter gesproken over een prevalentie van 5 à 10% (Jimenez, Guzman, Rodriguez, & Artiles, 2009; Lewis, Hitch, & Walker, 1994; Plume & Warnke, 2007; Snowling, 2000). Hoe hoog de prevalentie is in het hoger onderwijs is erg onduidelijk. Er zijn weinig betrouwbare prevalentiecijfers voorhanden voor dyslexie in het hoger onderwijs. De Vlaamse Onderwijsraad publiceerde in een rapport van 2006 de volgende ruwe cijfers. In een Nederlandse studie van Broeninck and Gorter (2001) bleken op basis van een steekproef van 478000 studenten er 2 à 3% dyslexie te hebben. In Engeland zijn preciezere cijfers voorhanden daar studenten die een Disabled Student Allowance aanvragen per district worden geregistreerd. In het academiejaar 2003-2004 hadden 5,39% van de studenten een gekende functiebeperking, waarvan het grootste deel tot de leerstoornissen werd ingedeeld (2,22% van het totale aantal). Een percentage van 2,22% zou in het academiejaar 2009-2010 in Vlaanderen een totaal aantal van 4356 studenten met een leerstoornis betekenen. Dit zijn enerzijds geen recente cijfers en anderzijds slechts ruwe schattingen van het werkelijke aantal. Men kan veronderstellen dat er twee redenen aan de oorsprong liggen van het gebrek aan concreet en recent cijfermateriaal. Enerzijds worden de cijfers nog niet overal consequent bijgehouden door de onderwijsinstellingen en anderzijds is er geen meldingsplicht voor studenten met een leerstoornis waardoor een deel van de populatie onbekend blijft. Bijkomend schuilt wel wat gevaar in het generaliseren van cijfers verzameld in specifieke contexten naar Vlaanderen. Vooreerst is gebleken uit de praktijk (Kleijnen & Loerts, 2006) dat dyslectici door hun taalgerelateerde problematiek geneigd zijn te kiezen voor meer technische richtingen en dus niet in alle onderwijsinstellingen even vertegenwoordigd zijn. Verder is het onderwijssysteem in Vlaanderen –zoals in vele andere landenzodanig dat buiten het in het bezit zijn van een diploma secundair onderwijs, er geen specifiek vereisten zijn voor een inschrijving in een bacheloropleiding (de opleiding geneeskunde buiten beschouwing gelaten). In landen waar de onderwijsorganisatie Brits geïnspireerd is, is vaak het master-apprentice model van toepassing waarbij studenten aan zware selectieprocedures onderworpen worden alvorens te worden toegelaten.

Wat echter wel duidelijk is, is dat er een aanzienlijke stijging is van het aantal jongvolwassenen dat zich na het afronden van hun secundaire studies inschrijft voor een academische of professionele bachelor opleiding. Cijfers uit de internationale literatuur (Hadjikakou & Hartas, 2008; Hatcher et al., 2002; Madriaga et al., 2010) en van ondermeer vzw Cursief[1] tonen aan dat steeds meer jongvolwassenen met dyslexie de weg vinden naar het hoger onderwijs. Binnen de Associatie Gent (cijfers van Cursief) werd in 2010-2011 een toename van 31% van het aantal aanvragen voor faciliteiten voor dyslexie genoteerd tov 2009-2010. In het jaar 2010-2011 was dit 10% tov 2010-2011. Wat er aan de oorsprong ligt van deze nieuwe ontwikkeling blijft voorlopig een bron van speculatie maar mogelijks dragen een vroegtijdige detectie en diagnosticering, efficientere remediëring en compensatie in de lagere en secundaire school en het organiseren van ondersteuning in het hoger onderwijs ertoe bij dat studenten hun leerstoornis minder als een belemmering voor een verdere opleiding ervaren. In een kwalitatief onderzoek rapporteerden 72% van de bevraagde studenten faciliteiten te hebben gebruikt in het secundair onderwijs (Bultinck, 2012). Vogel et al. (1998) haalden ook factoren aan bij de studenten zelf, zoals het feit dat ze zelf hogere apsiraties en verwachtingen koesteren voorbij het secundair onderwijs. Ook hebben de studenten meer zelfkennis en komen ze meer op voor hun rechten wat een efficiëntere planning tot gevolg heeft.

