Dyslexia in bilingualism

A case study of an English-Norwegian bilingual child with developmental dyslexia

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Abstract

Despite extensive research in bilingualism, there is a scarcity of studies investigating this area within the population of children with learning difficulties. Developmental dyslexia is a particularly interesting case of a learning difficulty as it concerns more directly the literacy aspects of learning and education. Spelling and reading difficulties reveal the challenges an individual with dyslexia faces; thus, understanding the impact of acquiring two different languages is vital for providing relevant interventions at school as well as for understanding the correlations between dyslexia and bilingualism. This study investigates the interactions between dyslexia and bilingualism, and aims to observe how dyslexia presents itself in a bilingual individual. The importance of language similarity, orthographic transparency and cognate effect is investigated through a set experiments and analysis of dyslexia assessment results. Data for this study is collected by means of qualitative (questionnaire and dyslexia assessment) and quantitative (RAN and word spotting tasks) methods based on a case study of an English-Norwegian bilingual with developmental dyslexia.

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1. Introduction

Accessing information through written language is one of the main ways of acquiring knowledge and staying informed. Despite the development of audio- and video-based technology that allows an alternative access to information, a significant amount of data is presented in text. Reading is a skill that is by most accepted as a given; however, for many it is a skill whose acquisition requires considerable amounts of effort and leads to frustration and anxiety. The most commonly diagnosed specific learning disorder affecting reading, writing and spelling is dyslexia. Its prevalence depends on language and population as well as the interpretation of the definition, but it is commonly estimated to range between 5% and 10 %. Considering its prevalence and impact on those affected, it is not surprising that dyslexia receives so much attention from research in multiple fields, such as linguistics, education and neuroscience. Understanding its aetiology and symptoms does not only shed light on how educators can plan interventions for dyslexic learners more effectively, but it also provides psycholinguists with additional perspectives on the mental processes, such as reading.

However, despite the vast amount of research on dyslexia, very little is known about its manifestation in speakers of multiple languages. Due to an increase in globalisation and migration, bilingualism has become more common than monolingualism among many populations. It is commonly believed that if a child has dyslexia, learning another language can be challenging or that being brought up in a bilingual setting might have a negative impact on the child's reading and writing skills development. While this belief is unsupported by research, the concern remains. At the same time, there is little research providing insight into how dyslexia manifests itself in bilingual speakers, and while the commonly held belief has weakened due to a more multicultural world, there is still a shortage of studies providing insight into the influence of bilingualism on dyslexia difficulties and the manifestation of dyslexia in bilingual individuals. It is, therefore, particularly important to investigate the relationship between these two populations.

Bilingualism is linked to multiple advantages, such as better-developed metalinguistic skills and enhanced executive function (Bialystok et al., 2008, 2014). If it can, indeed, enhance executive function, it becomes particularly relevant to studies on neurodevelopmental disorders, such as attention and hyperactivity disorders (ADHD, Corbett et al., 2006; Pani et al., 2013); autism (Rinehart et al., Robinson et al., 2009); and developmental dyslexia (Booth et al., 2010), which are directly related to changes in executive control. Developmental dyslexia is particularly interesting as it is concerned with reading skills; thus, it is interesting to investigate this particular neurodevelopmental disorder in the context of bilingualism. More recently, a number of studies, which investigate the relationship between the bilingual cognitive advantages and dyslexic individuals have been conducted by Vender and colleagues (e.g., Vender et al. 2018a; Vender et al. 2018b; Vender et al., 2019; Vender & Melloni, 2021).

However, investigating dyslexia in bilingual speakers has also important implications for understanding the impact languages have on each other, as well as how the process of reading and writing in two languages is affected by dyslexia. Languages differ not only in terms of their writing systems (i.e., the level at which sound is represented in script; e.g., letter-to-sound in most alphabetical languages), but also other properties, such as orthographic transparency. Orthographic transparency concerns the mapping between the graphic and phonological forms in a particular language (Miller, 2019). This correspondence between a grapheme and a phoneme determines how direct the mapping between written symbols and sounds in languages is (Snowling, 2019). Being exposed to two different scripts and orthographies of divergent transparencies might have an additional impact on the difficulties experienced by dyslexic bilinguals.

Furthermore, research in bilingualism has demonstrated that there is a correlation between linguistic similarity of the two languages and the amount of effort necessary to select the target language and inhibit the competing language (e.g., Prior and Gollan, 2011). This correlation is related to two prominent concepts in bilingualism, i.e., non-selective nature of linguistic activation (e.g., Abutalebi et al., 2008; Kroll et al., 2008; but see Costa & Caramazza, 1999) and Inhibition control (IC; Green, 1998). The non-selective language processing theory posits that both languages are activated in a parallel manner in the mental lexicon, and effort must be expended to inhibit the irrelevant language (Green, 1998). This might have particular implications for dyslexic individuals. If the languages share some properties (e.g., similar phonology or syntax), that might inhibit or facilitate lexical access. Cognate status (i.e., the degree of sharing of form and meaning across languages; e.g., *knife* [English] and *kniv* [Norwegian]) is of particular significance as it can have a vast impact on dyslexic individuals.

The objective of this study is, therefore, to investigate the interactions between dyslexia and bilingualism, and to observe how dyslexia presents itself in a bilingual individual. The approach in this work will focus on language dissimilarity in terms of orthographic transparency. The languages investigated here are English and Norwegian. The language choice is primarily justified by the context in which the investigation has taken place, i.e., an international school in Norway; however, it is also an interesting combination of languages due to their syntactic and semantic similarities as well as orthographic transparency dissimilarities.

The following work will first present the theoretical framework that will be the basis for the investigation as well as discuss most recent research in the areas of dyslexia and bilingualism relevant to the current study. It will then present a case study of a bilingual child who was diagnosed with dyslexia at the age of nine. Predictions concerning this particularly study will be discussed before the method section. The results of dyslexia assessment carried out on the pupil before the investigation as well additional tests will be presented and discussed. Finally, two tests designed to investigate the status of cognates in the bilingual dyslexic child will be presented and analysed.

2. Theoretical Framework

2.1. The written language

The connection between language and its written representation cannot be simply expressed in a direct one-to-one manner and requires a more thorough explanation. A crucial point is that the written system does not encode the meaning directly; it encodes the spoken language (Perfetti, 2003). They are, however, not equally comparable, and thus, cannot be analysed in a parallel manner (Aronoff & Rees-Miller, 2001). While the human language is a result of evolution, and infants acquire it naturally as part of their cognitive and social development, the written representation of language is a human construct, and as such it necessitates explicit instruction to be learned (Aronoff & Rees-Miller, 2001). Furthermore, *phoneme* and *morpheme,* which represent unconscious abstractions of the mental lexicon, are specifically defined and identified through property contrast to other items within their class (e.g., through the property of voicing, zeal and seal are distinguished by means of one phoneme contrast) and cover variants of one item (allophones and allomorphs e.g., English morpheme {past} comprises allomorphs /t/, /d/, and /Kd/). The smallest sound constituents of language, i.e. phonemes, converge to create morphemes, which constitute the smallest meaningful units of language, which in turn create words. A grapheme, on the other hand, is argued to be less precisely defined as it might relate to a phoneme or morpheme depending on the writing system it belongs to (Aronoff & Rees-Miller, 2001). Two perspectives are commonly applied when defining the concept of a grapheme: the *referential* view (where the grapheme is interpreted as a written unit referring to a phoneme) or the *analogical* view where grapheme is interpreted as a written unit that is lexically distinctive (Meletis, 2019). The referential view is more popular (e.g. Berndt, Reggia & Mitchum, 1987) (see also Henderson, 1985 for a discussion). Hence, the difference between a grapheme and a letter is that a grapheme maps directly into a phoneme. The graphemes *ea* and *ch* in *beach* map directly onto phonemes /e/ and /tʃ/ respectively. Thus, the mapping from orthography to phonology is more direct with the use of graphemes (Rey, Ziegler & Jacobs, 2000). In terms of the *analogical* view, a grapheme is tested via written minimal pairs (e.g., *house* and *mouse*), and similarly to phonological minimal pairs, it distinguished on the basis of one phoneme change. However, both views have been criticised on the basis that they are restricted to alphabetic writing systems (Meletis, 2019). Meletis (2019) claims that this concept needs to have a universal definition to allow a comparison of different writing systems. His proposal is to define graphemes as "units of writing which are (1) lexically distinctive, (2) have linguistic value (mostly by referring to phonemes, syllables, morphemes, etc.) and are (3) minimal" Meletis (2019, p 26). Overall, it is evident that the relationship between a defined phoneme and a more vaguely described grapheme can lead to challenges in establishing the direct connection between these concepts. This is particularly true when comparing languages and attempting to find similarities and patterns.

Languages differ in terms of the writing system they belong to and the orthography they are represented by. The writing system of a language determines the level at which the phonological information of a grapheme is encoded (Braze & Gong, 2017; Miller, 2019). In other words, the writing system defines the mapping between the symbols and linguistic units (Braze & Gong, 2017). The written system is defined as:

> a system of more or less permanent marks used to represent an utterance in such a way that it can be recovered more or less exactly without the intervention of the utterer. (Daniels & Bright, 1996)

Or

> a set of visible or tactile signs used to represent units of language in a systematic way, with the purpose of recording messages which can be retrieved by everyone who knows the language in question and the rules by virtue of which its units are encoded in the writing system. (Coulmas 1999, p.560)

The writing systems can be divided in terms of the level at which sound is represented in script. One way of representing sounds in writing is by assigning one specific symbol to each morpheme. This kind of writing is referred to as *logographic*, an example of which is Chinese with logograms encoding the meaning of specific words. The alternative type of the writing system, referred to as 'phonographic' (Rollings, 2004), encodes each sound at a syllable (syllabic) or letter (alphabetic) level of word (Perefetti & Liu, 2005). Most European languages are represented by an alphabetic writing system, and English is one of them; however, its grapheme-to-phoneme correspondence often goes beyond one letter to one sound correspondence. This point will be further elaborated on in the following section.

Within a specific type of writing system, one can distinguish different orthographies corresponding to each specific language. Orthography refers to a specific mapping between the graphic and phonological forms within one language (Miller, 2019). Thus, while English and Norwegian both belong to the alphabetic writing systems, they differ in their orthographies and grapheme-to-phoneme correspondence. To understand the spelling-to-speech correspondence, it is pertinent to discuss in more details the concept of orthographic transparency. Orthographic transparency refers to the orthographic representation of phonology in a particular language. It is expressed through grapheme-to-phoneme correspondence, which determines how direct the mapping between written symbols and sounds in languages is (Snowling, 2019). A commonly used term in the context of orthographic transparency is 'orthographic depth', which refers to the regularity of the grapheme-to-phoneme correspondence (Snowling, 2019). The more consistent and transparent the correspondence between symbols and sounds is the shallower the language is.

Conversely, an opaque language with many inconsistencies in the grapheme-to phoneme correspondence is considered a deep language. Thus, for example Finnish is considered a transparent (shallow) language where the correspondence between graphemes and phonemes is somewhat regular, while English is an example of an opaque (deep) language with many irregularities. What is meant by irregularity is the inconsistent matching between specific graphemes and phonemes within a language. For example, a given grapheme (e.g., [d] in *damage, educate, picked*) may represent more than one sound (i.e., /d/, / dʒ/ and /t/); and one sound (e.g., /ɪː/) may be represented by more than one grapheme (*meet, niece, quay, city*, Reid et al., 2008). The grapheme-to-phoneme correspondence is a feedforward manifestation of the orthographic transparency, while the phoneme-to-grapheme is a feedback manifestation of it (Lete et al., 2008 in Borleffs et al., 2019). The former can be exemplified in English with the grapheme 'a', which is pronounced differently in each of the following words: *lake*, *was*, *bag*, and *raw* (Borleffs et al., 2019). A relevant example of the latter can be the sound /k/, which is represented differently in spelling: *king*, *calm*, *opaque*, and *track* (Borleffs et al., 2019).

2.2. Decoding the written language - Normal reading development

While the process of encoding (i.e., using written symbols to express the sounds of speech) is important for the understanding of the relationship between speech and the written language, the process of reading development is crucial for understanding how readers decode i.e., recognise the written symbols as expression of sound units linked to meaning. Reading is a complex cognitive process that involves decoding written symbols and deriving linguistic meaning from the text (Catts & Kamhi, 2005). These two components of the reading process are based on the idea of a Simple View of Reading proposed by Gough and colleagues (Cough & Tunmer, 1986; Hoover & Gough, 1990 in Catts & Kamhi, 2005). They proposed to avoid applying a broader view of reading, which involves higher level thinking processes (such as evaluating, imagining, reasoning etc.) that can be developed and achieved by those who cannot read, as these processes are part of language use in general and are not limited to reading (Fries, 1963 in Hoover & Cough, 1990). Decoding, as previously stated, is the ability to convert graphic stimuli into linguistic referents (Crystal, 2011). The second component of the Simple View of Reading is linguistic comprehension, which relates to applying higher cognitive linguistic processes that allow the interpretation of words, sentences and discourses (Gough & Tunmer, 1986 in Catts & Kamhi, 2005). While reading has generally been considered a complex process, specific stages of this process can be distinguished and described.

More intensive and thorough research on reading development started in the 80s of the 20th century and researchers such as Charles A. Perfetti (1985), Marilyn J. Adams (1990), Philip Gough and Wesley A. Hoover (1990), and Linnea Ehri (1991) contributed significantly to the understanding of the stages this skill involves. The principles and ideas developed over the years have significantly contributed to the formulation of the model of typical reading development that will be discussed here. This model was initially developed by Louise Spear-Swerling and Robert Stanberg (1994, 1996), and it was further modified by Spear-Swerling (2013). This model of reading development describes six phases involved in the progression of proficient reading.

The first phase, i.e., Visual-Cue Word Recognition (also referred to as pre-alphabetic word recognition; Ehri 1991, 2005) refers to the period before a child learns alphabetic principles and relies on visual cues such a distinct shape of a word or a logo; i.e., contextual cues (Mason 1980). The context is particularly important as the child might recognise the word in a common setting (e.g. word *stop* on a red octagonal sign), but will usually fail to recognise the same word written in a different font or in a different context. The second phase is the Phonetic-Cue Word recognition (partial alphabetic reading), which begins around the time the child starts preschool or first grade. In this phase, the child can recognise some words, in particular the ones that begin with letters they can already associate with the correct sounds. There is a certain level of phonological awareness (i.e., an ability to manipulate, discriminate and recognise the sounds of a specific language; Wagner & Torgesen 1987) and some understanding of alphabetic principle (i.e., knowing that words consists of letters that represent specific sounds and being able to connect letters with their corresponding sounds in order to read and write). Typically, around this stage, the child can identify a word based on the initial and final letters. However, as the phonemic awareness (i.e., the understanding that spoken language can be divided into individual phonemes) is not developed yet, most of the letters in the middle of the word will not be recognised, and similarly spelled words can be easily confused (e.g., *boat* and *boot*). Word recognition must be, therefore, accompanied by visual cues to help recognise the context.

The following phase, which is called the Controlled Word Recognition (also called: full alphabetic; Ehri, 2005), is associated with a period where a child can fully use phonetic cues in word recognition. The level of phonemic awareness is much higher, and children in this phase, have a broader knowledge of grapheme-sound correspondence. Multisyllabic words are still challenging, and the word recognition is still not automatic at this stage. This phase is followed by Automatic Word Recognition (consolidated alphabetic phase; Ehri 2005), which involves the ability to automatically and accurately recognise a significant amount of common words. At this stage, a child uses the knowledge of letter patterns recurring in different words (e.g., prefixes, rimes), and the connections between graphemes and phonemes at a lower level become consolidated and allow the recognition of larger units (morphemes, syllables). Particularly, this ability to recognise larger units facilitates reading multisyllabic words (i.e., instead of relying on ten graphemes in the word *interesting*, the reader can use the knowledge of only four syllabic chunks (Ehri 2005). This ability leads to greater fluency in reading and less reliance on context.

