Universiteit Utrecht

# The influence of orthographic transparency on word recognition by dyslexic and normal readers

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Master thesis Taal, Mens & Maatschappij (Taalwetenschappen)

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July 2014

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## Foreword

This thesis is written as a completion of the master Taal, Mens & Maatschappij at Utrecht University. The subject of this thesis is orthographic transparency and dyslexia: a subject which was originally meant to be a research proposal for a master's course and ended up being a long-term project on a subject that has never been studied like this before. I have really enjoyed this journey, but I could not have done it without help from some people and that is why I would like to thank them in this foreword. First of all, I would like to thank my first supervisor, Bill Philip, for all the help, the comments and the inspirational feedback. And also, thank you for supporting me in the decision to write this thesis in English, because it has been a great lesson for me! Of course I would also like to thank the two schools and all participants who have helped me with collecting the data for this thesis, since the data collection, or rather: finding enough dyslexic participants, was one of the biggest struggles during the period I wrote this thesis.

Abstract

This thesis has investigated the effect of orthographic transparency within a single language, Dutch, on dyslexic readers. Much research has studied this topic between different languages, while this thesis wanted to test the claim that orthographic transparency is not a property of languages, rather of words. By means of a lexical decision task, it was tested whether dyslexic children benefited more from the transparency of words concerning reading accuracy and reading speed than non-dyslexic children. It was predicted that the dyslexic readers were significantly better and faster at recognizing the transparent words than the opaque words, and that the difference was significantly greater for the dyslexic group than for the non-dyslexic group.

In this study, 21 dyslexic children and 21 non-dyslexic children participated. They were matched on reading level by using a Dutch technical reading test, the One Minute Test (Eén-Minuut-Test). The experimental task in this thesis, a lexical decision task, consisted of 40 two-syllable words, of which 20 existing words and 20 pseudowords. The pseudowords were derived from the existing words by changing the consonants and leaving the vowels the same. The participants had to decide whether a word, either a transparent one or an opaque one, was an existing word or not. There were two versions of this task and each version had the same amount of transparent and opaque words. Participants were selected from two primary schools in the same region in the Netherlands to minimize the influence of dialectal differences. Therefore, the stimuli used for the lexical decision task was also controlled for dialect words when constructing the pseudowords.

The results showed that the dyslexic children were significantly more accurate judging transparent words than judging opaque words. The non-dyslexic children showed also a significant difference, although the effect of orthographic transparency was slightly greater for the dyslexics. There was no significant difference concerning reading speed for transparent and opaque words, neither for the dyslexic group, nor for the non-dyslexic group.

In conclusion, this thesis has confirmed that orthographic transparency plays a significant role within a single language too, showing that it is not a property of languages, but a property of words. This can help to develop new methods for treating children, and also adults, with dyslexia. Because dyslexic readers experience less problems with transparent words, treatment can focus more on the difficulty with opaque words. More research is needed to test whether the same holds for dyslexic readers in other regions of the Netherlands,

but also for dyslexic readers in other countries, and who speak other more transparent or more opaque languages than Dutch. Orthographic transparency is not only an important factor for multilingual readers with dyslexia, but also for monolingual readers with dyslexia and this information could help by developing treatments focused on dyslexia.

# 1. Introduction

One of the challenges when acquiring a language is learning to read. There are many factors that can influence the reading acquisition process in a language. One of them is the orthographic transparency of a language: the degree to which the correspondence between sounds and tokens exists. This so-called grapheme-to-phoneme correspondence can be one-to-one, which can be benefit the reading acquisition process, but it can also be one-to-many or many-to-one. In the latter, in so-called opaque languages, it is harder to translate spoken words to written words compared to more transparent languages. Various studies have confirmed that beginning readers have more difficulty decoding written words in opaque languages such as English, than in transparent languages such as Spanish (Spencer, 2000). This is even harder for children who already experience difficulties with reading, such as children with developmental dyslexia. However, many studies concerning orthographic transparency and dyslexia have compared so-called transparent languages with opaque languages to see whether there is an effect of orthographic transparency for dyslexic readers. These studies have been classifying whole languages as orthographically transparent or not, while it is rather a property of words. For this reason, this thesis will focus on the differences in orthographic transparency within one language, Dutch, to see if there is an effect of transparent and opaque Dutch words on reading ability and reading speed of dyslexic children. The main question is whether orthographic transparency alone causes the problems dyslexic readers encounter or orthographic transparency combined with other linguistic factors such as word stress or syllabic structure.

This thesis is organized as follows: first, the theoretical background introduces the definition of dyslexia used in this thesis and the differences between dyslexics, children with Specific Language Impairment, and poor readers. Next follows what previous studies already have discovered on the topic of dyslexic children in relation to word recognition and orthographic transparency. After this, the hypotheses of this study are defined and the predictions derived from these hypotheses. The method section includes the discussion of the participants, design, materials and procedure of the experiment. After the results, the discussion follows which includes the conclusion and the implications of this study.