Doel onderzoek

Deze toename houdt echter wel in dat de nood aan op wetenschappelijk onderzoek gebaseerde informatie over deze groep studenten zich opdringt. Aangezien deze trend zich wereldwijd voordoet, is wel wat internationale literatuur rond dyslexie in het hoger onderwijs voorhanden, maar dan hoofdzakelijk in Engelstalige landen (Hatcher et al., 2002; Reid, Szczerbinski, Iskierka-Kasperek, & Hansen, 2007; Swanson & Hsieh, 2009). Om verscheidene redenen is een generalisatie van deze bevindingen naar Vlaanderen niet zonder risico. Enerzijds zijn er verschillen in opzicht van de taal. Het Nederlands is een vrij transparente taal terwijl het Engels eerder niet-transparant is. De transparantie

[1] Een non-profit organisatie die in de Associatie Gent instaat voor de begeleiding van studenten met leer-stoornissen.

van een taal wordt bepaald door de mate waarin de transcriptie van fonologie naar orthografie een één-één relatie is. Dit kan vervolgens in relatie gebracht worden met de prevalentie van dyslexie in een bepaalde taal (Ziegler & Goswami, 2005). Verschillen in definiëringen van de stoornis en grote variaties in cut-of scores leiden tot andere populatiekarakteristieken. Bijkomstig zijn grote verschillen in onderwijscontext merkbaar tussen het Anglo-saksisch en het Europees onderwijssysteem. Terwijl hier iedereen met een diploma secondair onderwijs mag starten in het hoger onderwijs zijn in andere contrijen strenge selectieprocedures gangbaar. Ook verschillen in kostprijs van onderwijs leiden tot verschillen in populaties. Echter, naar ons weten is er op Nederlandstalig grondgebied nog geen onderzoek verricht bij studenten met dyslexie in het hoger onderwijs. Gegevens die wel voorhanden zijn, zijn voornamelijk gebaseerd op bevindingen vanuit de praktijk. Zo zijn er het handboek *Studeren met dyslexie* van Hofmeester (2002) en het *Protocol Dyslexie Hoger Onderwijs* (Kleijnen & Loerts, 2006) waar relevante kennis, informatie en richtlijnen worden meegegeven over diagnostiek en begeleiding van dyslexie in het hoger onderwijs. Een belangrijk hiaat in de bestaande initiatieven, is het ontbreken van een referentiepunt om het functioneren van de studenten met dyslexie te kunnen inschatten.

Een van de vooropgestelde doelen van dit onderzoek is daarom een beeld te schetsen van het cognitief profiel van deze groep studenten in vergelijking met studenten zonder functiebeperking. Met een wetenschappelijk gefundeerd theoretisch kader kan de toekenning van faciliteiten verantwoord worden en kan verder gebouwd worden aan de ontwikkeling van de ondersteuningsmaatregelen voor deze leerstoornis. Als gevolg van deze toename aan studenten met dyslexie in het hoger onderwijs, is ook de vraag naar assessment toegenomen. Gekaderd binnen het Gelijkekansendecreet van juli 2008 en de VN Conventie voor de Rechten van de Mens hebben studenten met een handicap (waaronder dyslexie) recht op aanpassingen, tenzij deze maatregelen voor de instantie die ze moet treffen een onevenredige belasting vormen. Dit recht wordt alleen toegekend bij een valide diagnose. Niet iedere student die zich aanmeldt voor faciliteiten, is in het bezit van een goed onderbouwd dyslexieattest en zonder dit attest kunnen jammer genoeg geen faciliteiten worden toegekend. Dit maakt dat de instellingen die verantwoordelijk zijn voor de attestering en de toewijzing van deze faciliteiten aan deze groep studenten baat hebben bij een wetenschappelijk onderbouwd en efficiënt diagnostisch protocol. Aan deze nood is toegemoetgekomen door een studie waar een predictief model werd opgesteld voor het diagnosticeren van dyslexie in het hoger onderwijs (Tops, Callens, Lammertyn, & Brysbaert, 2012). Waar studenten echter ook vaak nood aan hebben voor het optimaliseren van hun studies is kennis van hun sterktes en zwaktes. Ook op dit vlak kunnen onderwijsinstellingen en begeleidingsinstanties hun voordeel halen bij suggesties voor efficiente onderzoeksprotocollen. Een inschrijving in het hoger onderwijs is geen garantie voor succes. Ook op het vlak van slaagkansen van deze studenten is weinig geweten. Gezien het belang van lees- en schrijfvaardigheden binnen het hoger onderwijs is het niet ondenkbaar dat studenten met dyslexie binnen deze context extra benadeeld zijn. Bijkomstig werden verscheidene andere cognitieve problemen aangetoond die deels ook hun invloed kunnen hebben op slagen. Onderzoek vanuit het Anglo-Saksisch onderwijssysteem schetst een eerder positief beeld (Adelman & Vogel, 1990; Trainin & Swanson, 2005; Wessel, Jones, Markle, & Westfall, 2009) maar gezien de verschillen in onderwijssetting kan men in Vlaanderen niet van deze resultaten uitgaan. In studies over slaagkansen in een normale studentenpopulatie worden zaken als achtergrondkenmerken, persoonlijkheidskenmerken en studeervaardigheden als belangrijke beïnvloedende factoren aangewezen. Interessant zou zijn om binnen de groep studenten met dyslexie na te gaan welke factoren hier een invloed uitoefenen op studiesucces.