Subsequently, the reader reaches the Strategic Reading phase (around third to fourth grade) where reading comprehension strategies are applied. In this phase, a child will not only accurately recognise all the words in a sentence, but also use contextual information to establish the meaning of a new word. For example, Spear-Swerling (2013) explains that in the sentence: "Her scarlet cape flashed red in the crowd", the sentence context will allow to determine the meaning of the word *scarlet*. Moreover, around this phase, children posses a more developed morphological awareness (i.e., explicit knowledge of the smallest units of meaning, morphemes, and the ability to recognise and manipulate the structure of words by identifying prefixes, roots, and suffixes; Carlisle, 2010; Kirby et al. 2012). Morphological awareness is, however, present in pre-alphabetic children who can recognise morphemes in words they hear (e.g., the use of final -s, to signal plurality in a word like *dogs,* Spear-Swerling 2013). In the strategic reading phase, reading becomes a tool for collecting information and vocabulary development (Cunningham & Stanovich, 1991 in Spear-Swerling 2013). Finally, in the Proficient Reading phase, the reader can read critically and access more sophisticated literature. This contributes to a considerable development in verbal abilities, vocabulary range and general cognitive skills (Stanovich, 2000 in Spear-Swerling, 2013).

While these stages of reading development are universal across all languages, there are certain differences between various languages that concern the level at which the linguistic decoding takes place. Understanding the divergent orthographic complexity of various languages helps to understand why the reading process in different languages takes a slightly different form and time.

2.3. The orthographic depth hypothesis and the Grain size Theory

Two theoretical concepts are particularly relevant to understanding of how reading acquisition process unfolds in different languages. The two cross-language theories are *the orthographic depth hypothesis* (Katz & Feldman, 1983; Katz & Frost, 1992) and t*he grain size theory* (Ziegler & Goswami, 2005). The orthographic depth hypothesis posits that languages which exhibit different degrees of complexity in their correspondence between spelling and speech are expected to demonstrate different levels of dependence on articulatory coding, i.e., way of remembering a word not by storing its sound or meaning, but by storing the physical movement necessary to "produce its verbal expression" (Oxford dictionary of Psychology 2014) While the Orthographic Depth Hypothesis emphasises the importance of grapheme-to-phoneme correspondence, the Grain Size Theory (Ziegler and Goswami, 2005) provides a more thorough account for crosslinguistic variations in reading stemming from orthographic differences. "Speech recoding" concerns the mechanisms involved in translating written text into "internal speech", which, in turn, relates to speechlike mental representations devoid of overt and audible articulation (Alderson-Day & Fernyhough, 2015). A more varied approach means more flexibility in terms of the levels at which written speech recoding takes place. This is directly correlated with phonological awareness, which is developed in a sequence beginning with a shallow sensitivity to large phonological units (i.e., syllables) and ending with a deep sensitivity to small phonological units (i.e., phoneme; Ziegler & Goswami, 2005). A number of studies have demonstrated a hierarchical progression in the development of sensitivity to linguistic units in children (e.g.,see examples of studies discussed in Ziegler & Goswami, 2005). Children's sensitivity to larger phonological units develop earlier than their sensitivity to smaller units (Miller, 2019). Thus, word-level skills are mastered earlier than syllable-level skills (ca. the age of 3-4), and the syllables are mastered before onset-rime skills (ca. the age of 4-5), with the phoneme-level skills being mastered once children learn to read and write.

In some languages, reading relies more on the letter-to-phoneme correspondence (e.g., many alphabetical languages that have a clear correspondence, such as Italian or Finnish), while others must rely on bigger grain size units. This is because different languages have different levels of 'grain size 'at which the mapping between a visual symbol and a unit of sound is formed. Alphabetic languages exemplify a *fine-grained* level of mapping between letters and sounds, while logographic languages (e.g., Chinese) demonstrate a *coarse-grained* level between characters and syllabic units (Snowling, 2019). According to the Grain Size Theory, the differences in reading speed and accuracy between readers of various languages are linked to the different ways in which phonological recoding takes place (reading strategies differ in different orthographies). Thus, in a deep language, such as English, using larger units (e.g., rime) appears more effective than relying on smaller units (graphemes), which are highly inconsistent in English (Ziegler & Goswami, 2006). In fact, reading in English and similar orthographies might rely on both 'small unit' and 'large unit' recoding strategies simultaneously (e.g. Brown & Deavers, 1999 in Ziegler & Goswami, 2006). English, being an alphabetic language, poses a challenge to beginner readers, as the letter-to-phoneme correspondence turns out to be too small to actually decode the language successfully. The reader needs to rely on larger grain size, i.e., rimes, syllables, and morphemes.

The importance of orthographic depth has been investigated, for example, by Seymour, Aro and Erskine (2003), who compared 13 European languages with an alphabetic writing system. Children (at the end of Grade 1) from 13 different linguistic backgrounds were instructed to read single words and non-words aloud. Their study revealed a significant impact of orthographic depth. Children whose languages had more transparent orthographies performed better than children reading in English. The authors have, however, recognised that the results might not be conclusive as children start schooling at different ages (the English children were, on average, two years younger than the other groups of children in the study). However, a study by Spencer and Hanley (2004), which also investigated orthographic depth, provides an additional insight into this debate. The children in their study, came from Welsh and English schools which have similar forms of reading instruction and where children start schooling at the same age. The significant difference, however, was that, unlike English, Welsh is a transparent language. The results revealed a significant advantage of the Welsh children over the children from the English group, which supports the presupposition that orthographic depth plays a role in learning to read. However, despite the difference in performance between the two groups of children in their first year of reading acquisition, the authors admitted that these results of initial gains do not necessarily predict later advantages in reading comprehension.

2.4. Morphological complexity as a factor in reading development in opaque languages

Orthographic transparency has been studied as one of the main contributing factors to differences between reading acquisition in various languages. However, morphological complexity, which receives less attention in research, might provide additional insight into the understanding of the reading process in bilinguals. Morphological complexity concerns the structural composition of a word. It involves the likelihood and number of morphemes (smallest meaningful until of language that cannot be further divided e.g., in the word *worked*, *work* and *–ed* are two separate morphemes the second marks the past form of the verb) a particular lemma (canonical form of the word, commonly presented in a dictionary) can have. It is defined as the ability to recognise a root word and its morphemes, which greatly contributes to one's reading accuracy and speed. Lemmas, such as e.g., *work* might be part of a morphologically complex word with derivational (e.g., a *worker*) and inflectional (e.g., *working*) prefixes and suffixes or be part of a compound (e.g., *workplace*). As it has been previously noted, word-level skills are mastered earlier than syllable-level skills and the phoneme-level skills (Miller, 2019). Moreover, it has been demonstrated that morphological awareness becomes increasing more important for reading throughout the school years (e.g., Casalis, Colé & Sopo, 2004 in Borleffs et al., 2019), while the knowledge of morphology continues to develop (Berninger et al., 2010 in Borleffs et al., 2019). There is a progressive increase in reading achievement correlated to morphological awareness (Casalis, Colé, & Sopo 2004). This is particularly relevant to opaque languages as the reader uses the morphological structure of words (Borleffs et al., 2019), and the orthographies of these languages are controlled both by phonology and morphology. A particularly interesting point that Borleffs et al. (2019) make is that what is considered a phonemic irregularity in a given language (e.g., silent letter *b* in *bomb* in English) can be explained by means of morphology (*b* in *bombardment* becomes regular).

So far it has been empirically demonstrated that it takes significantly less time for users of transparent orthographies to become accurate and fluent readers than it takes for users of less consistent, opaque orthographies (Seymour et al., 2003). Thus, phonemic awareness and the grapheme-to-phoneme correspondence have been commonly accepted as significant factors in the development of reading skills. Fewer studies have investigated the importance of other typological properties (e.g., morphological complexity) of the given orthography on reading skills and dyslexia. Considering the fact that in alphabetic languages, both phonological and morphological information is recorded in the written form (Casalis, Colé & Sopo, 2004), it can be expected that morphological awareness plays a role in the reading process as well. In fact, there is a strong correlation between morphological awareness and phonological awareness (Casalis, Colé & Sopo, 2004). For example, in a study investigating knowledge of derivational morphology (Carlisle, 1988 in Casalis, Colé & Sopo, 2004), a sentence completion task devised to examine the complexity of transformations between base and derived forms revealed an effect of phonological abilities during a morphological process. The study demonstrated that if there was a phonological change in the derived form (e.g. *fifth;* base*: five*), as opposed to no change (e.g., *fourth*; base: *four*), the former case proved more challenging than the latter (Carlisle, 1988 in Casalis, Colé & Sopo 2004). This correlation between morphological and phonological awareness has also been demonstrated in a segmentation task (Casalis, 2001 in Casalis & Colé, 2004). In his study, Casalis (2001) presented evidence for a dependency of morphological segmentation on phonological segmentation. When deleting a suffix in a derived word, the task was more difficult when it required the "breaking up" of the last syllable (*rouge/rougeur* - red/redness*),* as opposed to the case where such manipulation was not necessary as the suffix corresponded to the entire last syllable (*noir/noirceur* - black/blackness). The correlation between morphological awareness and phonological awareness suggest that both play a role in the process of learning to read.

2.5. The dual-route model of reading

One of the most extensively studied and discussed models of reading is the dual-route model of reading (see Figure 1; Coltheart, Rastle, Perry, Langdon, & Ziegler 2001; Baron, 1977). It is a model of normal reading; however, understanding its stages and elements provides clues for explaining patterns of developmental dyslexia.

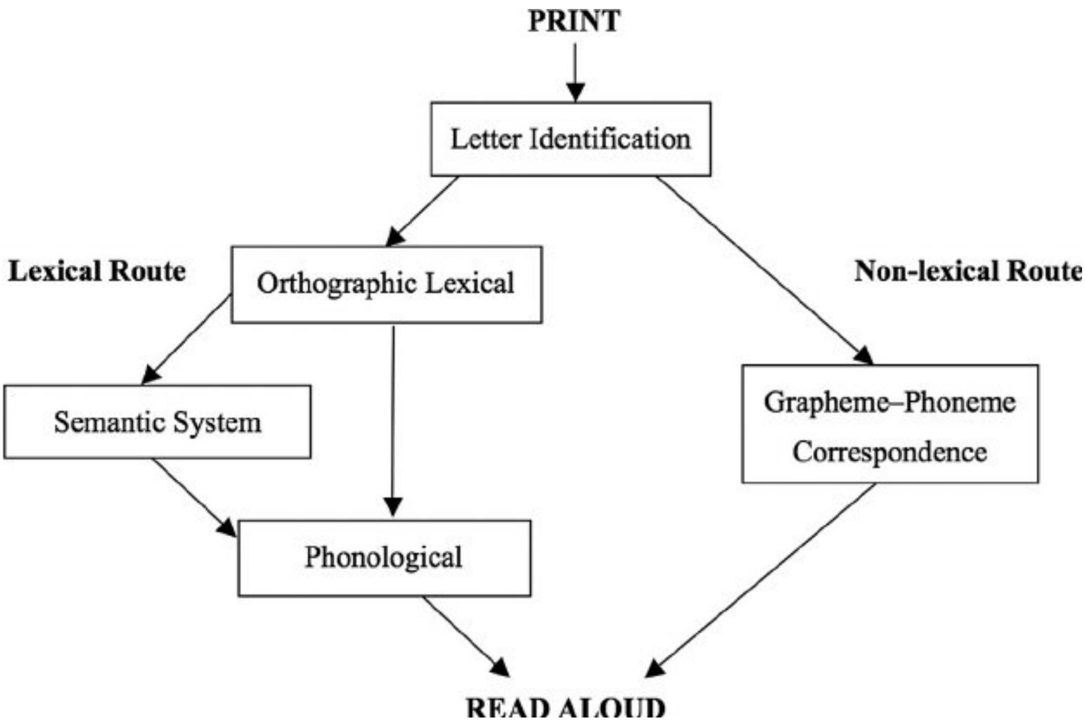


Figure 1. Dual-route model of reading. Adapted from Coltheart, M. (2006). Dual route and connectionist models of reading: An overview. London Review of Education, 4(1), 5-17.

The dual-route model of reading (see Fig 1; [Coltheart, Rastle, Perry, Langdon & Ziegler, 2001) suggests that there is a direct access (lexical route) for words with irregular grapheme-phoneme correspondences (e.g., *steak*, whose grapheme *ea* is not pronounced in the most common way, as in *speak*, *leak* or *sneak*) and an indirect sub-lexical route used for regular words (e.g., *hint* and *rave* as they are pronounced according to the standard pronunciations of their graphemes. These can be juxtaposed with *pint* and *have*, which do not follow the common pronunciations.) new words or pronounceable nonwords (letter strings whose patterns resemble regular words, but which are not part of the lexicon of a particular language; e.g., *smeak*, *nate*, [Harley, 2008]). In addition, some languages (e.g., English) have a number of extremely irregular words whose letter patterns do not resemble other words in that language (they do not have close lexical neighbours), which makes the word recognition and reading processes more challenging (e.g., *yacht*, *island*; Harley, 2008). The idea of a dual pathway of reading seems to have been initially suggested by de Saussure:

> We read in two ways; the new or unknown word is scanned letter after letter, but a common or familiar word is taken in at a glance, without bothering about the individual letters; its visual shape functions like an ideogram. (de Saussure, 1922; translated 1983, p.34 as cited in Coltheart 2005)

In the 1970s, two independent teams of linguists proposed comparable conceptions of the reading model which distinguished non-lexical and lexical routes of reading. Both Forster and Chambers (1973) and Mashall and Newcombe (1973) suggested that grapheme-phoneme rules appear to be involved in the pronunciation of new or unknown words, while familiar and irregular words are accessed via a semantic route (Forster and Chambers 1973 and Mashall and Newcombe 1973 in Castles, Bates & Coltheart, 2006). Figure 2 illustrates the stages from perceiving the written word to pronouncing it out loud.

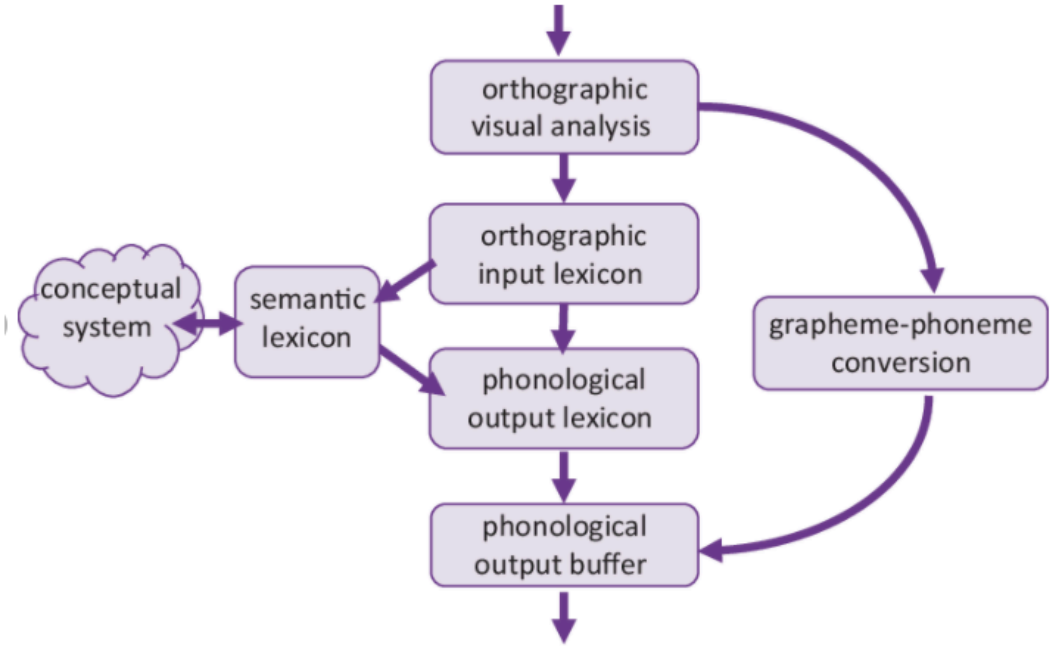


Figure 2. The Dual-route model for single word reading.