## 2. Theoretical Background

### 2.1 Developmental Dyslexia

There are many types of dyslexia, but this thesis is concerned with only one kind called developmental dyslexia[1] (henceforth simply dyslexia). This paragraph focuses on the problems children with dyslexia encounter. Although not every dyslexic reader is confronted with the same problems, all have a few shared characteristics in common: they all experience problems in reading, spelling, writing, speaking or listening, caused by a learning disability (Rathore, Mangal, Agdi, Rathore, Nema & Mahatma, 2010). Over the years, many different studies about dyslexia have contributed to the PHONOLOGICAL DEFICIT HYPOTHESIS, which claims that dyslexics mainly experience deficits in the phonological language domain. According to this hypothesis, due to the phonological difficulties they experience many dyslexics also have problems in tasks that require the processing of phonological information (Rack, Snowling & Olson, 1992). Examples of these problems are troubles remembering names of days, months and colors, and segmenting and categorizing speech sounds. Regarding the latter problem, individuals with dyslexia tend to blend speech sounds and letters. As a consequence, they experience problems in reading and spelling (Rack et al., 1992). For instance, when reading, many dyslexics confuse letters which look alike and stand close to each other in context, e.g. letters such as *d* and *b*, *J* and *L*, *M* and *W* (Rathore et al., 2010). In addition, several studies (e.g. Serrano & Defior, 2008) have shown that people with dyslexia perform most poorly on tasks where phonological awareness is tested. They have difficulty with the ability to reflect on and manipulate verbally spoken material with regard to the sound structure of words (Wydell & Butterworth, 1999). Tasks in which phonological awareness is tested are nonword reading tasks, pseudohomophone reading tasks, homophone choice tasks and similarity judgment tasks (Serrano & Defior, 2008). In nonword reading tasks, participants have to read aloud strings of letters which cannot exist in a certain language because they break the phonotactic rules of that language. For example, *srak* is a nonword in Dutch because the combination *sr* cannot exist at the beginning of a Dutch syllable. In pseudohomophone reading tasks, pairs of pseudowords and pseudohomophones have to be read aloud and a choice has to be made between them: Which of the two sounds like a real

[1] The term developmental dyslexia refers to a developmental disorder in which learning to read progresses with abnormal difficulty, while other abilities develop normally (Paulesu et al., 1996). Readers with developmental dyslexia never gained reading skills, in contrast to readers with acquired dyslexia, who did gain those skills once but later lost them (Frith, 1985).

word? Pseudowords are words that could have existed in a language but do not, such as *miva* in Dutch. Pseudohomophones on the other hand are pseudowords which are phonetically identical to real words, e.g., *vauw* in Dutch which sounds the same as the existing Dutch word *vouw*. In homophone choice tasks, participants have to fill in missing words in sentences by choosing between two homophones, such as *meid* and *mijt* in Dutch. Furthermore, similarity judgment tasks can be used to test phonological awareness among participants. In these tasks, participants have to judge whether any of the sound segments of two words sound alike, e.g. *potlood* (*/pɔtlo:t/*) – *botten* (*/bɔttən/*) in Dutch (Serrano & Defior, 2008). Grainger, Bouttevin, Truc, Bastien and Ziegler (2003) mention that a significant difficulty in reading pseudowords among children can be seen as a characteristic of developmental dyslexia.

After having discussed which problems are associated with dyslexia, it is important to note that the problems dyslexics experience are not due to factors like brain damage. Dyslexia is the case when unexpected reading difficulties are experienced by adults and children who are not lacking reading instructions and social opportunities, who do not have abnormally low intelligence, nor lack the necessary psychical abilities (e.g., hearing, vision) (Wydell & Butterworth, 1999; Shaywitz et al., 2002). The same criteria, however, are also used to diagnose another language disorder: Specific Language Impairment, also called SLI (Leonard, 1998). The difference between the two disabilities is to be found in the area where the child experiences the deficit. Whereas dyslexic children only experience phonological deficits, children with SLI can experience phonological as well as non-phonological deficits (Bishop & Snowling, 2004). For this reason, Bishop and Snowling (2004) do not rule out the possibility that children with SLI can develop dyslexia when reading problems persist. Examples of common non-phonological deficits among SLI children are omission errors, the deletion of words, as well as commission errors, incorrect use of agreement rules (Leonard, 1998). In short, both children with dyslexia and SLI can encounter reading problems and for instance, read *cloud* as *cold* (Rathore et al., 2010), but only children with SLI can also encounter grammatical problems and, for instance, utter a sentence such as: “Him going fishing.” or “Jim hold water.” (Leonard, 1998). In addition, dyslexic readers must not be confused with so-called poor readers, which are readers who show mostly the same phonological problems as dyslexics but less extensively. Badian (1994) demonstrated that dyslexics could be separated from poor readers based on deficits in automatic visual recognition and phonological recoding of graphic stimuli. Where dyslexic readers experience orthographic problems on top of the phonological problems, non-dyslexic poor readers only experience the latter (Badian, 1994). While poor readers can become normal readers, this does not hold for dyslexic readers; their reading skills may improve, but they will always experience difficulties in the orthographic and phonological area.

### 2.2 Word Recognition for Dyslexics

In normal development, the word recognition process begins with a phonological representation of the word wherein the word is visually represented, distinguishing different syllables and sounds. After this, a semantic representation of the word is formed on the basis of the accompanying phonological representation. For example, the word *tree* refers to a plant with a certain color, characteristics and size. This is the semantic representation someone can have of the word *tree*; it refers to the meaning of the word. The phonological representation is formed through the meaning of the syllables and phonemes a word consists of (Goswami, 2000). For the word *tree* it would be one syllable, consisting of three phonemes. When the vocabulary size of children is still small, the representations are holistic rather than analyzed in detail. For instance, it is not necessary for a child to analyze the phonological representation of the word *tree* further than that it consists of three phonemes and that it is different from the word *ski*. Later on, when the vocabulary size grows, the holistic representations are restructured because now there are more possibilities to choose from. This is more often done by words that have many similar-sounding neighbors, because they have to be analyzed in more detail in the process of recognizing the correct word (Goswami, 2000). For example, when the vocabulary size of the child has grown, it includes not only the word *tree*, but also the words *three* and *treat*. To analyze the word *tree* without confusing it with the other similar looking words, the phonological features that are represented become more fine-grained, e.g. whether a phoneme is voiced or voiceless. Through these phonological and semantic representations, words can be recognized and understood.