Participanten

Een groep van 200 eerstebachelorstudenten werd gerecruteerd uit 4 Vlaamse hogescholen en de Universiteit Gent. De groep studenten met dyslexie werd gerecruteerd in samenwerking met Cursief. Iedere student die zich aanmeldde voor het verkrijgen van compenserende maatregelen in het kader van dyslexie in het academiejaar 2009-2010 werd gevraagd om deel te nemen tot een aantal van 100 werd bereikt. Bijna alle studenten (van twee studenten was deze informatie niet ter beschikking) hadden in het lager of secundair onderwijs de diagnose dyslexie gekregen. Met uitzondering van twee studenten hadden ze ook allemaal individuele remediëring of bijles gekregen. Na 12 jaar onderwijs vertoonden alle studenten klinische scores op gestandaardiseerde testen voor lezen en/of spelling of hadden een valide dyslexieattest volgens de criteria van de SDN. In deze groep van 100 studenten waren er 41 mannen en 59 vrouwen, 37 volgden een academische en 63 een professionele bacheloropleiding. Deze groep werd gematcht op geslacht en studiekeuze. De recrutering van de 100 controlestudenten verliep via de studenten met dyslexie, via de studietrajectbegeleiders en de elektronische leerplatformen. De twee groepen verschilden noch op vlak van leeftijd noch op vlak van vloeiende intelligentie.

Cognitief profiel van studenten met dyslexie

Van deze 200 studenten werd een testbatterij afgenomen van een grote aantal cognitieve taken zoals intelligentie, lees- en schrijftaken, geheugentaken, een aandacht- en concentratietaak, hoofdrekenen, fonologische vaardigheden en snelbenoemtaken. Ook werden twee nieuwe instrumenten voor het diagnosticeren van dyslexie bij adolescenten afgenomen namelijk de IDAA (Van der Leij et al., 2012) en de GL&SCHR (De Pessemier & Andries, 2009). De resultaten werden vergeleken tussen de groepen en effect groottes werden berekend voor de verschillende maten. Hieruit bleek dat studenten met dyslexie in het hoger onderwijs met dyslexie blijvende problemen vertonen op vlak van lees- en schrijfvaardigheden (effect groottes voor accuraatheid tussen 1 en 2). Andere geassocieerde problemen die werden opgemerkt waren problemen met hoofdrekenen gemeten met de TTR (de Vos, 1992), fonologische vaardigheden en het ophalen van verbale informatie uit het lange termijn geheugen. De verschillen tussen de groepen waren prominenter aanwezig op maten voor snelheid dan op maten voor accuraatheid. Er waren geen verschillen op vlak van vloeiende intelligentie gemeten met de KAIT (Dekker, Dekker, & Mulder, 2004) maar wel op vlak van gekristalliseerde intelligentie. Hierdoor waren kleine verschillen merkbaar in totaal IQ. De overeenkomst tussen onze bevindingen en deze in de Engelstalige literatuur is groot waardoor kan gesuggereerd worden dat de taal en onderwijsorganisatie geen merkenswaardige invloed hebben op het profiel van een eerstejaarstudent in het hoger onderwijs. De resultaten geven ook evidentie voor de verantwoording van toegekende maatregelen voor deze studenten.