Note: Adapted from Friedmann, N., & Coltheart, M. (2016). *Handbook of communication disorders: Theoretical, empirical, and applied linguistics perspectives*.

The word is initially analysed by the orthographic-visual analyser (letter recognition system), which identifies letters, encodes the position of each letter and binds them to words (DRC; Coltheart et al., 2001). Thus, regardless of the type and size of the font used in the written text, this system allows one to recognize the relevant abstract letter and encode its position relative to the first and final letter of the word (Friedmann & Coltheart, 2016). The word is then stored in the graphemic/orthographic input buffer, which is sensitive to word length. Here, the words undergo morphological decomposition as the identification of the word in the lexicon requires the plain form of the stem, which can activate the corresponding entry. For example, the word 'houses' will be decomposed to 'house' and the plural marker 's'. After this stage, the information moves both to the lexical and sub-lexical routes. The lexical route begins with the orthographic input lexicon, which stores entries for familiar words, i.e., those the reader has previously encountered in written form (Friedmann & Coltheart, 2016). More frequent words are more rapidly accessed than low-frequency ones. The following stage involves accessing the phonological form, which takes place in the phonological output lexicon. This lexicon contains abstract sound information about the word. Finally, the information is transferred to the phonological output buffer. Here, the phonological information is held until the word is articulated. It is also in the phonological output buffer that smaller units (phonemes) are assembled into larger ones (words), and affixes are reunited with their stems (as in 'house' and '-s' plural marker) (Dotan & Friedmann, 2015 in Friedmann & Colheart 2016).

The lexical route is the one through which known and irregular words are processed. Regular words, non-words and newly encountered words require the sub-lexical route to be decoded. In the sub-lexical route, grapheme-to-phoneme conversion rules are applied during the reading process. Three stages are distinguished in the sub-lexical process of reading; i.e., *graphemic analysis, print-to-sound conversion* and *phonemic blending* (Coltheart, 1985; Friedman, 1995). The first stage involves the parsing of letters into graphemes. During the second stage, phonemes are assigned to the parsed graphemes. Finally, at the *phonemic blending* stage, phonemes are assembled in the phonological output buffer into a phonological representation of a word.

Both routes are believed to be activated during the reading process in skilled readers. The conceptual-semantic system is accessed in this process for comprehension and for choosing the correct pronunciation of heterophonic homographs (e.g., "lead", which is pronounce differently depending on whether the speaker refers to the chemical element (noun) or the action of being in charge (verb) in sentence context (Friedmann & Colheart, 2016). Reading via the lexical route is generally faster than via the sub-lexical route, which is used if the reader does not have a stored representation of the word in their lexicon. However, in the case of low frequency words, the time required to access the word in the reader's lexicon may lead to the activation of both routes, which, in turn, can result in delayed production if both provide different outputs. Low-frequency words will exhibit a larger regularity effect (consequence of a conflict resulting from an irregular word being analysed both through the lexical and non-lexical routes, which results in longer reaction time) because processing through the lexical route will be slower than in the case of high-frequency words, which will give the non-lexical route more time to simultaneously create a conflicting output.

The dual-route model o reading was designed in a way that would explain not only normal reading process, but also acquired and developmental reading disorders. Impairments to any of the stages of the reading process or connections between them can lead to specific reading difficulties, such as dyslexia, which is the most commonly recognised learning disability with a specific focus on problems with decoding abilities reading comprehension and spelling.

3. Dyslexia

3.1. Definition of developmental dyslexia

Defining dyslexia has proven to be a complex task as reading skills vary within the population, and there is no clear boundary between dyslexia and ‘normal’ reading. This dimensional characteristic of dyslexia leads to arbitrary attempts at deciding who is and who is not considered dyslexic in a particular context (Fletcher and Lyon, 2008). Furthermore, difficulties with establishing essential inclusionary and exclusionary characteristics of dyslexia have led to issues with identifying it (Fletcher and Lyon, 2008). Nevertheless, the concept is important because it helps to communicate the need for support and interventions in educational settings (Snowling, 2019). Numerous definitions of dyslexia have been suggested and applied within the educational and clinical contexts for diagnostic and intervention purposes. For the purpose of this work, the current definition of dyslexia by the International Dyslexia Association will be used. The definition has not changed since 2002 (IDA, Lyon et al., 2003) and is a revision of a previously applied definition from 1994. The definition from 2002 is, however, more specific and recognizes the neurobiological basis of dyslexia.

> “Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding [1]abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge. (Lyon et al., 2003)”

The definition characterizes dyslexia as a specific learning disability, which is crucial in distinguishing it from other learning disabilities (LD), particularly because there are clear criteria for identifying it (Fletcher and Lyon, 2008). It is precisely the difficulty in accurate and/or fluent reading of individual words and the struggle with spelling and decoding abilities, which distinguish dyslexia from the more general term ‘learning disabilities’ (LD). The difficulties lie in the domain of reading and spelling, which are unexpected considering

[1] Using the knowledge of letter-sound correspondences to correctly pronounce written words

the age and IQ of the person (Snowling et al., 2020). However, the explanation that dyslexia is 'specific' because of the aforementioned discrepancy characteristics has lost its credibility as it has been challenging to actually identify qualitative differences in reading that would distinguish children with dyslexia from those with more general learning problems (Snowling et al., 2020). Stanovich (1991 in Snowling et al., 2020) argued that lower scores on the IQ test (e.g., Wechsler scales, which are tapping both verbal skills and non-verbal/performance skills) might be the result of poor reading; hence, IQ-based discrepancy is not a reliable method of distinguishing dyslexic readers.

The definition further states that dyslexia is "neurobiological in origin", which is particularly interesting considering the evolution of the concept. Towards the end of the 19th century, Rudolf Berlin and Dejerine proposed that there exists a neurological reason for reading difficulties (Stein, 2017). Rudolf Berlin - a German ophthalmologist - was, in fact, the first one to use the term *dyslexia* with reference to his stroke patients who displayed a loss in reading ability despite other cognitive skills remaining unaffected (Stein, 2017). The idea of dyslexia being a neurological condition was further explored by a General Practitioner, Pringle Morgan, in 1896, who had a 14-year-old patient who was unable to learn to read or write despite having otherwise well-developed cognitive skills. Morgan (1896, in Stein, 2017) suspected that his patient's ability to perceive written text was the central cause of his condition; thus, he referred to it as "word blindness". This defect in visual perception, however, was later no longer considered the sole reason for difficulties experienced by dyslexic children. After the introduction of Universal Grammar and principles of 'generative phonology' (Chomsky, 1955), the views of developmental dyslexia shifted towards a deficit in the ability to acquire phonological skills and the visual basis of dyslexia was rejected completely. However, while the phonological deficit theory has been the dominant hypothesis explaining dyslexia, the neurobiological origin of dyslexia has been, in fact, supported by evidence from functional magnetic resonance brain imaging (Stein, 2017), and other neurobiological investigations (Lyon, 2003) that reveal differences in the temporo-parieto-occipital brain regions between regular readers and dyslexic readers. It is also crucial to recognize the importance of stating that reading difficulties associated with dyslexia appear unexpected in relation to the "provision of effective classroom instruction". This refers to the fact that these difficulties prevail despite adequate training in reading.

Furthermore, dyslexia is not related to general developmental delays and is not a general learning disorder. While dyslexia is not directly related to other cognitive abilities, comorbidity with other learning difficulties (e.g., moto-perceptual dysfunction syndromes or distractibility) is not uncommon. Lyon et al. (2003) stress, however, that while it is common for other comorbid deficits (e.g. in attention and mathematics) to co-occur in individuals with dyslexia, the cognitive characteristics of these comorbid deficits are nevertheless distinguished from the cognitive characteristics of deficits in basic reading skills. Elbeheri and Everatt (2007) point out that whether this co-occurrence is included in the definition of dyslexia or not depends on whether dyslexia is perceived as a purely literacy-focused difficulty or a multi-dimensional one involving other learning difficulties. This is further complicated by an attempt to establish whether dyslexia should be defined based on what the dyslexic person is lacking in comparison to some norm (exclusionary characteristics) or what such a person exhibits beyond the literacy problem (inclusionary characteristics). For example, Elbeheri and Everatt 2007) refer to the phonological deficit viewpoint as one explaining low reading levels in dyslexic people as a result of an underlying phonological deficit. In contrast, the IQ-reading achievement discrepancy method defined dyslexia in terms of what the reading weakness is not (i.e., it is not due to low intelligence). In fact, the IQ-reading achievement discrepancy method was one of the most commonly used diagnostics of dyslexia until 2004. However, as Snowling (2019) explains, IQ is no longer treated as a factor in diagnosing dyslexia, as discussed above. Instead, "response to interventions" is considered a more reliable measure for identifying the likelihood of dyslexic difficulties. Response to intervensions involves the child's response to provision specifically targeting the difficulties. If despite the effort and consistent and intensive support, the child's achievement levels are low or average, it is considered a good indication of dyslexia (American Psychiatric Association 2013 in Snowling et al. 2020). Fletcher & Vaughn (2009) argue that in the case of positive response to treatment where a child can catch up with peers, it is concluded that the condition is not persistent; thus, the label of dyslexia is not applicable. However, this approach has been criticised on the basis that the likelihood of being diagnosed following a comprehensive assessment with objective standards for referral is just as high as failure to respond to well-founded interventions. Thus, it is argued that it seems counterproductive to evaluate the response to intervention and wait with a formal assessment. Considering the above, Snowling et al. (2020) propose a few points to consider when diagnosing dyslexia. They argue that the term should not be used as an abbreviation for reading disorder and should only relate to a persistent difficulty with decoding and spelling fluency with an onset in early school years. Furthermore, they posit that there should be a slower progress in literacy-based areas at school, and a general weaker academic performance. Finally, they insist that co-occurring features should not be included in the main diagnosis, and the diagnosis should be defined as mild, moderate or severe.

In November 2016 at the IDA conference, the definition of dyslexia from 2002 was revisited; however, no changes were made as there was a general consensus among researchers and practitioners partaking in the conference. They concluded that both for research and practical purposes, the definition is relevant and meaningful; it provides inclusive criteria, but no operational criteria (i.e., thresholds for severity or eligibility).

3.2. Types of developmental dyslexia

In the light of the dual-route model of reading, dyslexia can be subdivided into different types depending on what part of the model been impaired. Understanding that the reading process involves several stages and two distinct routes helps to comprehend why dyslexia can manifest itself in different ways. The deficits can occur in any of these components or in the links between them. This leads to a variety of different error types and different difficulties encountered by dyslexic readers.

Having insight into the dual-route model of reading helps to understand the differences in symptoms between those various subtypes. Many of the commonly recognised types of developmental dyslexia stem from impairments in the lexical and sub-lexical routes and are referred to as *central developmental dyslexias.* The other group i.e., *peripheral dyslexias*, are those where the first, i.e., orthographic-visual analysis, stage is affected (Friedmann & Coltheart, 2016). Peripheral dyslexias comprise letter position dyslexia, attentional dyslexia, letter identity dyslexia, neglect dyslexia and visual dyslexia. The main responsibility of the orthographic–visual analyser is to encode abstract letter identities (Coltheart, 1981 in Friedmann and Rahamim 2014) to encode the relative position of letters within words (Peressotti & Grainger, 1995), and establish the attentional window that allows for the allocation of attention to a single word (Coltheart, 1981). Depending on which function is affected, a different type of peripheral dyslexia, with different characteristics will be exposed (Friedmann and Rahamim 2014). As these types of dyslexia result from deficits in the first stage of the reading process, they will be discussed before the central developmental dyslexias.

Peripheral dyslexias

Letter position dyslexia (LPD)

Letter position dyslexia is one of the peripheral dyslexias, which results from a deficit in the orthographic-visual analyser. While the reader can correctly identify the letters, the difficulty lies in encoding the correct order of the letters. It is usually middle and adjacent letters that migrate, whilst the first and final letters are hardly ever misplaced. Moreover, errors are more common for words for which an alteration to letter position creates an existing word. For example, *cloud* can be read as *could* or *fried* can be read as *fired*. This is particularly significant when the order of the middle letters is unspecified, as more than one entry matching the partial information is activated. For example, if the input specifies [f] in the beginning of the word, [m] in the end and [o] and [r] in the middle in an unspecified order, the possibility of a transposition error increases as both *form* and *from* can be activated (Friedmann & Coltheart 2016). However, It is worth noting that a factor that could likely affect the correct word choice is the context in which the given word appears. The chances of the word *diary* appearing in a sentence like: "Yogurt, feta cheese, and milk are dairy products" instead of *dairy* would be less probable. For example, Friedmann & Rahamim (2007) demonstrated that readers with LPD do not make as many errors when words are contextualized and appear in a sentence.

In the case of non-words, an impaired visual analyser would lead to the activation of an existing word if it shared the letter combination of the corresponding non-word. For example, the non-word *talbe* would lead to the activation of the word *table* in the orthographic input lexicon as the letter position encoding is impaired. At the same time, the word *nalbe* which is nonmigratable would not lead to the activation of any word in the lexicon. This would motivate the reader to use the sublexical route to decode the word, and thus, increase the potential for correct encoding. Furthermore, word frequency also contributes significantly to the rate of migration errors. For example, as a child is more familiar with the word *lion*, the word *loin* might not be read correctly. In this example, the initial and final letters are specified, and the middle letters are unspecified. However, word frequency contributes to selecting the more familiar item; thus, *lion* will be accessed first, and if the word was, in fact, *loin*, it would most likely lead to incorrect reading.

Omitting double letters is another error common in children with LPD. Importantly, the letters do not have to be adjacent (e.g., *butter*) for an individual with LPD to omit one of the letters. For example in the word *drivers*, one r can be omitted resulting in *divers*. Even thought the r's are in different positions in the word, for an individual with LPD, they are identical and might not be distinguished resulting in an omission of one of them (Friedman & Coltheart, 2016).