In the case of dyslexic readers, word recognition processes are different. Seidenberg and McClelland (1989) observe that “developmental dyslexia could be seen as a failure to acquire the knowledge that underlies word recognition and naming” (p.26). It is difficult for dyslexic children to recognize individual words, because they have problems with the identification of phonological segments of different sizes within words. Following the Phonological Representations Hypothesis, the phonological processing difficulties in dyslexics are caused by a lack of segmental specificity in phonological and semantic representations, which are necessary for word recognition processes (Goswami, 2000). As a consequence, different syllables and sounds are not well distinguished through which the phonological representations of words are not reliable. This is one of the reasons why dyslexic children unconsciously mix up different phonemes and insert or leave out letters, especially while spelling multi-syllabic words (Rathore et al., 2010). This can occur in word recognition as well as in word naming while reading out loud (Rack et al., 1992).

## 2.3 Orthographic Transparency and Dyslexia

While dyslexia has often been studied within one single language, it is also interesting to look at dyslexic readers across different languages with different orthographies, since the success of a dyslexic reader can also be influenced by the level of orthographic transparency (Serrano & Defior, 2008). Orthographic transparency refers to an important concept in the process of learning to read and write: the grapheme-to-phoneme correspondence. This is described as the extent to which graphemes consistently map onto one and the same phoneme and vice versa in an alphabetic writing system (Ziegler & Goswami, 2005). Graphemes are the smallest parts of words which can represent one or more phonemes. Most of the graphemes can be represented by letters. Phonemes are the sound units that words consist of. Phonemes do not only include vowels and consonants, but also diphthongs like /ei/, /ui/ and /ou/, which can be found in the Dutch language (Rietveld & Van Heuven, 1997). Examples of graphemes are the following letter characters from the Dutch alphabet: *a*, *k* and *oe*. Phonemes correspond to graphemes in a way that the phoneme /r/ can correspond to the graphemes <r> and <rr> in the Dutch language[2]. Although the phoneme /r/ in the Dutch word *irriteren* ('to irritate') is represented by two different graphemes, respectively <rr> and <r>, it still concerns the same phoneme in both cases. Graphemes can also map to various phonemes. For example, the grapheme <c> in Dutch corresponds to both the phonemes /k/ and /s/ in words like *café* ('cafe') and *cel* ('cell'). In transparent orthographies, grapheme-to-phoneme correspondences are mainly one-to-one, while in opaque orthographies several graphemes can correspond to the same phoneme and conversely, several phonemes can be represented by the same grapheme. In other words, the correspondences of graphemes to phonemes is very consistent in transparent orthographies and somewhat chaotic in opaque orthographies. Different languages have their own place on a continuum of degrees of orthographic transparency with Spanish being a language with a very transparent orthography, as illustrated in (1a), while the English language is orthographically more opaque, exemplified in (1b) (Spencer, 2000).

[2] Slashes represent phonemes, while angled brackets represent graphemes.

(1) a. *Spanish: /o/ = <o>: banco, hermoso, coleta*

b. *English: /o/ = <o>, <oa>, <ough>, <oe>: low, oath, though, toe*

In (1a), there is a one-to-one mapping of the phoneme /o/ and the grapheme <o>: the phoneme /o/ is in all three words realized as the allophone [əʊ], or [o:], and represented by the grapheme <o>. For this reason, Spanish has a transparent orthography. In (1b), on the other hand, it is shown that English cannot be called orthographically transparent. Although the phoneme /o/ is realized by the allophone [əʊ], it is also represented by four other graphemes: <o>, <oa>, <ou> and <oe>. Because of this one-to-many mapping, English has a fairly opaque orthography.

Since children diagnosed with dyslexia do not show all the same symptoms within one language, a question arises as to whether dyslexic children experience the same problems in transparent orthographies (e.g., Spanish) as they do in opaque orthographies (e.g., English). Spencer (2000) showed that languages with more transparent orthographies, such as Turkish, Greek, Spanish, Italian and German, turn out to be less difficult for beginning readers than languages with more opaque orthographies such as English and Danish. Indeed, the study of Serrano and Defior (2008) demonstrated that Spanish dyslexic children had less problems concerning accuracy because of the transparent orthography of the Spanish language. They had more problems concerning speed instead, compared to the chronological age-matched and the reading level-matched control group. Furthermore, Seymour, Aro and Erskine (2003) concluded in their study that children who learn to read in languages with a transparent orthography (e.g., Finnish and Greek) show less wider variation in reading development than children who learn to read in languages with an opaque orthography (e.g., English and Danish). Nonetheless, these results may not be completely due to orthographic transparency since syllabic structure was also taken into account in the study of Seymour et al. (2003). Since the syllabic structure in English and Danish is more complex than in Finnish and Greek, this also influenced the results (Seymour et al., 2003). However, a transparent orthography can still benefit language learners since there have been studies highlighting the cognitive factors involved when using different orthographies. These have shown that opaque orthographies make heavy demands on memory, unlike transparent orthographies. Transparent orthographies require a much more limited activation of brain regions than opaque orthographies (Spencer, 2001). Moreover, transparent languages can facilitate processing for non-dyslexic and dyslexic adults, resulting in higher reading accuracy levels and faster reading speed (Spencer, 2010).