Een exploratieve factor analyse op het cognitief functioneren

Alle variabelen uit de eerste studie werden ingevoerd in een exploratieve factor analyse (EFA). Met deze techniek kan het aantal variabelen gereduceerd worden aan de hand van de covariantie tussen de variabelen. Deze covariantie wordt bij deze statistische techniek verondersteld te zijn ontstaan door de aanwezigheid van een onderliggende, latente variabele die een oorzakelijke invloed uitoefent op de geobserveerde variabelen. Hier werd deze techniek gebruikt over de groepen heen. Hoe meer de groepen verschillen op een variabele, hoe meer de latente variabele het verschil tussen de groepen weergeeft in plaats van de variantie binnen groepen. Effect sizes werden berekend op deze latente variabelen om uiting te geven aan de grootte van het groepsverschil. Een model met 10 factoren kwam het beste overeen met de data. De factoren lezen, spelling, flits orthografie (IDAA), fonologie, snelbenoemen, hoofdrekenen en leesvloeiendheid resulteerden grote effecten tussen groepen. De factor gekristalliseerde intelligentie die een verzameling was van subtests die woordenschat, kennis en ophalen van verbale informatie uit het geheugen testten, had een medium effect. De subtests voor vloeiende intelligentie laadden op twee aparte factoren die geen verschil aangaven tussen groepen. Een meer algemeen profiel van het cognitief functioneren van studenten met dyslexie in het hoger onderwijs werd alsdus opgesteld en suggesties voor een efficiente evaluatie van de verschillende factoren werden aangereikt.

Studieuitkomst en predictoren voor succes

Om studiesucces na te gaan bij studenten dyslexie in het hoger onderwijs, werden van de 200 studenten die deelnamen aan de eerste algemene studie, de studieresultaten na drie jaar hoger onderwijs opgevraagd. Om een correcte vergelijking van studietrajecten te kunnen doen, werden enkel de generatiestudenten in de analyses betrokken. Dit resulteerde in een groep van 99 studenten met dyslexie en een controlegroep van 89 studenten. Uitval en het behalen van een diploma na drie jaar werden in rekening gebracht. Uit de resultaten bleek het hebben van dyslexie zowel uitval als studiesucces te beïnvloeden. Studenten met dyslexie hebben meer kans op uitval dan hun medestudenten zonder dyslexie. Van de groep studenten die niet uitvielen in hun eerste studie, bleken studenten met dyslexie minder kans te hebben op het behalen van hun diploma binnen de modelduur van 3 jaar. Binnen de groep met dyslexie werd tevens gekeken naar factoren die uitval en slagen beïnvloeden. Hoe hoger het opleidingsniveau van de ouders, hoe meer kans op het voortzetten van de studie en slagen. Er werd ook een geslachtseffect gevonden. Dyslectische meisjes hebben meer de neiging te stoppen met studeren maar diegenen die doorstuderen hebben meer kans op slagen dan hun mannelijke medestudenten. Bepaalde persoonlijkheidskenmerken, gemeten met de NEO-PI-R (Hoekstra, Ormel, & de Fruyt, 2007), bleken ook een invloed uit te oefenen op studiesucces. Met name studenten met dyslexie die altruistisch zijn, minder conscientieus en neurotischer hebben meer kans op uitval dan hun dyslectische tegenhangers. Zo heeft ook extraversie een negatieve invloed op uitval maar een positieve invloed op slagen bij de volhouders. Naast achtergrondfactoren en persoonlijkheidskenmerken hebben vooral studeervaardigheden een belangrijke impact op de studies, voornamelijk op doorstuderen. Hier werd op de LASSI een principale componenten analyse uitgevoerd om de 10 subschalen te reduceren. Hierbij kwamen we tot dezelfde bevindingen als (Cano, 2006). Deze vond een onderverdeling in drie componenten namelijk strategieën gericht op doelmatigheid (GS), strategieën met een affectieve component (AS) en de strategieën die het begrip monitoren (CMS). Deze drie componenten werden gebruikt in de analyses. Bleek dat enkel verminderde GS een verhoogde kans op uitval tot gevolg had. Verder hadden de studeervaardigheden voornamelijk een invloed op slagen. Goed ontwikkelde AS en CMS verhogen de kans op slagen maar vreemd genoeg hebben ook slecht ontwikkelde GS een positieve impact op slagen. Mogelijks heeft dit te maken met de subschaal faalangst. Misschien leidt faalangst bij studenten met dyslexie tot betere prestaties. Tenslotte is er goed nieuws voor de instellingen die veel tijd en moeite steken in het voorzien van faciliteiten. Het gebruik van deze faciliteiten had bij de studenten met dyslexie een positief effect op slagen. De aanwezigheid van comorbide stoornissen zoals dyscalculie en ADHD deed studenten meer doorstuderen maar de kans op slagen was verminderd. Een vervolgstudie met inbegrip van de studenten die nog niet afstudeerden kan een finaler beeld geven van de prestaties van studenten met dyslexie.