It has been speculated that LPD might result from a general visual problem, which would then lead to transposition errors concerning symbols and numbers as well. However, it has been demonstrated (Friedmann, Dotan, & Rahamim, 2010) that migration errors of symbol sequence and number are not common in children with LPD. In terms of treating LPD, reading while tracing the words letter-by-letter with a finger proves effective as it leads to a significantly reduced number of migrations errors (Friedmann & Rahamim, 2014). Classifying letters through the use of different colours does not facilitate the reading process and leads to an increase in the number of migration errors (Friedmann & Coltheart, 2016). Diagnosing this dyslexia correctly has important implications for effective treatment interventions, as it is believed to be easily overlooked in some languages. Using migratable words (where changes to middle letter position forms another existing word) in testing can reveal the specific difficulties readers with LPD have. As this type of test in not common in standard reading tests, it might be challenging to detect the issue. Semitic languages (such as Hebrew and Arabic) are commonly used as examples of languages where migration errors occur often. This is due to their unique morphological structure wherein roots commonly comprise three consonants (trilateral consonant roots), and adding vowels, affixes or doubling the consonants leads to the formation of nouns, adjectives and verbs. Due to the fact that these languages are rich in migratable words, detecting LPD is easier because the errors are common.

Attentional dyslexia

Another type of peripheral dyslexia is attentional dyslexia, which is characterized by the migration of letters between neighbouring words. In this type of dyslexia, the letters of the target word appear in a neighbouring word, but they preserve their corresponding within-word position. For example, the word pair *win fed* can be read by an individual with attentional dyslexia as *fin fed* (Friedmann, Kerbel & Shvimer, 2010). These migrations occur between the target word and words surrounding it from four directions, i.e., left and right (horizontally) as well as above and below (vertically). However, it has been reported (Mayall and Humphreys, 2002) that horizontal migrations occur more commonly in the direction from right to left, which means that the letters from the word on the right migrate more often to the words on the left than the other way round. Thus, words on the left appear more vulnerable to migration errors. However, these findings appear inconsistent with the findings presented by Mozer

(1983) and Humphreys et al. (1990) who observed more migrations occurring from left to right (i.e., from the first word to the second one). Similarly, low-frequency words and non-words are more prone to migration errors (Saffran & Coslett, 1996 and Hall et al. 2001 in Friedmann, Kerbel & Shvimer, 2010). Moreover, migrations are more common when the change to the target word results in an existing word, e.g., the word pair *mild wind* can be read as *wild mind*. Attentional dyslexia also involves omission errors, similar to the ones exhibited in LPD. Therefore, an individual with attentional dyslexia can read the word pair *clay plan* as *clay pan* as the l's in these two words appear identical to the reader, and the only detail that distinguishes them from each other is that they belong to two different words. The inability to bid letters to words makes it difficult for individuals with attentional dyslexia to realise the distinction between the two letters. It has been hypothesised (Shallice, 1988) that that these errors result from an inability to focus attention on one item within the visual field and filter irrelevant noise in the form of neighbouring letters and words within the visual field. Interventions in this type of dyslexia involve covering neighbouring words during reading; for example, by using a "reading window" (Shvimer, Kerbel, & Friedmann, 2009). Attentional dyslexia is more easily identified and exposed in languages whose orthographic and morphological structure are associated with high probability of creating existing words as a result of between-word migration.

Letter identity dyslexia and neglect dyslexia

Two types of peripheral dyslexia will be discussed much more briefly here as there have not been many accounts of these types of dyslexias within the area of developmental dyslexias. Letter identity dyslexia and neglect dyslexia have been more thoroughly discussed in literature concerning acquired dyslexia. However, as they are recognised and some cases of developmental letter identity and neglect dyslexias have been described, it is appropriate to discuss them briefly. Letter identity dyslexia concerns difficulties related to abstract letter identity. Individuals with this type of dyslexia experience difficulties with accessing the abstract identity of letters from their visual form. This results in an inability to name letters, identify the name and sound of a written letter or recognise corresponding letters in different cases (e.g., *A* and *a*). Neglect dyslexia, on the other hand, is related with a difficulty to pay attention or recognise stimuli (word or letters) present on one of the sides of the visual field (Friedmann & Coltheart, 2016). Letters or words are, therefore, omitted, added or substituted on one side of the word or text. In the case of developmental dyslexia, neglect dyslexia has been identified so far at the word level. If the omission, addition or substitution of letters results in an existing word, these errors are more likely to occur (e.g., *rice* can be read as *ice* and linked to the semantic meaning of *ice*). Therefore, this type of dyslexia is particularly challenging in languages with dense orthographic neighbourhoods, in which substitution, omission, or addition of letters leads to a high probability of creating another existing word. Treatment for developmental neglect dyslexia involves manipulations that attract attention to the side of the text that is neglected. Nachman-Katz and Friedmann (2010) tested manipulations in the form of tracing the word letter-by-letter, which led to the decrease in errors by 22%, tapping with their finger on the neglected side of the word, which led to a decrease in error rate by 19%, using a small blinking light on the neglected side of the test leading to a decrease in error rate by 15%, and placing a coloured vertical line on the neglected side (decrease in error rate by 14%).

Visual dyslexia/ orthographic input buffer dyslexia

Visual dyslexia is a type of peripheral dyslexia characterised by errors involving substitutions, omissions, migrations, and additions of letters (Marshall & Newcombe, 1973). Visual dyslexia affects all functions of the orthographic-visual analyser, i.e., letter identification, letter position within the word, and letter-to-word binding. Visual dyslexia is identified when the difficulties cannot be accounted fro by other types of dyslexias, i.e., letter position dyslexia, attentional dyslexia, letter identity dyslexia and neglect dyslexia. The impairment occurs in the output of the orthographic-visual analyser; thus, it involves all types of errors characteristic for the other individual peripheral dyslexias. Errors and letter migrations appear both within and between words. Therefore, the simplest way to establishing what type of dyslexia an individual has is by elimination. For example, if an individual makes migration errors within the words but not between words, it is classified as LPD; however, if both errors are present, it is most likely visual dyslexia. Conversely, if the errors concern between words migrations, but not within words migration, it is evidence for attentional dyslexia. The reverse case of both errors appearing would lead to the conclusion that it is a case of visual dyslexia.

Central developmental dyslexias

Similarly to peripheral dyslexias, central developmental dyslexias can be subdivided according to the place of deficit. The above-described types of developmental dyslexia result from a deficit in the orthographic-visual analyser. Central developmental dyslexias are dyslexias resulting from impairments to the lexical and sub-lexical routes of the reading process. There are two extensively researched types i.e., surface dyslexia and phonological dyslexia, which will be discussed first. These will be followed by a description of the other central developmental dyslexias, i.e., vowel letter dyslexia, deep dyslexia, and access to semantics dyslexia.

Surface dyslexia

Surface dyslexia is an example of dyslexia resulting from an impairment occurring in the lexical route (which has several components, and a deficit in each of these or in their connections can result in surface dyslexia), which leads to reading aloud through the sub-lexical route (Friedmamnn & Coltheart, 2016). This implies that a reader with surface dyslexia will read via the grapheme-to-phoneme conversion (GPC), and as a result, struggle to read irregular words that do not follow general GPC rules of the specific language. Such reader will, therefore, tend to make over-generalization errors, such as reading "broad" as "brode" or "island" as "eyesland" (Harley, 2008). Other errors involve pronouncing silent letters in words such as: "stomach", "receipt" or "comb" and reading words that may lead to ambiguous conversion to phonology, e.g., "bear" read as "beer" (Friedmamnn & Coltheart, 2016). Children with surface dyslexia struggle as well with ambi-phonic graphemes, which can represent more than one phoneme. For example, the grapheme/letter *i* in English is pronounced as /ɪ/ in *kid* and /ɑɪ/ in *kind*. Therefore, surface dyslexia is particularly evident in opaque languages, such as English, which have irregular grapheme-to-phoneme conversion (GPC) rules, i.e., correspondence between the written form and its pronunciation (e.g., the grapheme 'a' is pronounced differently in each of the following words: *lake*, *was*, *bag*, and *raw* [Borleffs et al., 2019]). Finally, in the case of certain languages in which stress is determined lexically rather than marked orthographically, words with more than one syllable can be difficult to read (Friedmamnn & Coltheart, 2016). For example in Polish, stress is determined by orthographic rules according to which the penultimate syllable is stressed. In English, on the other hand, stress is determined lexically, and its position is not completely predictable, so it must be memorized. The position of the stress can be used to distinguish heteronyms (e.g., *produce*, which is a noun meaning fruit and vegetables when the stress falls on the first syllable, and a verb meaning to create/make, when the stress falls on the second syllable). This is also true for languages in which not all vowels are specified in the orthography (e.g., Arabic). The accurate oral reading of such irregular and unpredictable words requires access to lexical, word-specific knowledge. Such information is stored in the lexical route, in the orthographic input lexicon, so when reading aloud via the lexicon is not possible, these words are liable to be read incorrectly. In contrast, regular words for which there is only one possible way of reading via the sub-lexical route are read correctly, even if they are infrequent. Individuals with pure surface dyslexia (i.e., with only the lexical route being affected) can use their sub-lexical route to read, which enables them to read pseudo-words (Castles, Bates, & Coltheart, 2006).

Comprehension is also often affected in surface dyslexia, which is particularly true for homophonic words. Since the word cannot be recognised orthographically, it needs to access the conceptual system through a different route. It has to "travel" after the grapheme-to-phoneme conversion to the phonological output buffer, access the phonological input buffer and lexicon, and reach the semantic lexicon to access the conceptual system. For instance, by following the grapheme-to-phoneme conversion rules, the phonological output buffer will lead to the production of a phoneme sequence of the word *here,* which will be produced in inner speech. The phonological input buffer and phonological input lexicon will, then, allow access to the conceptual system. However, since the reading occurs through the sub-lexical route, the word might be interpreted as *here* or *hear*, as they are homophones.

Surface dyslexia is also associated with slower-than-normal reading, which is the result of processing each word through the grapheme-to-phoneme conversion. Considering the type of errors described above and the nature of surface dyslexia, it is expected that languages with more irregularities, ambiphonous letters, underrepresentation of vowels and silent letters will be more difficult for individuals with surface dyslexia. It might also be easier to detect surface dyslexia in less transparent orthographies (Zoccolotti et al., 1999).

Phonological dyslexia

While surface dyslexia is the manifestation of impairments in the lexical route, phonological dyslexia manifests itself as impairment in the sub-lexical route. This means that individuals with phonological dyslexia use only the lexical route to read (Harley, 2008). Thus, the main difficulty lies in reading non-words (pseudowords) and new words. Words stored in the lexicon are read correctly. This is crucial for understanding why children with developmental phonological dyslexia take much longer to learn to read; for them every word they encounter is considered new. This challenge becomes evident as well when the child starts learning a new language. The impairment in the non-lexical route can concern damage to phonological representations or direct connections between orthography and phonology. According to Friedman (1995), phonological dyslexia can result either from an impairment of orthographic-to-phonological processing (where non-word repetition is adequate, but function words are read poorly) or an impairment of general phonological processing (where function words are read adequately, but non-words are read relatively poorly; Friedman, 1995 in Harley, 2008).

With reference to the three-stage model of sub-lexical processing (Coltheart, 1985; Friedman, 1995), a disruption to specific stages can manifest itself through specific difficulties related to reading non-words and function words. As described in the discussion on dual-route model, three stages can be distinguished in the sub-lexical route. A disruption in the first stage (*graphemic analysis*), leads to more difficulties with reading non-words with multiple correspondences between graphemes and phonemes. Non-words in which each grapheme corresponds to a single letter are easier to read (Newcombe & Marshall, 1985). Disruption in the following stage, i.e., *print-to-sound conversion*, leads to difficulties related to the size of the unit; thus, phonological assembling of larger units, i.e., syllables, can be carried out, while assembling smaller units such as onset, bodies or phonemes is impaired (Lesch & Martin, 1998 in Harley, 2008).

Vowel letter dyslexia

Another type of the central developmental dyslexias, which is less commonly discussed in literature, is vowel letter dyslexia. An impairment to the sub-lexical route concerning the processing of vowels is believed to be the reason for this type of dyslexia (Khentov-Kraus & Friedmann, 2011 in Friedmann & Coltheart 2016). Vowel letter dyslexia is characterized by omissions, substitutions, transpositions and additions of vowels (e.g., the word *bit* can be read as *bat* or *but)*. Being a deficit in the sublexical route, this type of dyslexia occurs mainly in reading non-words and new words, and it is more common when a vowel error in a target word results in an existing word.

Deep dyslexia

Deep dyslexia is another type of central developmental dyslexias, which is characterised by the production of semantic paralexias (i.e., semantic transposition and supplementation errors produced during the reading process resulting from reduction in reading ability; e.g., *lime* is read as *lemon* or *sour*). Deep dyslexia also involves morphological errors (e.g., omission of morphological affixes, as in reading *played* as *play*; Crisp & Lambon Ralph 2006); thus, individuals with this type of dyslexia might experience more difficulties within morphologically complex languages. Deficits in the sublexical grapheme-to-phoneme conversion route and in the lexical route between the orthographic input lexicon and the phonological output lexicon are believed to restrict the reader to read via meaning (Ellis & Young, 1988). Therefore, non-words are particularly challenging as there is no direct connection to the semantic representation. Similarly, function words and abstract words, which cannot be visualised pose a significant problem for children with deep dyslexia. Thus, target function words might result in being substituted with another function word or a visually comparable/identical concrete word (Coltheart, 1980; Coltheart, Patterson, & Marshall, 1987). Friedmann & Coltheart (2016) assert that children with deep dyslexia lexicalise non-words (read them as similar existing words; e.g., *diger* is read as *tiger*) or claim that they cannot read the words.

Access to semantics dyslexia

One other type of dyslexia, which results from a deficit in further stages of the reading process, is access to semantics dyslexia (also known as direct dyslexia). This type of dyslexia is somewhat unusual because individuals with this type of dyslexia can read a text aloud fluently and accurately; however, they cannot understand the written words (Friedmann & Coltheart, 2016). Castles, Crichton, & Prior (2010) postulate that the fact that these individuals can read accurately implies that the lexical route between the orthographic input lexicon and the phonological output lexicon as well as the sublexical route are not impaired. Most likely, the impairment concerns the conceptual/semantic system or the access from the orthographic input lexicon to the semantic lexicon. If the impairment is located in the conceptual/semantic system, it would be likely called a semantic deficit rather than dyslexia. However, if it is a semantic deficit, it is expected that the difficulties would concern both reading and listening comprehension. Speech production would also be affected resulting in semantic errors (Nickels & Howard, 1994; Friedmann, Biran, & Dotan, 2013). On the other hand, if the deficit concerns the connection between the orthographic input lexicon and the semantic lexicon, it is more likely to accept that the disorder is a type of dyslexia. In this case, listening and word productions are not impaired, and the deficit is limited only to reading comprehension. However, due to the inhibition of accessing semantics of the written text, individuals with access to semantics dyslexia struggle reading heterophonic homographs. Thus, a sentence such as "I shed some tears because I found some tears in my purple shirt" will be read incorrectly by an individual with access to semantics dyslexia (Friedmann & Coltheart, 2016).

3.3. Dual-route model of reading in the light of the anglocentric research in reading development

The above-described types of dyslexias are explained here through the principles of the dual-route model of reading. However, while significantly influential, this model is not the only one that can explain developmental dyslexia, and it is by no means devoid of criticism. One of the main criticisms concerning the dual-route model of reading is that the need for two separate routes appears to be confined to the English language, while the majority of European languages with transparent orthographies could rely on one route (Share, 2008). According to the dual-route model, two different procedures are required to read correctly non-words (e.g., *slint*) and exception words (e.g., *pint*). The grapheme-phoneme correspondence is necessary to decode nonwords, while the exception words require a different route as they do not follow regular grapheme-phoneme rules of the English language. However, while English has a number of exception words, many of the European orthographies are somewhat regular in terms of grapheme-phoneme correspondences (Seymour et al. 2003). Some (e.g., Bishop & Snowling, 2004; Ziegler & Goswami, 2005) question, therefore, the necessity for a dual-route model of reading. It has been further suggested that this dual-route structure has only developed for English (Ziegler & Goswami, 2005). Share (2008) makes an interesting observation regarding the duality (non-words/exception words; regular/irregular) of the architecture of the dual-route model and juxtaposes it with the duality derived from the transition from a novice to an expert common to the acquisition of any skills. He states that, just like with other skills humans acquire, reading is a process during which one transitions from a slow, step-by-step performance to one that is faster and more automitised. This is based on the premise that regardless of the orthography, all words are at some point unfamiliar to the reader, which necessitates a form of algorithm for words encountered for the first time. Simultaneously, after several encounters, this word is recognised automatically; therefore, he suggests the term decipherability/automatizability for an orthographic dualism.