In earlier research, for instance, Wimmer and Goswami (1994) compared beginning readers in English and German, and the results showed that the orthographic transparency of the languages had a huge influence when reading pseudowords. The German children scored better in reading pseudowords than the English children. The results of this study suggested that the process of word recognition not only differs between dyslexic and non-dyslexic readers but also between orthographies (Wimmer & Goswami, 1994). In addition, Landerl, Wimmer and Frith (1997) showed that English dyslexic children made much more severe reading errors in both word and pseudoword reading than German dyslexic children, who experienced only problems when reading pseudowords. This suggested that English is harder for dyslexic readers because of its orthographically opaque spelling compared to the more transparent spelling of the German language (Spencer, 2000). This was also suggested in the study of Spencer and Hanley (2003), in which a Welsh-English comparison was made which showed that children learning to read in Welsh did perform significantly better when reading existing words as well as pseudowords than children learning to read in English. Spencer (2007), however, suggested that languages must not only be divided into orthographically transparent or opaque to see what kind of effect it has on reading and spelling abilities. He argues that a complex term such as orthographic transparency can also move in two different directions: phoneme-to-orthography (P-O or spelling) and orthography-to-phoneme (O-P or reading) (Spencer, 2007). While transparent languages such as Finnish and Turkish show one-to-one mapping in phoneme-to-orthography relations, an opaque language such as English shows many-to-many mapping, which includes one-to-many and many-to-one. However, there are also languages which are more in-between. For instance, German and Greek are highly transparent in the orthography-to-phoneme direction, but more opaque in the phoneme-to-orthography direction (Spencer, 2007). So, while Finnish and Turkish readers should experience less difficulties in spelling as well as reading, and English readers more difficulties, German and Greek readers will experience less difficulties in reading and more in spelling. However, it has to be noted that this does not mean that dyslexics in different languages experience different problems. Ziegler, Perry, Ma-Wyatt, Ladner and Schulte-Körne (2003) showed in their cross-linguistic research that there are more similarities between orthographies than differences. The same was found in the study of Paulesu et al. (2001), where the reading deficit of Italian dyslexic adults differed not at all from the deficit of the French and English dyslexic adults. Thus, the degree of transparency of a language's orthography can benefit dyslexic readers, but it does not mean that the problems they encounter are qualitatively different across different orthographies.

Additional research in which comparisons were made between transparent and opaque languages among dyslexic and non-dyslexic readers have examined the idea that dyslexic children can benefit from learning to read in a language with a transparent orthography. Messbauer and de Jong (2003) suggest that this could help to gain relatively high levels of phonological awareness. What not many studies have yet examined is that there are differences in transparency also within the vocabulary of a single language: some words are more transparent than other words. An example of more transparent and less transparent words of the Dutch lexicon are, respectively, in (2a) and (2b).

(2) a. *ram, stil, verbaal ('ram', 'silent', 'verbal')*
    b. *mijd, mijt, meid ('avoid', 'mite', 'girl')*

In (2a), a few examples are shown of words which have a one-to-one grapheme-to-phoneme correspondence. These words are written according to how they sound. For example, in the word *ram*, you hear the phonemes /r/, /a/, /m/ and to write the word you use the corresponding graphemes: [r], [a], [m]. The same holds for the words *stil* and *verbaal*. Thus, the words in (2a) are quite transparent. In contrast, the words in (2b) are more opaque. The three words in (2b) are all pronounced in the same way, but each word is spelled differently and has a different meaning. In Dutch, as can be seen in (2b), the [d], which is normally a voiced consonant, is pronounced in the same way as the [t], a voiceless consonant, at the end of a word. Another problem arises for the diphthong [ij], which is spelled differently than the diphtong [ei], but not pronounced differently. Thus, some Dutch words can use different graphemes to represent the same phonemes, which makes the word an "opaque word", while other Dutch words have a one-to-one mapping between graphemes and phonemes and therefore "transparent words". These differences in orthographic transparency in words within a language can affect literacy acquisition and processing, as pointed out by Baron and Strawson (1976).

In this thesis, an attempt will be made to find an answer to the question whether orthographic transparency alone affects dyslexic reading or if it is a combination of orthographic transparency, syllable structure, stress and other linguistic characteristics of languages. On the hand, studies have shown that orthographic transparency influences the performance of dyslexic readers on tasks which involve reading transparent and opaque words and pseudowords of different languages (Goswami, 2000; Landerl et al., 1994; Messbauer & de Jong, 2003; Rathore et al., 2010; Seidenberg & McClelland, 1989; Wimmer & Goswami, 1994). Reading proficiency is made harder when reading is done in an orthographically opaque language such as English, while reading in an orthographically transparent language such as Spanish can facilitate the reading development (Spencer, 2000). However, there are also studies (e.g., Seymour et al., 2003) which point out that other factors besides orthographic transparency could also play a role in dyslexic reading. For instance, although the orthographic transparency of Dutch is comparable to that of Portuguese, because the two languages have different syllabic structures (respectively, complex and simple), dyslexic reading may still be more difficult in Dutch than in Portuguese. The simple syllabic structure of a language (e.g., as in Spanish) could also have contributed to the conclusion of Serrano and Defior (2008) that speed problems will be more evident than accuracy problems among dyslexic readers in transparent orthographies. To investigate whether orthographic transparency is a property of whole languages or rather words, a lexical decision task will measure dyslexic and normal reading performance (in terms of speed as well as accuracy) of existing words and pseudowords, varying in orthographic transparency, within the same language (Dutch).