Het SERIOL model voor visuele woordherkenning en dyslexie

Van de 200 studenten uit de cognitieve studie, namen er 40 (20 dyslexie – 20 controle) deel aan een experiment waarin de hypothese van Whitney and Cornelissen (2005) over dyslexie en letter positie encodering werd getest. Zij stellen dat dyslexie mogelijks wordt veroorzaakt door een probleem met de links-rechts verwerking van woorden en dit specifiek in het eerste deel van het woord tussen de woordbegin en de fixatiepositie binnen het woord. Om dit te onderzoeken werd gewerkt met clusters van drie medeklinkers (TRV, ZMP, ...) die op verschillende locaties in de twee visuele velden tachistoscopisch werden gepresenteerd. Accuraatheidsniveaus van de letteridentificaties tussen de twee groepen werden vergeleken. Volgens de hypothese van de auteurs van het SERIOL model, zouden dyslectici slechter presteren op de eerste letter in het linker visuele veld ten gevolge van een verstoorde omzetting van de retinale code in een abstracte code nodig voor toegang tot de betekenis van het woord in het mentale lexicon. Deze hypothese kon echter niet bevestigd worden. De identificatiepatronen van de twee groepen waren vergelijkbaar behalve dat de groep studenten met dyslexie minder goed presteerde op de middelste letter. Dit kan gekaderd worden binnen de theorie dat er sprake is van verhoogde laterale maskering bij dyslexie (Martelli et al., 2009; Pernet et al., 2006). Ook kon binnen de dyslexie groep dit verhoogde crowding effect in relatie gebracht worden met de scores op een woordleestaak. Verder vonden we wel algemene evidentie voor het SERIOL model voor normale visuele woordherkenning.

Referenties

Adelman, P. B., & Vogel, S. A. (1990). College graduates with learning-disabilities - Employment attainment and career patterns. *Learning Disability Quarterly, 13*(3), 154-166. doi: 10.2307/1510698

Ahissar, M. (2007). Dyslexia and the anchoring-deficit hypothesis. [Review]. *Trends in Cognitive Sciences, 11*(11), 458-465. doi: 10.1016/j.tics.2007.08.015

Bishop, D. V. M. (2006). Dyslexia: what's the problem? *Developmental Science, 9*(3), 256-257. doi: 10.1111/j.1467-7687.2006.00484.x

Blomert, L., & Willems, G. (2010). Is There a Causal Link from a Phonological Awareness Deficit to Reading Failure in Children at Familial Risk for Dyslexia? *Dyslexia, 16*(4), 300-317. doi: 10.1002/dys.405

Bosse, M. L., Tainturier, M. J., & Valdois, S. (2007). Developmental dyslexia: The visual attention span deficit hypothesis. *Cognition, 104*(2), 198-230. doi: 10.1016/j.cognition.2006.05.009

Broeninck, N., & Gorter, K. (2001). *Studeren met een handicap. Belemmeringen die studenten met een lichamelijke beperking, psychische klachten of dyslexie in het hoger onderwijs ondervinden*. Verwey-Jonker Instituut.

Bultinck, E. (2012). *Begeleiding bij dyslexie doorheen de jaren: een kwalitatief onderzoek bij jongvolwassenen.* Master in pedagogical sciences. Unpublished thesis, Ghent University.