However, in terms of the dualism of the reading process, a one-route model might be sufficient for most of the alphabetic European orthographies. Seidenberg and McClelland (1989) proposed an alternative model of reading, which consists of a single processing procedure capable of correctly pronouncing non-words and exception words. This model of reading, called the connectionist model (parallel distributed processing model; NB.: the basic model is also referred to as the Triangle model, due to its structural presentation), is based on the premise that reading involves three types of codes (i.e., orthographic, meaning and phonological; Harley, 2008). These codes are linked with each other through feedback connections (see figure 3).

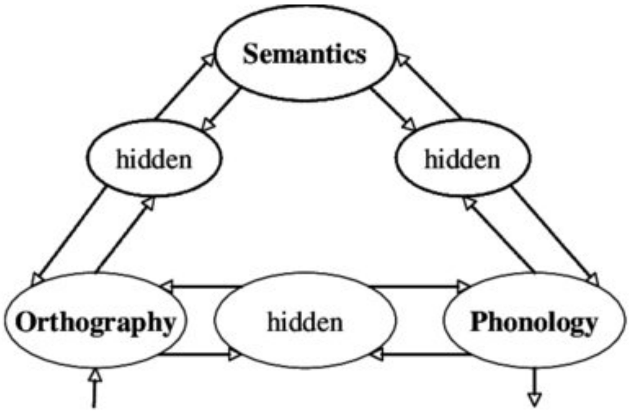


Figure 3. The standard (Seidenberg & McClelland, 1989) connectionist "triangle" model of reading aloud. *Note: Adapted from Bates et al., (2007)*

Activation of the orthographic code occurs through exposure to an input (e.g., letter string). This activation then spreads to other units; however, the amount of activation of further units is determined by a distributed (data is spread and shared across different nodes which are connected and dependent on each other) pattern (Plaut, 1999). This means that learning is based on experience, and the procedure used for an efficient task completion involves the juxtaposition of the output produced by the model with the correct target pattern (Rumelhart et al., 1986 in Seidenberg, 2007). This happens by means of backpropagation, which is a learning algorithm governed by weighted connections between units (including hidden nodes) which lead to appropriate transformations between the nodes (e.g., orthographic and phonological), and, hence, learning based on the exposure of the system to the script (Plaut, 1999). The connectionist model of reading does not distinguish between lexical and sublexical processes. The processing of input is completed by all parts of the system (Plaut, 1999).

3.4. Theories of developmental dyslexia

Despite the amount of research and evidence concerning developmental dyslexia, there is still an on-going debate regarding the actual causes of it. Several theories have been suggested that could account for this disorder. Among the most popular theories are: the phonological theory (e.g., Liberman 1973; Vellutino 1979; Snowling, 2000), magnocellular theory (Stein & Walsh 1997), and the cerebellar theory (Nicolson & Fawcett 1990; Nicolson et al. 2001); however, none of the current theories can entirely account for all the difficulties faced by dyslexic children (Ramus et al., 2003). It is, in fact, the number of different symptoms associated with dyslexia that make it difficult to explain its origin (Ramus, 2004). Apart from the overt reading difficulties, dyslexic children can also exhibit problems related to balance and motor control as well as sensory difficulties (Ramus, 2004). Furthermore, as previously noted, a number of neuro-developmental disorders often co-occur in patients with dyslexia. Among the most common ones are specific language impairment (SLI), attention deficit hyperactive disorder (ADHD) and dyspraxia (Ramus, 2004). Due to the number of factors to consider, research on dyslexia has primarily focused either on investigating one particular cognitive symptom and its cause (e.g., the deficit in representing and processing speech sounds is linked to the problems in learning grapheme-phoneme correspondences under the phonological theory of dyslexia) or on establishing a theory that would account for the correlations between reading difficulties and sensory and motor symptoms (e.g., under the magnocellular theory of dyslexia, sensory and motor dysfunctions can be accounted for alongside reading difficulties due to a deficient functioning of the magnocells; Ramus, 2004). Nevertheless, the aforementioned deficits are not pervasive across all dyslexic patients, and a mixture or lack of some deficits might appear in different individuals (Snowling, 2019). It is, therefore, important to discuss the various theories of dyslexia and assess their contributions to accounting for the primary symptoms of dyslexia. Three leading theories of dyslexia have received particular attention in the field; i.e., the phonological theory, the magnocellular theory, and the cerebellar theory, which will be discussed in the following section.

The phonological theory

Currently, the leading theory of dyslexia is the phonological theory based on the phonological deficit hypothesis. According to this theory, specific impairments occur in the representation, storage and/or retrieval of speech sounds (Liberman 1973; Vellutino 1979; Snowling 2000; Caylak 2010). This leads to difficulty in learning the relationship between letters/ graphemes (orthography) and speech sounds (phonology), and by extension, difficulty in reading (Ramus et al., 2003; Caylak, 2010). Two neurolinguistic processes are involved in expanding the linguistic repertoire of readers; i.e., orthographic mastery and phonological mastery (Caylak, 2010). The former concerns the ability to process the visual form of words, while the latter deals with the ability to translate letters (graphemes) into corresponding sounds (phonemes) for unfamiliar words (Caylak, 2010). However, if these processes are impaired, the representation and use of phonological information is not optimal which leads to problems in reading acquisition (Goswami, 2000, Caylak, 2010). Ramus et al. (2003) explain that there is a straightforward connection between the cognitive deficit and the behavioural problem. At the biological (neurological) level, the origin of the disorder is believed to be congenital anomalies in left-hemisphere perisylvian brain areas (e.g., Ramus et al. 2014; Shaywitz *et al*., 2002). Stein (2018) adds that there is a direct connection between the phonological impairments in dyslexics and substantial abnormalities in cerebral connectivity and cortical structure (in particular, the left hemisphere language network is affected). These links have been demonstrated by imaging studies (Hampson et al., 2006; Xia et al. 2015). Further evidence supporting the phonological deficit theory derives from studies, which demonstrate poor performance in tasks involving phonological awareness (PA), phonological re/de-coding, i.e., Rapid Automatized Naming (RAN) and reading fluency (Caylak, 2010; Norton et al., 2015). However, considering the number of different symptoms associated with dyslexia, the phonological theory does not account for sensory and motor difficulties; thus, it is considered by some to be just one aspect of the more general disorder.

Alternative theories challenge the phonological theory by arguing that the phonological deficit is a secondary consequence of a more basic auditory or visual deficit. The rapid auditory processing theory (Tallal, 1980) postulates that the problems arise from difficulties in perceiving short or rapidly varying sounds (Tallal, 1980 in Ramus et al., 2004). The visual theory (Lovegrove et al., 1980; Livingstone et al., 1991; Stein and Walsh, 1997), on the other hand, posits that the difficulties with processing written text arise from visual impairments. This theory has its roots in the late 19th century, when dyslexia was believed to be due to problems with the visual processing of words (see Stein, 2018, for a review).

The major issue identified with the phonological theory is that it does not provide an explanation for the cause of the failure to gain phonological skills. An understanding of the pathophysiological mechanisms that lead to the inability to develop phonological skills would help define developmental dyslexia (Stein, 2018). The phonological theory is often referred to as a mere tautology, as its main tenet is that dyslexia is the inability to translate letters to sounds which is precisely what reading is; thus, it appears to provide a definition rather than an explanation of the causes.

The cerebellar theory

The cerebellar theory accounts for symptoms related to motor skills deficiencies (Nicolson & Fawcett, 1990; Nicolson et al., 2001). The cerebellum is a brain region, which plays a role in the integration of sensory perception and motor control, but which has also been linked to linguistic skills (Nicolson & Fawcett, 2010). It is postulated that the cerebellum plays a role in speech articulation as it depends on motor control abilities (Ramus et al., 2004). Additionally, tasks that require automatisation (e.g., driving, reading, as well as learning grapheme-phoneme correspondences) are also controlled by the cerebellum. Patients with acute cerebellar damage show a characteristic dissociation between time estimation and loudness estimation, which has been shown to occur in dyslexics as well (Nicolson et al., 2001). However, automatisation skills problems that would potentially explain difficulties with establishing correct grapheme-to-phoneme correspondence, as well as the motor control difficulties that affect speech articulation are not the only correlations between dyslexia and motor skills deficiencies. Nicolson et al. (2001) have also suggested a link between poor handwriting in dyslexic and motor skills impairments as well as reduced 'working memory' due to reduced articulation speed (see Fig 4.).

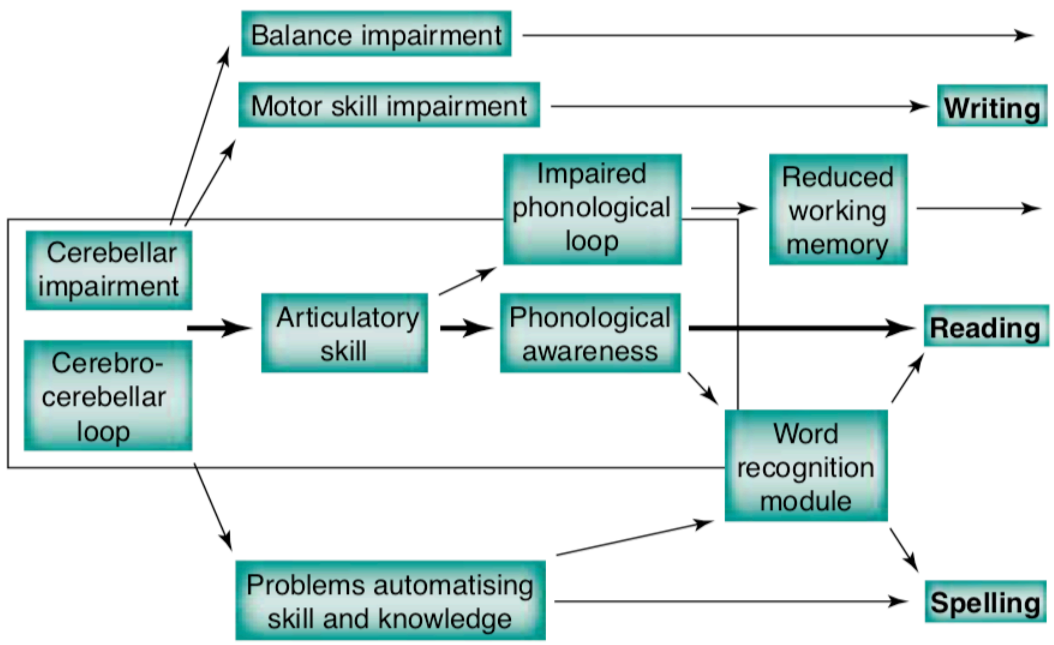


Figure 4. A hypothetical causal chain.

Note: Adapted from Nicolson, R. I., Fawcett, A. J., & Dean, P. (2001). Developmental dyslexia: the cerebellar deficit hypothesis. Trends in neurosciences, 24(9), 508-511.

Finally, if the quality of articulatory representation is reduced, the sensitivity to onset, trim and phonemic structure of language could be negatively affected, thus, leading to deficits in phonological awareness. The cerebellar theory of dyslexia provides an explanation for the phonological deficits as outlined by the phonological deficit theory.

The magnocellular theory

The magnocellular theory (Stein & Walsh, 1997) unifies the evidence from visual and auditory theories together with the cerebellum theory. This theory is based on the premise that impairment of sensory timing results in a failure to acquire the ability to sequence letters in a word and the sounds that make up the word. Thus, dyslexia is linked to problems with the temporal processing of visual information (Stein, 2018). The signal travelling through the retina is carried to the visual cortex of the brain (Snowling, 2019). This transfer of signal is carried out by magnocellular and parvocellular neurones which are specialised in processing "fast-moving, brief stimuli of low spatial frequency" and "static or slow-moving stimuli of high spatial frequency and colour" respectively (Snowling, 2019, p 48). It is magnocellular neurones (L. magnus = large) that are specialised in rapid visual processing (Stein, 2018) that help us understand motion and orientation of objects around us. They are greater in size than parvo cells, which allows them to transmit signals faster; however, they cannot define fine detail (e.g., a difference between 'a' and 'o', Stein, 2018). Studies investigating the correlation between the magnocellular pathway and dyslexia (e.g., Talcott et al. 2000; Elbrahimi, 2019) have used experiments designed to test the participants' ability to detect the direction of the movements of dots. In such experiments, a display of moving dots is systematically manipulated with dots moving randomly in various directions (random dot kinematogram (RDK)). Failing to detect the direction of movement is considered evidence of a deficit in the magnocellular system (Snowling, 2019). There is evidence that the development of the magnocellular system is impaired in dyslexics (Stein, 2018), with the abnormality having a genetic, immunological and nutritional basis (Stein, 2019). Evidence from post-mortem examinations (Livingston et al., 1991) in five dyslexic brains in comparison to five control brains showed smaller magnocellular neurons in the lateral geniculate body (Norton et al., 2015). In dyslexic readers, motion sensitivity is therefore reduced resulting in unsteady binocular fixation and unstable visual perception (Stein, 2001). Thus, dyslexic readers often experience that the letters in the text they read appear to move around.

In summary current theories of developmental dyslexia propose a variety of biological and cognitive explanations. Moreover, the fact that two of the hypotheses (i.e., the magnocellular theory and the cerebellar theory) have a biological basis, while the phonological theory is phrased in terms of cognitive mechanisms creates additional difficulty in attempting to compare them. The cerebellar and magnocellular theories have a parallel component. The cerebellar deficit might, however, account for the phonological difficulties (as outlined by the phonological theory) on a biological level, which has been demonstrated above (Nicolson et al. 2001). However, while the theories might possibly overlap or support each other, each has been challenged on different grounds.

The challenges with the main theories of developmental dyslexia

The phonological theory fails to account for the sensory and motor disorders that are commonly present in dyslexic individuals. Furthermore, not all individuals with dyslexia have a phonological deficit. Pennington (2006) argues for a multiple deficit model of dyslexia and asserts that phonological difficulties are not necessary to account for dyslexia. He posits that the aetiology of behaviourally defined developmental disorders is multifactorial and cumulative. Saksida et al. (2016) have also presented evidence for deficits that are outside of the phonological domain in many dyslexics. Nevertheless, the phonological deficit has been the most common deficit observed in a study conducted by Ramus et al. (2003), which assessed the three leading theories of developmental dyslexia. The cerebellar theory might possibly account for the phonological deficits, and could be a more convincing theory accounting for dyslexia. However, while it accounts for the motor deficits, it does not provide an explanation for the sensory deficits (Ramus et al., 2003). Finally, the magnocellular theory could potentially account for all the above mentioned deficits, but it has also been criticised and challenged. The arguments concerning visual and auditory impairments are considered to be particularly challenged as a number of studies have failed to replicate findings concerning the latter disorders (e.g., Heath et al., 1999; Hill et al., 1999). Finally, there is a somewhat weak connection between the sensitivity of the magnocellular system and reading; thus refuting the causality effect (Snowling, 2019).