## 2.4 Hypotheses and Predictions

This thesis will test the different predictions of two alternative hypotheses:

H1: Orthographic transparency alone interacts significantly with dyslexic reading performance.

H2: Orthographic transparency in combination with other necessarily co-occurring linguistic factors interacts with dyslexic reading performance.

If orthographic transparency alone is the cause of the problems dyslexic readers experience, it is predicted that there will be a robust significant contrast in performance between transparent and opaque existing words and pseudowords for the dyslexic readers. There may also be a minimal contrast of this sort for the non-dyslexic readers, however, they will be less robust or non-significant. Specifically, reaction times with transparent (pseudo)words will be faster than reaction times with opaque (pseudo)words, and this difference will be significantly greater for dyslexic than for normal readers. Concerning accuracy, the dyslexic readers will perform significantly better on transparent existing words and pseudowords than on opaque existing and pseudowords. This difference will also be significant for the non-dyslexic readers, but less significant.

On the other hand, if orthographic transparency must be combined with other linguistic factors (such as syllabic structure) to cause problems in dyslexic reading performance, it is predicted that no contrasts will be found, neither concerning speed nor accuracy.

| | Predictions |
|---|---|
| H1. | For dyslexic readers, significant contrasts in performance will be observed between transparent (pseudo)words and opaque (pseudo)words, and, if any similar contrasts occur for normal readers, they will be significantly different from those occurring with dyslexic readers. |
| H2. | There will no significant contrasts in performance between transparent (pseudo)words and opaque (pseudo)words, neither for dyslexic readers nor for normal readers. |

## 3. Method

### 3.1 Participants

The experimental group of this thesis consisted of 21 children (mean age = 11.8 years, SD = 0.75) who have been clinically diagnosed with developmental dyslexia since a few years. The age range of the group was between 11 and 13 years of age. Among the experimental group, there were 13 boys and 8 girls, all of which whose mother tongue was standard Dutch. Their reading level was tested by means of the One Minute Test (Eén-Minuut-Test), using the C-scale to calculate the reading level of the control group. The control group consisted of 21 children (mean age = 9.2 years, SD = 1.03) who were average readers for their age and have not experienced reading problems before. Their reading level was also tested by means of the Een-Minuut-Test, to be sure that they were a reliable and valid control group compared to the experimental group. The age range of the control group was between 8 and 12 years of age. This group consisted of 12 boys and 9 girls, all of which whose mother tongue was standard Dutch. Only monolingual children were included in this thesis[3]. All children originated from the same language region in the Netherlands.

### 3.2 Design

The experimental task of the experiment was a lexical decision task in which the participants had to decide if the series of letters shown on the computer screen was a word or not. A mixed design was used in which the two-level between-subjects factor was dyslexic or normal readers and the two two-level within-subjects factors were orthographic transparency (transparent vs. opaque) and word type (existing word vs. pseudoword). There were two dependent variables: response time (speed) and correct judgment (accuracy).

### 3.3 Materials

#### 3.3.1 One Minute Test

First, the children took a standardized Dutch word reading test called the Eén-Minuut-Test (One Minute Test) (Brus & Voeten, 1973). This technical reading test was used as a pre-test to measure the word-decoding ability of the participants. The test consists of 116 unrelated

[3] Exposure to the English language from childhood on cannot be avoided among Dutch children anymore, since English has become more and more common in showing for example English cartoons are seen on television. Besides this, Dutch children receive formal instruction in English in primary school from the fifth grade on. This exposure can however contribute to the learning of opaque words, since English is an opaque language.

words, which differ in length and difficulty. Participants had to read these words aloud within one minute, as correctly and quickly as they could[4]. There were two versions of the test (version A and version B), both matched for word length, word complexity and word frequency. The amount of words, the participant read correctly within 1 minute was the raw score. Words that were spontaneously corrected during the One Minute Test were seen as correctly read words, in accordance with the instructions of the test by Brus and Voeten (1973).

### 3.3.2 Lexical Decision Task

The experimental task in this experiment, the lexical decision task, consisted of 40 two-syllable existing words and 40 two-syllable pseudowords. All words, which were all nouns, and all pseudowords were equally divided into transparent and opaque series of letters. Word length was held constant, because research has shown that long pseudowords take more time than short pseudowords, especially for dyslexics, although word length does not affect the reading speed for high frequent words (Martens & De Jong, 2006). The 40 pseudowords were constructed by changing the consonants and leaving the vowels the same, so they would still look like their existing Dutch equivalents. A word was categorized as transparent when there was a one-to-one mapping between phonemes and graphemes; when every letter was pronounced in the way it has been acquired when learning the Dutch alphabet. For example, the letter *a* is learned in Dutch as the short vowel phoneme /a/, but the same letter *a* can also represent the long phoneme /a:/. Examples of transparent pseudowords and opaque pseudowords are shown in (3a) and (3b), respectively (IPA phonetic transcription provided in square brackets).