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive profile of students who enter higher education with an indication of dyslexia. *PLos One, 7*(6). doi: 10.1371/journal.pone.0038081

Cano, F. (2006). An In-Depth Analysis of the Learning and Study Strategies Inventory (LASSI). *Educational and Psychological Measurement, 66*(6), 1023-1038. doi: 10.1177/0013164406288167

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition, 91*(1), 77-111. doi: 10.1016/S0010-0277(03)00164-1

De Pessemier, P., & Andries, C. (2009). *GL&SCHR Dyslexie bij +16-jarigen. Test voor Gevorderd Lezen en Schrijven*. Antwerpen, Belgium: Garant.

de Vos, T. (1992). *Tempo Test Rekenen*. Amsterdam: Pearson Education.

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Nunes, G., Jobert, A., . . . Cohen, L. (2010). How Learning to Read Changes the Cortical Networks for Vision and Language. *Science, 330*(6009), 1359-1364. doi: 10.1126/science.1194140

Dekker, R., Dekker, P. H., & Mulder, J. L. (2004). *Kaufman Adolescent and Adult Intelligence Test - Nederlandstalige versie: Handleiding*. Leiden, The Nederlands: PITS.

Ghesquiere, P., Boets, B., Gadeyne, E., & Vandewalle, E. (2012). Dyslexie: Een beknopt wetenschappelijk overzicht. In A. Geudens, D. Baeyens, K. Schraeyen, K. Maetens, J. De Brauwer & M. Loncke (Eds.), *Jongvolwassenen met dyslexie.Diagnostiek en begeleiding in wetenschap en praktijk.* (pp. 41-54). Leuven/ Den Haag: Acco.

Hadjikakou, K., & Hartas, D. (2008). Higher education provision for students with disabilities in Cyprus. *Higher Education, 55*(1), 103-119. doi: 10.1007/s10734-007-9070-8

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology, 72*, 119-133. doi: 10.1348/000709902158801

Heim, S., Tschierse, J., Amunts, K., Wilms, M., Vossel, S., Willmes, K., . . . Huber, W. (2008). Cognitive subtypes of dyslexia. *Acta Neurobiologiae Experimentalis, 68*(1), 73-82.

Helenius, P., Tarkiainen, A., Cornelissen, P., Hansen, P. C., & Salmelin, R. (1999). Dissociation of normal feature analysis and deficient processing of letter-strings in dyslexic adults. *Cerebral Cortex, 9*(5), 476-483. doi: 10.1093/cercor/9.5.476

Hoekstra, H. A., Ormel, J., & de Fruyt, F. (2007). *NEO-PI-R/NEO-FFI: Handleiding*. Amsterdam, The Netherlands: Hogrefe Uitgevers.

Hofmeester, N. (2002). *Studeren met dyslexie.* Apeldoorn, Nederland: Maklu Uitgevers nv.

Jimenez, J. E., Guzman, R., Rodriguez, C., & Artiles, C. (2009). Prevalence of specific learning disabilities: The case of dyslexia in Spain. *Anales De Psicologia, 25*(1), 78-85.

Kleijnen, R., & Loerts, M. (2006). *Protocol Dyslexie Hoger Onderwijs*. Antwerpen/Apeldoorn: Garant.

Lewis, C., Hitch, G. J., & Walker, P. (1994). The Prevalence of Specific Arithmetic Difficulties and Specific Reading Difficulties in 9-Year-Old to 10-Year-Old Boys and Girls. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 35*(2), 283-292. doi: DOI 10.1111/j.1469-7610.1994.tb01162.x

Lobier, M., Zoubrinetzky, R., & Valdois, S. (2012). The visual attention span deficit in dyslexia is visual and not verbal. *Cortex, 48*(6), 768-773. doi: 10.1016/j.cortex.2011.09.003

Madriaga, M., Hanson, K., Heaton, C., Kay, H., Newitt, S., & Walker, A. (2010). Confronting similar challenges? Disabled and non-disabled students' learning and assessment experiences. *Studies in Higher Education, 35*(6), 647-658. doi: 10.1080/03075070903222633

Martelli, M., Di Filippo, G., Spinelli, D., & Zoccolotti, P. (2009). Crowding, reading, and developmental dyslexia. *Journal of Vision, 9*(4), 1-18. doi: 10.1167/9.4.14

Menghini, D., Finzi, A., Benassi, M., Bolzani, R., Facoetti, A., Giovagnoli, S., . . . Vicari, S. (2010). Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia, 48*(4), 863-872. doi: 10.1016/j.neuropsychologia.2009.11.003

Nederland, S. D. (2008). *Diagnose dyslexie. Brochure van de Stichting Dyslexie Nederland. Herziene versie*. Bilthoven, The Nederlands: Stichting Dyslexie Nederland.