Snowling (2019) proposes that a conceptual framework should be in place to bring together evidence from different methodologies in order to explain how dyslexia develops. Both case-control methods and investigations at different levels of description (biological, cognitive and behavioural) should be incorporated. Further studies should investigate individuals and how they differ from one another in terms of deficits, and further exploration of the precursors of dyslexia present at an early stage of development should be continued to understand the disorder before literacy takes place (Snowling, 2019). Following the suggestions, further research into the causal precedence in dyslexia and investigation of individuals should be considered to effectively investigate the disorder.

3.5. Tests of dyslexia

The Logos test was administrated in March 2018 in Norwegian. An equivalent English version of Logos does not exist; hence, diagnosing students whose first language is not Norwegian poses a difficulty for evaluating dyslexia in Norway. Logos is primarily a diagnostic tool used for dyslexia testing. However, it is also used to accurately map students' reading profile and help identify the areas that need to be addressed when designing differentiated program for specific students. The test has been developed in accordance to research specifically related to dyslexia as well as the reading process and the theory behind the Simple View of Reading (Cough & Tunmer, 1986). It is also based on Høien and Lundberg's (2012) model of word decoding (see Fig 5), which is closely linked to the dual-route model of reading (Ellis and Young, 1988; Coltheart et al., 1993, 2001; Zorzi, 2010). As Høien and Lundberg's (2012) model of word decoding is central to Logos design, a brief discussion explaining the model will be provided prior to presenting Logos.

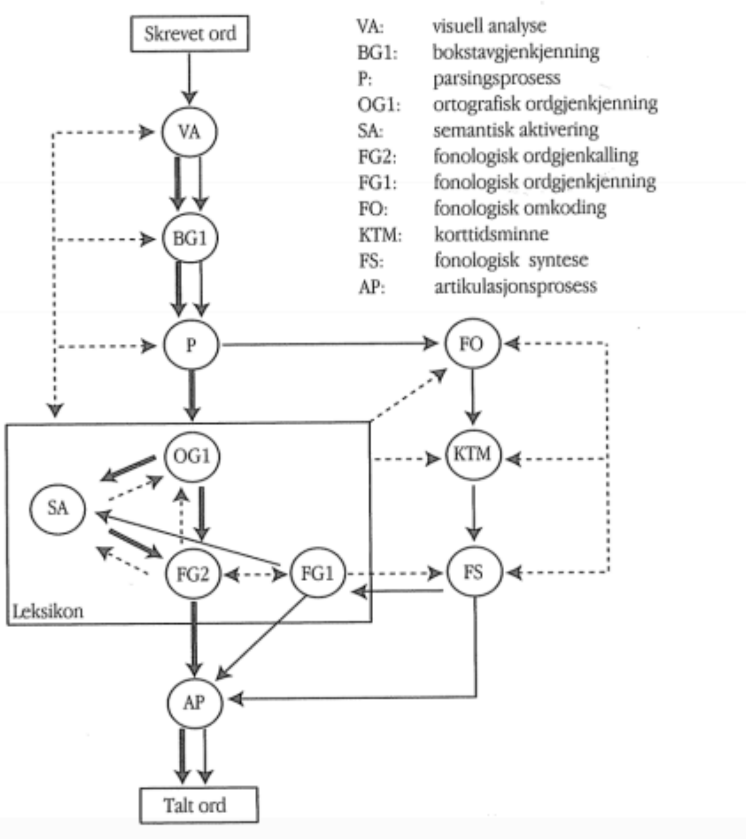


Figure 5. Høien and Lundberg's (2012) model of word decoding.

According to Høien and Lundberg's (2012) model, there are different sub-processes involved in the process of reading. The first stage, i.e., visual analysis (visuell analyse, VA), concerns the ability to recognize and analyse the visual input, during which the distinct letters and morphemes are distinguished. Fast and correct letter recognition (bokstabgjenkjenning, BG1) is considered critical for efficient word recognition. The segmentation, or parsing, process

(Parsingprosessen, P) involves the actual division of segments a given word consists of. This means that the word is divided into its orthographic components such as letters, syllables and morphemes. While this process is considered to operate in an automatic way in competent readers, it is often more problematic for readers who have poor orthographic awareness. In the next stage of the reading process, orthographic word recognition (ortografisk ordgjenkjenning, OG1; on the graph it is represented by thick arrows) takes place where the orthographic units of a given word are recognized and matched with the semantic representation of the orthographic sequence. At this point, the word is recognized in the mental lexicon, and all information concerning the word, i.e., its meaning (semantisk aktivering, SA) as well as phonological (fonologisk ordgjenkjenning FO1) and grammatical aspects are accessed.

The alternative route to the orthographic word decoding is the phonological word decoding (on the graph, it is indicated by thin arrows) which requires the knowledge of grapheme to phoneme conversion rules in a given language. The orthographic parts recognized during the segmentation process (Parsingprosessen, P) are converted into phonological units. This process, however, requires the ability to store phonological information of smaller units (phonemes) before they can be merged into larger units (i.e., morphemes, syllables). Thus, short-term memory (korttidsminne, KTM) plays a significant role in phonological decoding (Vellutino, Fletcher, Snowling & Scanlon, 2004) as it stores temporarily the audio segments (closely linked to phonological memory which plays a role in integrating meaning during the reading process; Spear-Swerling 2013). As short-term memory and working memory tend to be weaker in dyslexic students (Vervara et al 2014), it is often recommended to use larger units (morphemes, syllables) for decoding practice. It is during the next stage, i.e., phonological synthesis (fonologisk syntese FS) that the information is integrated and the sound combination provides the relevant basis to locate the word in the mental lexicon. Difficulties at this stage of word recognition may be due to poor grapheme-to-phoneme correspondence knowledge, inadequate phonemic awareness or short-term memory deficit.

During the process of learning to read, readers develop an orthographic representation of a word that is stored in long-term memory. Thus, the process of reading becomes automatic, and the orthographic route is preferably used. The phonological route is, thus, commonly used for reading pseudo-words or words the reader has not encountered before. Impairments in different parts of the reading process will lead to different difficulties; thus, identifying the area a particular reader is struggling with allows planning a more effective and targeted intervention that addresses the particular weaknesses.

Considering the above, Logos has been designed in a way that allows to observe which stages of the reading process are affected and which strategies need to be implemented to strengthen the student's weaknesses. Moreover, in the case of dyslexia, identifying the actual stages that are affected during reading provides information for understanding the nature of the reading difficulty and type of dyslexia. Apart from following the principles of Høien and Lundberg (2012) model of word decoding, Logos is structured in a way that allows identifying the gaps in the key stages of the learning process of reading. It is, therefore, not only useful for diagnosing reading difficulties, but it also provides indications concerning problems in reading development. Logos relates to the model of typical reading development proposed by Spear-Swerling (2013) as discussed in the previous section.

4. Bilingualism

4.1. Definition of bilingualism

While it is true that the majority of the European population speak more than one language, understanding what is defined as bilingualism appears challenging, in particular within psycholinguistic or neuroscientific research. Most studies generally present dissimilar definitions of bilingualism and apply varied features characterising a bilingual speaker (Francois Grosjean, 1998). Francois Grosjean observed that this can undoubtedly lead to conflicting or irreplaceable results (1998). Most fundamentally applied criteria for defining bilingualism are: age of acquisition and L2 fluency. For example, speakers who are raised in a bilingual environment since birth or early childhood will apply different cognitive mechanisms (incidental acquisition) to those who become bilingual in adulthood (metalinguistic learning, Calvo et al., 2016). Including research participants with divergent L2 age of acquisition might influence the results of a study as different cognitive mechanisms were involved in the process of becoming bilingual (Paradis 2009 in Calvo et al. 2016). It is, however, worth noting that age of acquisition does not directly correlate to proficiency advantage. While strategies applied by young speakers are considered more efficient than metalinguistic learning of L2 at an older age, factors such as: motivation, aptitude and exposure can also significantly contribute to a proficiency advantage in late bilinguals (Chin and Wigglesworth 2007). The second characteristic, i.e., L2 fluency is particularly problematic for research as bilingualism is defined on a spectrum from "the ability to use more than one language" (Mackey 1962, p. 52 in Chin and Wigglesworth 2007, p.5) to "native-like control of two languages" (Bloomfield, 1933, p. 55 in Chin and Wigglesworth 2007, p. 5). Both extremes pose potential challenges for research. One definition allows the possibility of more than two languages, which might have additional implications for studies (e.g., Kave et al. 2008), considering that speaking an additional language involves different cognitive processes. The other appears to oversee the fact that bilinguals are rarely balanced in the use of both languages in all life contexts. A more precise definition of bilingualism came from Grosjean (2013) who defined it as "the use of two or more languages (or dialects) in everyday life" (Grosjean 2013 p. 5). For the purpose of this thesis, bilingualism will be understood as the use of two languages on a daily basis in everyday life.

4.2. Non-selective nature of bilingual processing

Studies in psycholinguistic research have demonstrated ample evidence that supports the notion that bilingual processing is non-selective (e.g., naming words task in Schwartz, Kroll & Diaz 2007; or naming pictures task in Costa et al. 2000). This means that both languages are continuously active regardless of which one is needed for a specific task or situation (Kroll, 2008). This fact is particularly significant for bilingual research as it contributes to understanding the links between the two linguistic systems both in terms of potential facilitation and inhibition. Several models of language processing have been suggested to account for the simultaneous activation of both languages. Two of the most commonly discussed models are the comprehension Bilingual Interactive Activation model (BIA; Dijkstra & Van Heuver 1998, which has become the basis for designing the Bilingual Interactive Activation plus model BIA+; Dijkstra & Van Heuver 2002) and the Inhibitory Control model (IC, Green, 1998). However, it must be noted that the difference between comprehension and production might lead to different implications with regards to bilingual effect (Kroll and Tokowicz, 2005; Kroll et al. 2015). A number of empirical studies will be discussed below to explain the models of bilingual processing. The characteristics of the BIA+ and IC models (Dijkstra, 2005) are presented in table 1.

Table 1

Characteristics of bilingual non-selective models of processing

BIA+ model (Dijkstra & Van Heuven, 1998)	**Inhibitory control model (Green, 1986, 1998)**
Resting level activation of words reflects the state of language activation as well as	Language task schemas (specifying how a task is performed) can compete and cooperate

proficiency	
" Stimulus list composition (previous items) affects activation state of word forms	Schemas can alter the activation level of lexical representations (lemmas)
" Participant expectations do not exert strong effects on the activation state of words	Stimulus list composition (previous items) affects activation state of lemmas
" Top-down inhibition effects on the non-target language arise via language nodes	Participant intentions can affect the activation state of items
" Identification and decision levels interact	Reactive top-down inhibition effects operate on lemmas, not on word forms
Resting level activation of words reflects the state of language activation as well as proficiency	Identification and decision levels interact

Note. Adopted from Dijkstra, T., & Kroll, J. F. (2005). *Bilingual visual word recognition and lexical access*. Handbook of bilingualism: Psycholinguistic approaches, 178, 201.

In a study by Sunderman and Kroll (2006), the BIA model was compared to the Revised Hierarchical Model (RHM; Kroll & Stewart 1994). This model of bilingual word processing assumes separate lexicons for L1 (dominant language) and L2 (less dominant language) at lexical level and a shared conceptual level of word processing (see Fig 5).

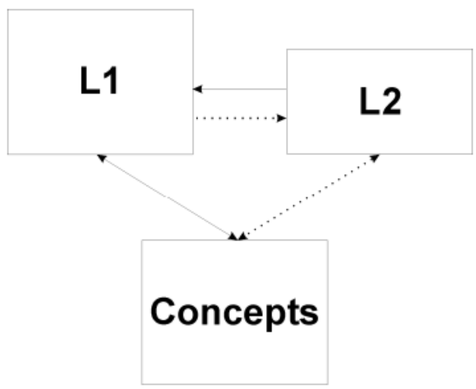


Figure 6. The Revised Hierarchical Model.

Note: Adapted from Kroll & Stewart 1994

BIA, on the other hand, suggests an integrated lexicon with additional language nodes, which determine language membership. The hierarchical nature of BIA relates to the bottom-up relationship between features, letters, words and language nodes. As demonstrated in Figure 6, the model posits that a particular string of letters will lead to the activation of a selected number of lexical candidates from both languages.

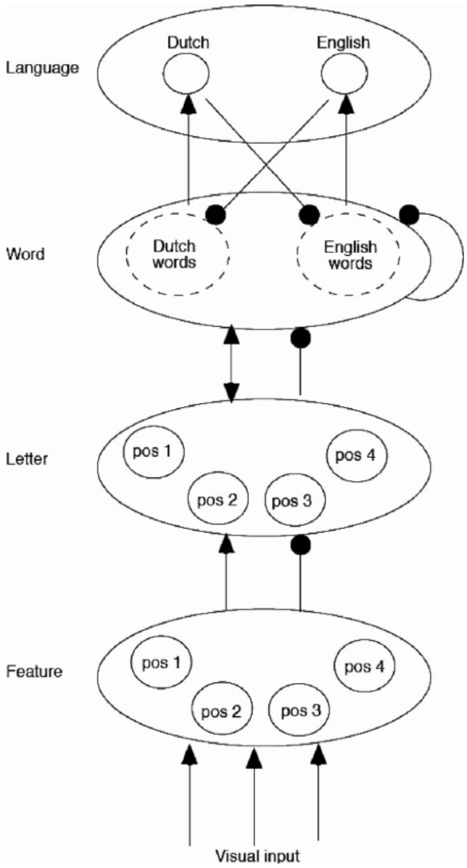


Figure 7. The BIA model of bilingual language processing.

Note: Adapted from Brysbaert, M., & Duyck, W. (2010). Is it time to leave behind the Revised Hierarchical Model of bilingual language processing after fifteen years of service? *Bilingualism – Language and Cognition*, 13(3), 359-371.

There is, however, a top-down inhibition effect resulting from a competition effect between the activated nodes. Ultimately, the unintended language is supressed. However, while BIA assumes that lexical form relatives are active during lexical activation, RHM assumes that it is translation equivalents that are active. Sunderman and Kroll (2006) observed how different stages of proficiency influence the activity of these two competitors. The subjects of the study were native English speakers with different levels of L2 (Spanish) proficiency. The experiments involved completing a translation recognition task with three conditions: (a) form related lexical neighbours (*cara-card*), (b) form related translation neighbours (*cara-fact*), and (c) meaning related words (*cara-head*). The results of the experiments supported the RHM assumptions. Less proficient speakers experienced an interference effect in the form-related translation neighbour condition as they need to first translate the item into L1 before they can access the conceptual level. Regardless of L2 proficiency, there was a slower rejection of form-related pairs. The study supported as well the predictions of BIA assumptions as they revealed a slower rejection of form-related pairs regardless of L2 proficiency.

In another study, which investigated inhibitory control, Costa and Santesteban (2004) reviewed the asymmetrical switching cost – experimental effect supporting the idea that lexical access necessitates inhibitory processes. The Inhibitory Control model (IC model), proposed by Green (1998), suggests a proportional correlation between the amount of inhibition applied in response to the activation of lexical nodes of non-target language, and the speaker's proficiency level in that particular language. According to the IC model, speaking in L2 (less dominant language) requires greater inhibition effort for L1. Furthermore, this inhibition persists until the subsequent trial, which leads to difficulties providing a response in L1. The study by Costa and Santesteban (2004) aimed to replicate the results of a study conducted by Meuter and Allport (1999), which provided evidence for asymmetric switching cost (larger switching cost for L1 than L2) connected to larger inhibition for the dominant language (L1). Costa and Santesteban (2004), did not manage to replicate the results of Meuter and Allport (1999), as no asymmetric switching cost was observed. They concluded that the switching performance of highly proficient bilinguals does not depend on the proficiency of the languages engaged in the task. They further speculated that the difference is the result of shifting from a reliance on inhibitory control to the reliance on language-specific selection mechanism proportional to the increase in proficiency.