(3) a. *zarpon* [zarpɔn]
b. *traben* [tra:bən]

Every letter of the pseudoword in (3a) is pronounced in exactly the same way the sounds are learned when learning the Dutch alphabet, with a short *a*-sound and a short *o*-sound, namely [ɑ] and [ɔ]. Although the same grapheme is used for the pseudoword *traben* in (3b) as well as for the pseudoword *zarpon* in (3a), they are differently pronounced. In (3a) the grapheme *a* is pronounced as a short phoneme, [ɑ], while in (3b), it is pronounced as a long phoneme, [a:].

[4] This test conflates speech production with word recognition. However, since it is independently known that dyslexia does not manifest itself in production (Gulpen & Maassen, 2005; Van Berkel, Wiers & Hoeks, 2006), it can be used as a reliable means of testing the concerned population.

In addition, the letter *e* in (3b) is not pronounced as [ɛ], as it is learned, but as a schwa ([ə]). In Dutch, when the letter *e* is in an unstressed syllable, it is pronounced as a schwa which resembles the sound of the letter *u* in the Dutch word *mug* ('mosquito'). For these reasons, *zarpon* was categorized as a transparent pseudoword, while *traben* was categorized as an opaque pseudoword. The pseudowords were carefully constructed in such a way that they did not contain vowels or consonant clusters which are not used in the Dutch language, such as the consonant cluster *kpf*, for example. In addition, the pseudowords were controlled for the influence of voiced and voiceless consonants on the resemblance of an existing Dutch word. For example, the pseudoword in (4a) is not a good pseudoword because, when pronounced out loud, it resembles the existing Dutch word in (4b).

| | | | |
|---|---|---|---|
| (4) | a. | *forken* | [forkən] |
| | b. | *vorken* | [vorkən] |

The two words are exactly the same, except that in (4a) the word begins with a voiceless fricative, while this is a voiced fricative in (4b). In addition, the pseudowords were controlled for containing parts of existing words. For example, the series of letters in (5a) is not a proper pseudoword because it consists partly of an existing Dutch word, *gil*, while the series of letters in (5b) is a proper pseudoword since *gir* nor *hon* are existing words in Dutch:

| | | | |
|---|---|---|---|
| (5) | a. | *gilhon* | [xɪlɦɔn] |
| | b. | *girhon* | [xɪrɦɔn] |

The words were shown separately on a computer screen in a single order. For this task, two different versions were created, because an existing word like *kalfje* could not be in the same version as the derived pseudoword *falkje*. Therefore, every version of the lexical decision task consisted of 20 existing words (10 transparent and 10 opaque) and 20 pseudowords (10 transparent and 10 opaque). As mentioned earlier, there were two dependent variables in this experiment: speed and accuracy. Children with dyslexia in transparent orthographies such as Spanish can be detected by very slow reading speed alone, since their accuracy is at ceiling. However, children with dyslexia in opaque orthographies such as English can be detected by very slow reading speed in addition to a high error rate (i.e. low accuracy) (Ziegler & Goswami, 2005). Since Dutch is not a transparent language like Spanish, nor an opaque language like English (Seymour et al., 2003), the participants in this thesis were tested on reading accuracy as well as on reading speed. Reading accuracy was measured by the number of correct responses the participant had given in deciding whether the shown word was a word or not. When the word was recognized as a word, the participant was instructed to push the Z-key on the keyboard. When the word was not recognized as a word, the participant was instructed to push the M-key on the keyboard. This kind of response was preferred instead of a verbal response, because of the possible influence of verbal skills when using a verbal response. Therefore, a keyboard response was used to prevent that children who were verbally less fluent would have longer reaction times. Reading speed was automatically measured and registered by the program OpenSesame, starting from the moment the series of letters was shown on the computer screen until the moment the participant pushed the Z- or the M-key. There was no time limit on the shown series of letters. In addition, the choice was made not to let the participants read the words out loud, because in that case, the non-dyslexic children could benefit from being quicker readers than the dyslexic children. This could influence the reaction times. The stimuli of the lexical decision task can be found in the Appendix.

## 3.4 Procedure

The location of the experiment was a quiet room with a computer in the schools of the children, so they were situated in a familiar environment where they felt at ease. All tasks were executed with one participant at the time to avoid any distractions from other participants while performing the tasks. The materials from the lexical decision task were shown via the computer screen. All participants passed through the same procedure, with first the pre-test, the One Minute Test, and then the lexical decision task, and received the same instructions before performing each task. These instructions included telling the participants what they would see on the computer screen and what they had to do. During the instructions, participants were allowed to ask questions, because it was important that they knew precisely what they had to do during the experiment. Before starting the lexical decision task, a few practice items were shown on the computer screen to be sure that the participants knew what they had to do during the experiment. The non-dyslexics were not tested on the same day as the dyslexics, because the results of the One Minute Test first had to be analyzed to match the reading level of the dyslexics with the reading level of the non-dyslexics.

## 3.5 Data Analysis

After the tasks were performed by all participants, the reading accuracy with which the participants made the decisions concerning words and pseudowords during the experiment, was coded and analyzed. Every correct decision was marked by the number 1, every incorrect decision was marked by the number 0. A correct decision was made when a word was recognized as a word and when a pseudoword was recognized as not being a word. An incorrect decision was when the participant wrongly decided that a word was not a word or a pseudoword was a word. Because the lexical decision task was carried out by using a keyboard response, the participants had to decide on whether the shown series of letters was an existing word or not. Concerning the reaction times which were registered during the lexical decision task, they were first converted from OpenSesame into an Excel data file. After this, the Excel data file was transformed into a SPSS data file, wherein the reaction times were further analyzed.