Pernet, C., Valdois, S., Celsis, P., & Demonet, J. F. (2006). Lateral masking, levels of processing and stimulus category: A comparative study between normal and dyslexic readers. *Neuropsychologia, 44*(12), 2374-2385. doi: DOI 10.1016/j.neuropsychologia.2006.05.003

Plume, E., & Warnke, A. (2007). Definition, symptoms, prevalence and diagnosis of dyslexia. *Monatsschrift Kinderheilkunde, 155*(4). doi: 10.1007/s00112-007-1480-2

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain, 126*, 841-865. doi: 10.1093/brain/awg076

Reid, A. A., Szczerbinski, M., Iskierka-Kasperek, E., & Hansen, P. (2007). Cognitive profiles of adult developmental dyslexics: Theoretical implications. *Dyslexia, 13*(1), 1-24. doi: 10.1002/Dys.321

Snowling, M. (2000). *Dyslexia. Second Edition.* Oxford: Blackwell Publishers.

Stanovich, K. E. (1988). Explaining the difference between the dyslexic and garden-variety poor readers: The phonological-core variable difference model. [Article]. *J Learn Disabil, 21*(10), 590-&.

Stein, J., & Walsh, V. (1997). To see but not to read; The magnocellular theory of dyslexia. [Article]. *Trends in Neurosciences, 20*(4), 147-152. doi: 10.1016/s0166-2236(96)01005-3

Swanson, H. L., & Hsieh, C. J. (2009). Reading Disabilities in Adults: A Selective Meta-Analysis of the Literature. *Review of Educational Research, 79*(4), 1362-1390. doi: 10.3102/0034654309350931

Szmalec, A., Loncke, M., Page, M. P. A., & Duyck, W. (2011). Order or Disorder? Impaired Hebb Learning in Dyslexia. *Journal of Experimental Psychology-Learning Memory and Cognition, 37*(5), 1270-1279. doi: 10.1037/a0023820

Taroyan, N. A., & Nicolson, R. I. (2009). Reading words and pseudowords in dyslexia: ERP and behavioural tests in English-speaking adolescents. *International Journal of Psychophysiology, 74*(3), 199-208. doi: 10.1016/j.ijpsycho.2009.09.001

Tops, W., Callens, M., Lammertyn, J., & Brysbaert, M. (2012). Identifying students with dyslexia in higher education. *Annals of Dyslexia, 62*(3), 186-203. doi: 10.1007/s11881-012-0072-6

Trainin, G., & Swanson, H. L. (2005). Cognition, metacognition and achievement of college students with learning disabilities. *Learning Disability Quarterly., 28*, 264-272.

Van der Leij, A., Bekebrede, J., Geudens, A., Schraeyen, K., G.M., S., Garst, H., . . . Schijf, T. J. (2012). *Interactieve Dyslexietest Amsterdam-Antwerpen: Handleiding.* Uithoorn.

Vogel, S. A., Leonard, F., Scales, W., Hayeslip, P., Hermansen, J., & Donnells, L. (1998). The national learning disabilities postsecondary data bank: An overview. *J Learn Disabil, 31*(3), 234-247.

Wessel, R. D., Jones, J. A., Markle, L., & Westfall, C. (2009). Retention and Graduation of Students with Disabilities: Facilitating Student Success. *Journal of Postsecondary Education and Disability, 21*(3), 116-125.

Whitney, C., & Cornelissen, P. (2005). Letter-position encoding and dyslexia. *Journal of Research in reading, 28*(3), 274-301.

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*(3), 415-438. doi: 10.1037/0022-0663.91.3.415

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*(1), 3-29. doi: 10.1037/0033-2909.131.1.3