4.3. Cognate effect

A phenomenon particularly relevant to the study of bilingualism is cognate effect. Cognates are words, which diachronically derived from the same source and share phonological, orthographic and semantic similarities across languages (Crystal, 2011). For example, the English word *knife* and the Norwegian word *kniv* are examples of cognates. Cognates can exert facilitatory or inhibitory effects on bilingual word retrieval and comprehension. A cognate facilitation effect results from a simultaneous activation of lexical nodes from both languages. According to the cascaded activation model of lexical access (Caramazza, 1997; Costa et al., 2000), cognates will be named faster than non-cognates in a production task because the activation flow from lexical to phonological levels spread proportionally across the languages facilitating the retrieval of the relevant word. The activation happens in a cascaded fashion as the phonological word form is activated before the lexical form is reached.

A study by Costa and Caramazza (2000) examined the cascaded activation models. The cascaded activation models are commonly juxtaposed with the discrete, serial models, where the phonological activation is limited to the selected lexical node as opposed to all nodes been activated as in the case of cascaded activation models. By testing the performance of bilingual participants instructed to name cognates and non-cognates, they investigated to what extent the non-selected lexical nodes activate their phonological properties. Their predictions were that according to the cascaded activation model of word production, cognates will be named faster than non-cognates. A group of Catalan-Spanish bilingual and a control group of Spanish monolinguals participated in the study. Two experiments were designed to test the predictions. Experiment 1 involved picture naming in Spanish. These comprised cognates in Spanish and Catalan (e.g., *gato-gat* [cat]), and non-cognates (e.g., *mesa-taula* [table]). A difference in response time (RT) was observed for the bilingual group, which named the pictures representing cognates faster. These results provide support for the cascaded model of lexical access. The purpose of Experiment 2 was to observe the impact of language dominance on the cognate effect. The results revealed a stronger cognate facilitation effect in the non-dominant language. Participants whose more dominant language was Catalan showed more cognate effect when performing in English (less dominant language).

4.4. Benefits of bilingualism

Bilingualism has been linked to exerting cognitive benefits on the speaker, such as improving executive function (Bialystok, Craik, Green & Gollan, 2009 in Bialystok 2011; Grosjean & Li, 2013) an enhancing metalinguistic awareness (Bialystok et al. 2008, 2014.). These cognitive benefits give bilingual speakers an advantage over monolingual speakers, which has been demonstrated in multiple studies (see Adesope et al., 2010 for a review on studies investigating EF in bilinguals; Bialystok, Craik, Green & Gollan, 2009; Grosjean & Li, 2013; Vygotsky, 1962), and which has been used as an argument to encourage the use of multiple languages. However, one common concern among parents and teachers is the introduction of more languages to children with neurodevelopmental disorders, such as hyperactivity disorders (ADHD, Corbett et al., 2009; Pani et al., 2013); autism (Robinson et al., 2009); and developmental dyslexia (Booth et al. 2010; Swanson et al., 2009, 2010; Bacon et al., 2013). While the concern has not been supported by research in literature on developmental dyslexia, likewise little research (e.g., Vender et al. 2020) has been conducted showing the contrary and providing evidence for bilingual advantage in this group of children. To understand better the possible correlation between bilingual cognitive advantage and developmental dyslexia, the benefits in executive function and metalinguistic awareness will be discussed together with a relative indication for a connection to typical difficulties experienced by dyslexic children.

Positive cognitive effects in the executive function (EF) system are the most commonly investigated benefits related to bilingualism (see Adesope et al., 2010 for a review on studies investigating EF in bilinguals; Bialystok, Craik, Green & Gollan, 2009; Grosjean & Li 2013). Executive control involves mental processes necessary for more effortful cognitive tasks (Diamond 2013). It is associated with the ability to concentrate, pay attention and inhibit other tasks. Inhibition (self-control and interference control), working memory and cognitive flexibility are believed to be central to EF (Diamond 2013; Lehto et al. 2003; Miyake et al. 2000). The abilities to concentrate on a task, selectively pay attention to specific points, and flexibly shift attention, which are governed by the executive control system, are believed to be enhanced by certain habits and activities. Research on bilingualism has demonstrated that executive control can be enhanced due to the bilingual's unique property, which allows operating successfully and correctly with two divergent systems. The bilingual advantage in EF has been demonstrated in studies, which, among others, investigated inhibitory control (e.g., Bialystok, 1999; Bialystok, Craik, Klein, & Viswanathan, 2004; Martin-Rhee & Bialystok 2008) and cognitive flexibility (e.g., task-switching and language switching – Prior and MacWhinney, 2010). The enhancement of EF in bilinguals is linked to the non-selective nature of the bilingual mental lexicon (Beauvillain & Grainger 1987; Costa 2005), which implies a joint activation of both languages. To ensure that the target language is selected, greater attention efforts, as well as selection and conflict resolution skills are required to suppress the competing language (Bialystok 2011). An attentional mechanism is likely involved (Bialystok, Craik and Luk, 2008), which allows focusing on the target language while ignoring interference from the competing language. For example, as discussed in the preceding section, Green (1998) suggested Inhibitory control as a possible mechanism: due to experiencing a lexical conflict resulting from the competing languages, the bilingual must exert more effort in order to inhibit the non-target language, which leads to greater attention monitoring - part of the executive control processes. Thus, it is suggested that this Inhibitory control system will be enhanced in bilingual speakers if it indeed participates in ordinary language processing (Bialystok, 2011).

One of the factors researched in the context of bilingualism is the similarity between the languages and its effect on inhibition control. While it is not entirely defined what constitutes similarity in the context of language comparison, it appears that the level of similarity is commonly based on the written system the languages belong to, and their syntactic and semantic properties. Orthographic transparency is not usually mentioned in studies on language similarity in bilinguals. However, as it is an important property in the context of the reading process and dyslexia, it appears to be a relevant factor for potential studies on EF benefits of bilingualism in dyslexic readers. An example of a study investigating language similarity was conducted by Prior and Gollan (2011) who examined the connection between language-switching and task-switching. Both of these are associated with “switch costs” in the case of a change in response set, which has been discussed in more details in the preceding section. The switch cost is revealed by a slower reaction time (RT) in comparison to trials with no such change (e.g., Meuter, 2005). The direction of switching tasks has somewhat important implications as switching from an easier task (in the case of language – dominant language, L1) to a more difficult task (less proficient language, L2) results in smaller switch costs than in the reverse direction. Suppressing the previous task (competing language) is more difficult when the task is easier (language more dominant) as it requires more inhibition (Green 1998; Meuter and Allport, 1999). While this phenomenon is rather counterintuitive, it has been explained through task-set intertia hypothesis (Wylie & Allport, 2000), which postulates that the switch cost results from the interference arising from the completion of a previous task. This means that the active suppression of the easier task (more dominant language, L1) during a trial with a more difficult task (less proficient language, L2) will still be present at the beginning of a successive trial with the easier task (more dominant language, L1).

Language similarity factor has been examined in a study conducted by Oschwald et al. (2018), who included bidialectalism (“speaking a dialect in addition to a standard language” p. 3). Similarly to the study conducted by Prior and Gollan (2011), Oschwald et al. (2018) predicted that the efforts necessary for the speaker to suppress interference have an effect on EF. However, Oschwald et al. (2018) hypothesised that language similarity might have two distinct effects on EF. Increased similarity between languages will either require more inhibition effort and lead to the enhancement of EF (Barac and Bialystok, 2012) or generate more adaptation (due to shared grammar, syntax and phonology), which would facilitate lexical access and language comprehension, and hence lead to less effort on the part of EF. According to this, less similar languages require stronger attentional control and monitoring, which would result in more training of EF. Results from previous studies vary with some studies revealing facilitation effect of language similarity (e.g., Bialystok et al. 2003, Barac and Bialystok 2012 with focus on bilingual children) and others not showing a difference (e.g. Costa et al. 2006 with young adults). Inconclusive results were also revealed in studies including bidialectalism (e.g., Kirk et al. 2018); In a study by Kirk et al. (2018), naming latencies of monolingual (English) speakers and bidialectals (English and Dundonian - regional Scots dialect) were compared. Similarly to previous studies on groups of bilinguals, longer naming latencies and a cognate effect were observed when the participants switched between the dialect and standard English. Most of the studies, however, either assessed only EF or linguistic performance which does not provide enough information on the potential connection between language processing demands and EF.

Oschwald et al. (2018) tested four language groups: monolinguals (speakers of Standard German), bidialectals (speakers of Standard German and Swiss German dialect) and bilinguals (one group of *similar bilinguals* speaking L2 from Indo-European language and a group of *dissimilar bilinguals* speaking an L2 from Non Indo-European language family) in order to assess whether language similarity has an effect on EF and linguistic performance. The prediction was that weaker performance in linguistic tasks will correlate with a bigger advantage in EF tasks. The linguistic part of test involved: *verbal fluency* task, *lexical decision-making* task, and the *concreteness effect in a word recognition* task. The EF part of the test involved: *flanker* task and *Simon* task to measure inhibition, *color-shape* task and *parity-magnitude* task to measure mixing and shifting abilities, *squares* task and *digits* task to measure monitoring ability and *figural* task and *numerical* task to measure WM. The results of the study confirmed the prediction that language similarity yields opposite effects on linguistic and EF performance. Increase in language similarity leads to an increase in linguistic accuracy, while at the same time reducing EF performance. Hence, dissimilar languages seem to require stronger attentional control and monitoring, which might be the justification for a more enhanced EF.

The other cognitive benefit of bilingualism often explored in literature on bilingual advantage is enhanced metalinguistic awareness (Vygotsky 1962; Bialystok 1986).

Metalinguistic awareness is defined as the ability to focus on different levels of linguistic structures (Chin & Wigglesworth, 2007). Therefore, morphological awareness, phonological awareness, sentence awareness and semantic awareness are all considered in studies on metalinguistic awareness in bilinguals. Bilingual speakers appear to exhibit an advantage over monolingual speakers in their ability to analyse language forms and recognise the arbitrariness of the relationship between meaning and form (e.g., bilinguals can more easily accept grammatically well-constructed but nonsense sentences, such as “Apples grow on noses” than monolinguals; Bialystok, 1986). This advantage over monolingual children can be demonstrated in any writing system (Bialystok, Luk & Kwan, 2003), and it has been hypothesised to be the result of bilinguals developing a strategy for language analysis in order to overcome interlingual interference (Cummins, 1978). Furthermore, language similarity is also a contributing factor for the bilingual advantage in metalinguistic awareness. In particular, if the two languages share the same system, strategies and expertise from one language can be transferred to the other. This correlation is justified by means of cross-linguistic transfer theory (Kuo et al., 2016), which predicts that if the two languages share a linguistic feature (e.g. specific phonological structure) and that feature is more prominent or complicated in the dominant language, learning of the second language will be facilitated (Kuo et al., 2016). However, if only one of these conditions is met, and the dominant language has a simpler linguistic feature, negative transfer can be expected (Bialystok et al., 2003). This positive transfer has been demonstrated in a number of studies (positive transfer of literacy skills across languages e.g., Geva & Siegel, 2000; Oller & Eilers, 2002). For example, in their study, Bialystok, Majumder and Martin (2003) demonstrated that in a phoneme awareness task in English, monolingual English-speakers were outperformed by bilingual Spanish-English and Hebrew-English speaking. The bilingual advantage was credited to the fact that Spanish and Hebrew are more transparent than English.

One of the most commonly applied tests for assessing metalinguistic morphological awareness is the Wug Test (Berko, 1958), which tests the children’s ability to add inflections to nonsense words (the most basic example of this test assess the children’s awareness of creating English plural forms: “This is a WUG. Now there is another one. There are two of them. There are two ________”; Berko, 1958). In a study by Barac & Bialystok (2012), a group of monolingual children and three groups of bilingual speakers (Spanish-English, French-English and Chinese-English) were tested and compared on a battery of language proficiency tasks including the Wug test. Language similarity and language education were factors included in the study. The results confirmed an advantage of bilinguals over monolinguals in the Spanish-English group. However, the two other groups of bilinguals performed more poorly than the monolingual group. The difference between the Spanish-English bilingual group and the two other groups of bilinguals was justified on the grounds that Spanish-English bilinguals had the advantage of linguistic similarity and the use of English as the language of instruction in their education. The results indicate that there is a bilingual advantage in metalinguistic awareness; however, access to explicit learning in both languages as well as linguistic similarity might be significant contributing factors (Vender et al., 2021).

Furthermore, research on phonological awareness (PA) in bilingualism has provided interesting insight into the relevance of early second language exposure and language similarity. Similarly to morphological awareness, phonological awareness is closely linked to early exposure, which leads to an advantage in understanding the arbitrariness of language (Bialystok, 2001). Bilinguals also show more sensitivity to similarities and differences between the languages, which leads to stronger abstract language representations (Kuo & Anderson, 2010). Similarly to other metalinguistic skills, phonological awareness also transfers to other languages. However, studies investigating the relationship between bilingualism and phonological awareness have not shown a significant advantage in this skill in bilinguals over monolinguals (e.g., Bialystok, Majumder & Martin, 2003; Bruck and Genesee, 1995; Campbell and Sais, 1995Yelland et al., 1993). Most of the studies reported some advantages in selected tasks (e.g., deleting morphemes from words or onset-rime segmentation), but some of the advantages disappeared by the end of Grade 1 (reported by Bruck and Genesee, 1995; Campbell and Sais, 1995; and Yelland et al., 1993), and some were attributed to the phonological or syllabic structure of the languages involved (French in Bruck and Genesee, 1995; and Italian in Yelland et al., 1993). Bialystok, Majumder and Martin (2003) tried to establish the impact of bilingualism on phonological awareness by including different groups of bilinguals in their study in order to investigate the language similarity as a factor in potential difference. Therefore, they included a group of Spanish-English bilinguals and a group of English-Chinese bilinguals. The Spanish-English group showed an advantage over the other group of bilinguals and monolinguals. However, Bialystok, Majumder and Martin speculated attributing the advantage to the particular linguistic similarity (sound structure) between Spanish and English. They suggested that some pairs of languages may be more prone to the discovery of phonological structures. Moreover, they considered the simple phonetic structure of Spanish as a contributing factor, which could have promoted early access to phonological awareness. Finally, they also recognised the importance of the language of literacy instruction. The performance was higher when tasks were all in English, which was the language of literacy instruction for some of the participants. However, when the language of testing was the same as the language of literacy instruction, there were no group differences observed. Overall, the study concluded that bilingual children do not develop phonological awareness more easily than monolingual children.

4.5. The characteristics of English and Norwegian

Considering the importance of language similarity, the following section will discuss in more detail the particular characteristics of the two languages involved in the study; i.e., English and Norwegian.