## 4. Results

### 4.1 Results EMT

The mean score on the One Minute Test (Eén-Minuut-Test) was 54.6 (SD = 10.76) for the dyslexic children and 58.9 (SD = 12.50) for the non-dyslexic children. The minimum score a dyslexic had on this test was 30 while the maximum score was 74. For the non-dyslexics, the minimum score was 26 and the maximum score was 83. The difference between the mean scores of the two groups was non-significant, $t(40) = 1.19$, $p = .24$. This means that the two groups did not significantly differ in reading level.

### 4.2 Results LTD Reading Accuracy

The mean score on the lexical decision task for the dyslexics was 31.8 (SD = 4.16) and for the non-dyslexics 30.4 (SD = 3.31). If all the answers were correct on this task, the highest score was 40. The minimum and maximum score for the dyslexics was 23 and 39, while it was 24 and 36 for the non-dyslexics. The difference between the mean scores of the two groups was non-significant, $t(40) = -1.15$, $p = .26$. However, this held for all the word types. Therefore, in table 1 are the scores shown of the different word types: existing, pseudo, transparent and opaque.

*Table 1* *Mean scores of the dyslexic and the non-dyslexic children on the lexical decision task (maximum score = 20)*

| | Dyslexic group (N = 21) | Non-dyslexic group (N = 21) |
|---|---|---|
| Existing words | 15.4 (SD = 2.54) | 13.4 (SD = 2.46) |
| Pseudowords | 16.3 (SD = 2.35) | 17.1 (SD = 2.04) |
| Transparent words | 17.3 (SD = 1.80) | 16.8 (SD = 2.09) |
| Opaque words | 14.4 (SD = 2.99) | 13.6 (SD = 2.96) |

Table 1 shows that the dyslexic group has a higher mean score than the non-dyslexic group on existing words, transparent words and opaque words. Only for pseudowords, the mean score of the non-dyslexic group is higher. However, only the difference in mean score on existing words was significant, $t(40) = -2.65$, $p < .05$. When looked at the difference between existing and pseudowords within the two groups, this was non-significant for the dyslexic group, $t(20) = -1.60$, $p = .13$, while it was highly significant for the non-dyslexic group, $t(20) = -5.47$, $p < .001$. The difference in mean scores concerning transparent and opaque words was significant among the dyslexic group, $t(20) = 5.00$, $p < .001$, and also among the non-dyslexic group, *t*(20) = 3.74, $p < .01$. Thus, both groups scored significantly better on transparent words than on opaque words. In addition, this difference in mean scores concerning transparent and opaque words was significantly greater for the dyslexic group, $r = .75$, than for the non-dyslexic group, $r = .64$.

## 4.3 Results LTD Reading Speed

The mean reaction times of the dyslexic and the non-dyslexic group on transparent and opaque words are shown in table 2.

*Table 2* *Mean reaction times of the dyslexic and the non-dyslexic children on the lexical decision task (reaction times in milliseconds)*

| | Dyslexic group (N = 21) | Non-dyslexic group (N = 21) |
|---|---|---|
| Existing words | 24441.9 (SD = 8853.45) | 21237.1 (SD = 4323.59) |
| Pseudowords | 43516.7 (SD = 29530.02) | 40288.7 (SD = 26098.75) |
| Transparent words | 35097.3 (SD = 16997.98) | 32379.9 (SD = 12685.92) |
| Opaque words | 32861.3 (SD = 20814.29) | 29145.9 (SD = 17408.08) |

Table 2 shows that dyslexics are slower on all word types than non-dyslexics. It also shows that the mean reaction times of the dyslexic children as well as those of the non-dyslexic children are faster on existing words than on pseudowords. This also holds for the opaque words, of which the mean reaction times are faster than on transparent words. The difference in mean reaction times between existing and pseudowords was significant for the dyslexics, $t(20) = -3.76$, $p < .01$, as well as for the non-dyslexics, $t(20) = -3.66$, $p < .01$. This difference was slightly greater for the dyslexic group, $r = .64$, than for the non-dyslexic group, $r = .63$. However, the difference in mean reaction times between transparent and opaque words was not significant for the dyslexics, $t(20) = 1.12$, $p = .28$, and neither for the non-dyslexics, $t(20) = 1.51$, $p = .15$.

## 5. Discussion

### 5.1 Conclusion

In this thesis, it was examined whether orthographic transparency alone causes the problems dyslexic readers encounter or that it is combined with other linguistic factors. Dyslexics and non-dyslexic children completed a lexical decision task in which they had to decide whether the shown word, either a transparent or an opaque one, was an existing word or not. The results have shown that there was a significant effect of word transparency on the accuracy with which the participants made the correct decisions. They performed significantly better when they were seeing a transparent word and significantly worse when they were shown an opaque word. While both the dyslexic group and the non-dyslexic group showed this significant difference, the effect size was greater for the dyslexics than for the non-dyslexics, supporting the predictions made in paragraph 2.4. However, there was no significant difference found concerning reading speed, measured by the reaction times during the lexical decision task. Although the mean reaction times on transparent words were higher than on opaque words for both groups, meaning that the response time was faster when opaque words were shown, this difference was non-significant. In conclusion, this thesis shows that orthographic transparency does play a significant role among dyslexic readers and that it is rather a property of words than of whole languages.

### 5.2 Implications

Because orthographic transparency influences the reading accuracy of dyslexics, more than of non-dyslexics, this could be a very important factor to keep in mind when developing new treatments for dyslexic children. When it is shown that the transparency of a word can influence the reading accuracy of a dyslexic child, treatments can be focused more on the trouble they have with opaque words since there is no one-on-one relation between graphemes and phonemes. At the same time, this thesis gives evidence for the argument that orthographic transparency is not just a property of whole languages, but a property of words. This thesis has been one of the first studies to investigate orthographic transparency within one single language, instead of between different languages. With the results of this thesis, it can be said that most of the Dutch words are transparent, rather than that Dutch is a transparent language. When stating that Dutch as a language is transparent, one can assume that opaque words in Dutch are very scarce. However, the Dutch vocabulary contains enough opaque words which are frequently used and with which dyslexics experience great difficulty. In this way, languages cannot be ‘more dyslexic’ or ‘less dyslexic’, instead words can be more difficult or less difficult for dyslexic readers. This study pointed out that opaque words are more difficult for dyslexics and transparent words are less difficult; concerning reading accuracy, not reading speed though.

Since orthographic transparency turns out to be an important factor among dyslexic, further research is needed on this topic. For instance by using a larger group of participants; also from different regions in the Netherlands since the participants in this study came from the same region. However, it is important to carefully select the stimuli in follow-up research because of the many Dutch dialects and regiolects. In this study, it was controlled for that no pseudowords were real or known words in the region from which the participants came. For further research it is recommended that the stimuli of existing words are better selected, especially when the dyslexic group is matched with a reading level group as in this thesis was done. There was the possibility in this study that a dyslexic older child, already knew a word like *ijskap* or *moraal*, while a non-dyslexic younger child did not knew that word. To control for this, stimuli must be carefully selected in that neither the dyslexics nor the non-dyslexics know the existing words, because then you are sure that you do not test the lexicon of the participants too, but only the effect of orthographic transparency on the recognition of the stimuli by the participants. In addition, further research in other languages is also needed. Many studies are done between different languages concerning orthographic transparency, but this is the first to study one single language. More results are needed from studies with other languages such as English or Spanish on this topic. In this way, the claim that has been made in this study, that orthographic transparency is a property of words rather than whole languages, can be further confirmed. When other studies confirm this claim, there can be further investigation to the implementation of this knowledge in the treatment of dyslexia. When the problem is not the transparency of a language, but the transparency of words in that language, treatment can be more specified for dyslexics who all speak different languages.

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Appendix

| Version A | | | | | |
|---|---|---|---|---|---|
| toekan | existing word | transparent | stuwer | existing word | opaque |
| beleid | existing word | opaque | kafeer | pseudoword | transparent |
| fykies | pseudoword | opaque | boerin | existing word | transparent |
| kalbon | pseudoword | transparent | mimiek | existing word | opaque |
| antiek | existing word | transparent | eclips | existing word | opaque |
| scharel | pseudoword | opaque | rebouw | pseudoword | opaque |
| rijles | existing word | transparent | delhin | pseudoword | transparent |
| bochel | existing word | opaque | omroep | existing word | transparent |
| rolaam | pseudoword | transparent | loitet | pseudoword | opaque |
| tankeb | pseudoword | opaque | ijpsak | pseudoword | transparent |
| leriëf | pseudoword | opaque | sulfer | existing word | opaque |
| mentor | existing word | transparent | witlof | existing word | transparent |
| foftee | pseudoword | transparent | papier | existing word | transparent |
| hangar | existing word | opaque | onraag | pseudoword | transparent |
| kosmos | existing word | transparent | delict | existing word | opaque |
| leding | pseudoword | opaque | nesros | pseudoword | transparent |
| cipier | existing word | opaque | lewerd | pseudoword | opaque |
| meezan | pseudoword | transparent | fazant | existing word | transparent |
| borset | pseudoword | transparent | pijbad | pseudoword | opaque |
| paling | existing word | opaque | vilzer | pseudoword | opaque |

| Version B | | | | | |
|---|---|---|---|---|---|
| lebeid | pseudoword | opaque | litwof | pseudoword | transparent |
| ijskap | existing word | transparent | banket | existing word | opaque |
| slager | existing word | opaque | heldin | existing word | transparent |
| moksos | pseudoword | transparent | locheb | pseudoword | opaque |
| ruwets | pseudoword | opaque | temron | pseudoword | transparent |
| fysiek | existing word | opaque | sorbet | existing word | transparent |
| pariep | pseudoword | transparent | lijres | pseudoword | transparent |
| berouw | existing word | opaque | reliëf | existing word | opaque |
| orgaan | existing word | transparent | afkeer | existing word | transparent |
| zilver | existing word | opaque | kimiem | pseudoword | opaque |
| roebin | pseudoword | transparent | escilp | pseudoword | opaque |
| toenak | pseudoword | transparent | zafant | pseudoword | transparent |
| sensor | existing word | transparent | toilet | existing word | opaque |
| rangah | pseudoword | opaque | ledict | pseudoword | opaque |
| toffee | existing word | transparent | deling | existing word | opaque |
| bijpad | existing word | opaque | moraal | existing word | transparent |
| orpoem | pseudoword | transparent | wereld | existing word | opaque |
| fulser | pseudoword | opaque | taniek | pseudoword | transparent |
| riciep | pseudoword | opaque | balkon | existing word | transparent |
| zeeman | existing word | transparent | laping | pseudoword | opaque |