English language: Orthography and phonology

The English language belongs to the Indo-European family of languages, and it is further subcategorised as a Germanic language. Its Germanic nature is primarily attributed to the influence Anglo Saxons invasions (5^{th} and 9^{th} centuries BC) had on the development of the language spoken by native inhabitants of the British islands. Another important change came with the Norman invasion, which introduced French and Latin (Perfetti and Harris, 2017). The combination of these two divergent sources of language had an unusual effect on the development of the English language and its written form. Initially, Latin and French were used for written records and official correspondence (Fisher, 1984: 161, see Chancery Standard[2]), while the Germanic influence was mostly present in the spoken language. Adjusting the script and the writing system from the Latin language to express the language spoken by lay people required some adaptations to the orthography and grammar of modern English. Old records reveal that many English words had several different spelling variants (e.g., 'e' often added at the end of words *goodnesse*, vowels commonly interchanged encrease, 'u' and 'v' often interchangeable deliuvering, apostrophes often used instead of 'e' brush'd, Baron, 2011). Remarkably, these variations were not only present in different texts, but also within one text. As this impacted the language's credibility, the need for

[2] "By the early 1430s the Chancery had developed its own 'standard' written English which more closely resembled today's modern Standard English than other texts from the period, such as personal letters. Due to the prestige and authority of any documents written by the Chancery and the need for a standardised form of English for official bodies, Chancery English became the most commonly accepted written standard and thus a forerunner to modern standard English" (Richardson, 1980 in Baron 2011)

standardisation emerged. Since the first attempt at creating a standardised form of the written language, i.e, Chancery Standard, it had taken several centuries before the English spelling became regular and standardized (Baron, 2011; Perfetti and Harris 2017). However, it needs to be noted that variations exist between different standards of English (e.g, the British English spelling of the word *colour* differs from the American English spelling which omit the 'u' *color.* However, within each system, the spelling is standardised). While all modern alphabetic orthographies are standardized, not all languages are actually controlled by an official academy such as Académie Française for the French language or Rat für deutsche Rechtschreibung for the German language. English does not have an official body providing a prescriptive standard; it is governed by descriptive standards. Standard English consists of 26 letters adapted from the Roman alphabet (which was not optimal for encoding all the sounds of the English language). As there is a number of dialects of English in the world, the number of phonemes ranges from 37 to 42 (Perfetti and Harris, 2017 p.7), which is sizable considering that languages on average have ca. 30 phonemes (Hay and Nauer, 2007 in Perfetti and Harris 2017, p.7).

Despite the establishment of standard spelling of English words, the previously described influences led to multiple inconsistencies in the mapping between the written form and phonology on the grapheme-to-phoneme level. As previously discussed, English is defined as having an opaque (deep) orthography. This situation creates more challenges for the readers, as they must rely more on groups of letters, morphemes and lexical information, than a letter-by-letter reading (common for alphabetic languages) to decode a written text (Miller, 2019). The reason for such orthographic irregularities stems from the fact that English "orthography sometimes encodes morphology at the expense of grapheme-phoneme consistency" (Perfetti and Harris, 2017 p.7). An example is the past tense morpheme –ed which is orthographically consistent, but which differs phonologically depending on the sound proceeding the morpheme (played - /d/, hunted - /ɪd/, and walked - /t/, Miller, 2019). In the case of derivational morphology, the phonological information of the stem might also change in some English words (e.g. *nation* and *national* or *resign* and *resignation*, Miller, 2019). In these cases the spelling remains the same at the expense of phonological change.

There are certain characteristics of the English orthography, which make it distinguishable from the majority of other alphabetic languages, and which define the language as opaque in terms of its grapheme-to-sound correspondence. For example, Brinton and Brinton (2010) list some unique characteristics of the English language. The most prominent ones state that a) a sound in English can be represented by a number of different graphemes (e.g. /i:/ in quay, meet, evil); b) one grapheme can represent more than one sound (e.g., [d] in damage, education); c) a grapheme can represent no sound at all (e.g., *k̲nee*, *receip̲t*). These specific attributes contribute to particular spelling challenges not only for English native speakers but also for learners of English as a foreign language.

The Norwegian language: orthography and phonology

Similarly to English, Norwegian belongs to the Indo-European family of languages and is further subcategorised as northern Germanic language. This means that its characteristics are closely linked to other northern Germanic language, i.e., Danish and Swedish, which allows speakers of these languages to communicate with a considerable level of understanding (Klouman, 2002). The Norwegian language is based on the alphabetic principle, which is the idea that letter patterns correspond to specific sounds of the spoken language. The letters in the Norwegian language derive from the Latin alphabet; however, the Norwegian alphabet is extended by additional letters, i.e., æ, ø and å, corresponding to three sounds uniquely present in the Norwegian spoken language. The letters x, z, w and c are mostly used to represent loan words from other languages. Table 2 shows the Norwegian consonant inventory.

Table 2

Norwegian consonant inventory

		Coronal			
	Labial	Dental/alveolar	Retroflex	Dorsal	Laryngeal
Plosives	p, b	t, d	ʈ, ɖ	k, g	
Nasals	m	n	ɳ	ŋ	
Fricatives	f	s	ʃ	ç	h
Liquids		ɾ	ɽ, ɭ		
Approximants	ʋ, (w)			j	

Note: Adapted from Kristoffersen (2000)

Most letters in the Norwegian alphabet correspond to one specific phoneme; however, there are also several consonant clusters, e.g., rs, sk, skj, sj, skj). In terms of the Norwegian vowel system, one of the most crucial aspects is that the length of the vowels is phonologically relevant. This means that there are minimal pairs in Norwegian that differ from each other with respect to the length of the vowel, for example *gul (yellow) – gull (gold), hele (whole, all) – helle (pour).* With regards to the Norwegian written language, there are two standard written forms of the language, i.e., bokmål (evolve during the union with Denmark; based on

Danish) and nynork (modern alternative to bokmål developed on the basis of Norwegian dialects). Unlike English, both bokmål and nynorsk are governed by an official language council called Språkrådet.

Norwegian written language is not characterised by many exceptions; thus, it is considered a shallow (transparent) language, which makes it easier to learn for those who are struggling to learn the alphabetical principle.

Comparison between English and Norwegian

While both English and Norwegian belong to the group of Germanic languages, there are significant phonetic differences between them. These differences were not as prominent before the 15th century, as Old English was greatly influenced by the language that arrived to the British islands with the Viking invasions. However, the most significant change that led to many phonological differences between English and Norwegian in the course of their evolution was the Great vowel shift, which affected all the vowels in the English language. This resulted in the rise of long vowels in their place of articulation. Vowels which could not be further raised developed into double-vowels or diphthongs. Thus, long vowels /i/, /u/, and /a/ in Norwegian word correspond in a regular way to diphthongs in similar English words. Table 2 presents some examples of this correspondence between Norwegian and English cognates.

Table 3

Comparison between long vowels /i/, /u/, and /a/ in Norwegian and diphthongs in similar English words.

Norwegian /iː/	**English / ɑɪ/**
Å like	To like
Å smile	To smile
Norwegian / ɑː/	**English / eɪ/**
Å hate	To hate
Å bake	To bake

Note: Adapted from Klouman (2002)

The Great Vowel Shift was one of the main changes that led to quite distinct vowel inventories between these two languages. Additionally, the fact that the length of a Norwegian vowel leads to a change in meaning gives Norwegian a wider range of phonemes. However, at the same time, due to the number of dialects, there is no accepted pronunciation for Norwegian (Husby et al. 2011). Thus, it is common to refer to UEN Urban East Norwegian, as the accepted standard of spoken Norwegian. Figure 8 shows the overlap between Norwegian and English vowel sounds. The vowels on the white background indicate an exact overlap between the two languages. The vowels on the grey background indicate an overlap to a certain degree, while the vowels on he black background indicate that there are no English equivalents.

i	e	æ	ɑ	y	ʉ	ø	u	o
i:	e:	æ:	ɑ:	y:	ʉ:	ø:	u:	o:

Figure 8. Norwegian vowels and their overlap with English vowel sounds.

Note: Adapted from Husby et al. (2011)

Norwegian and English share most consonants, with the exception of retroflex consonants, which are present in Norwegian but not in English, and postalveolar consonants, which appear in English but not in Norwegian. Figure 9 shows the overlap between the Norwegian and English consonant sounds. Similarly to the figure with vowels, the background colour indicates the degree of overlap.

p	b	t	d	ʈ	ɖ	k	g	l	ɭ	r
m	n	ɳ	ŋ	f	v	s	ʃ	ç	j	h

Figure 9. Norwegian consonants and their overlap with English consonant sounds.

Note: Adapted from Husby et al. (2011)

5. The present study

5.1. Case study

The approach for the current study was to collect qualitative and quantitative data that can provide a comprehensive illustration of the particular case of dyslexia in bilingualism. A case study has been selected as the study design for this project. The choice of study design was made based on several factors. First, the specific area of psycholinguistic, i.e., bilingualism makes it challenging to find a homogenous group of subjects in terms of their proficiency in both languages while controlling for other variables such as age, SES; thus, there exists a potential risk of inconsistent data if the process of establishing the bilingual profile is not done effectively. Furthermore, access to individuals with the particular characteristics of a dyslexic bilingual is somewhat limited in the location where the study was conducted, which narrows done the potential target group for the study. Next, the nature of the research question indicates that the study is of a descriptive and causal type (Trochim, 2000 in Wei & Moyer, 2008), which means that it describes a phenomenon and attempts to determine a cause-and-effect relationship between variables. As the objective is not to observe changes over time, the study does not require a longitudinal approach. Neither does it intend to compare different sets of languages, so it does not require different study groups to be compared. Finally, as the study requires quite detailed analysis of tests results and the participant's dyslexia profile, the choice of a single case study allows a careful and thorough investigation of the research question.

Qualitative data will be collected through bilingual profile questionnaire and through an analysis of the dyslexic test results in English and Norwegian. Quantitative data will be collected through two experiments that will investigate the cognate effects in both languages. One of the experiments will involve the rapid automatized naming task (RAN; Logos Subtest 14 Quick naming of known objects), which maps the student's ability to quickly name a number of known objects. The participant is presented with a series of pictures representing five objects randomly repeated. The participant's task is to name the items from top left to bottom right. Before the task begins, the test leader goes through the pictures with the participant, and they agree on what the pictures illustrate. The goal is to measure the naming speed. The time is registered manually. To investigate cognate facilitation effect in a receptive reading task, a word-spotting task was developed based on one of the tasks from the Norwegian Logos test "Å skille mellom ord og homophone nonord" (Distinguishing between words and homophone non-words). This subtest measures orthographic recognition skills. The participant is presented with two stimuli on the screen - a word and a homophonic (or near-homophonic) non-word. The task is to decide which of the two stimuli represent a correctly spelled word. A homophonic non-word is pronounced in the same way as the corresponding target word. The correct answer, therefore, presupposes orthographic recognition. If the participant uses a phonological decoding strategy, both words result in the same audio package so that they cannot be distinguished. Short time in combination with several errors indicates guessing. Long time use, on the other hand, is a sign that the student has tried to solve the task and answered to the best of his/her ability. Both accuracy and time (R1) are registered automatically. For the purpose of this study, the word spotting task has been modified to include both Norwegian and English homophones to observe the effect of bilingualism on dyslexia.

5.2. Predictions

As the objective of this study was to observe how dyslexia presents itself in bilingualism, the main focus will be on the dyslexia assessment results in both languages as well as the cognate status and its impact on performance in the two languages used by the participant. The first prediction concerns the transferability of the linguistic features of English and Norwegian into the other language. As the mental lexicon of a bilingual person is of a non-selective nature, it is expected that the interaction between the languages will affect the dyslexic individual in a more explicit way. That means that spelling patterns of one language might interfere with the other language.

Furthermore, it is predicted that in the experiments concerning the evaluation of the cognate effect, both languages will show a cognate facilitation effect in the production task (RAN), and a cognate interference effect in the comprehension task (word spotting). This is based on the predictions of the cascaded activation model of lexical access (Caramazza, 1997; Costa et al., 2000; Dell, 1986).

Finally, it is predicted that orthographic transparency contributes to the amount of errors made by the bilingual individual. It is expected that the participant will make fewer errors in the more transparent language, i.e., Norwegian, because the correspondence between the grapheme and phonemes is more direct and consistent. More errors are expected to be made in the more opaque language, i.e., English due to its inconsistent GPC. In more opaque orthographies children present higher error rates than children in transparent orthographies (Seymour et al., 2003).

5.3. Participant

The study participant was selected based on her bilingual and dyslexic profile. The pupil was an eleven-year-old student attending an international school in Norway where English was the medium of instruction. As the participant was under age, a consent form was required to be signed by the parents.

6. Method

6.1. Bilingual profile and language proficiency questionnaire

Method & Design

A bilingual profile questionnaire adapted from Marian, Blumenfeld and Kaushanskaya (2007) was administrated to establish the pupil's linguistic background and evaluate their language proficiency in English and Norwegian (Appendix 1). The questionnaire consisted of three main parts: Demographic characteristics, Norwegian and English proficiency. The purpose of the questionnaire was to acquire a more thorough understanding of the participant's language background, as well as collect additional information about the participant's own perception of their linguistic experience (whether they feel equally fluent in both languages, or what they prefer to use in specific social situations) as well as their proficiency in both languages. The information collected through the questionnaire would provide an understanding of the pupil's language dominance, typical usage, and perceived proficiency. The first part of the questionnaire; i.e., Demographic characteristics consisted of six questions regarding the pupil's age, gender, basic health condition (vision and hearing), country of birth and residence. The questions in the Language background section concerned the participant's: exposure to written and spoken English and Norwegian, cultural and national identity, own evaluation of linguistic proficiency in both languages, their language usage and language preference during various daily activities (e.g., talking to yourself, doing simple mental Math tasks). In total, eight questions comprised this section of the questionnaire. All the answers to the above-described questions were scored descriptively. The final section, i.e., Norwegian and English proficiency, consisted of six questions, which were scored numerically on a scale from one to ten. The questions concerned the length of time the pupil spent using each language at home and at school as well as factors contributing to their language learning (e.g., interactions with friends, school, reading, watching TV etc.). Finally, questions concerning the pupil's dialect, accent and language switching were included at the end of the questionnaire.

Procedure

The data was collected in an environment that was safe and comfortable for the participant. She was asked to relax and answer the questions read by the administrator. The participant was informed that she could take a break at any time, and there was no time limit. The questions were all in English and the administrator used English to communicate with the participant.

Results and discussion

The pupil is an eleven-year-old student attending an international school in Norway where English is the medium of instruction. The pupil has attended the International school from the first grade (from the age of six), before which they had been at a kindergarten for one year.

Even though they were born in Norway, the pupil spent most of their childhood in Switzerland where they lived for the first five years of their life. The pupil also attended a Swiss nursery and kindergarten for two years. They claimed that they did not remember nor did they speak Swiss German. The participant is an English-Norwegian bilingual, raised by a native English-speaking father and a native Norwegian-speaking mother. The parents use their native languages in communication with MW, so they are regularly exposed to both Norwegian and English.

They participant found it challenging to answer the question concerning their language dominance. They said that they “think, it is Norwegian”, but they know more English words. Norwegian was the first language in order of acquisition according to the participant. It was also difficult for the participant to provide an answer concerning the percentage of language usage in different scenarios. They felt, however, that the majority of time spent on listening, speaking and reading is definitely in English. Their answer to the question concerning the choice of language when the conversation partner is equally fluent in both language depended on the context. The pupil reported that their preferred language of communication with classmates is Norwegian, while English is chosen when speaking with a sibling. When asked about their cultural identity, they responded that they feel more Norwegian as they are “used to the cold”. When asked about the choice of language during specific activities, the pupil admitted using English for simple mental Math calculations as well as talking to herself. However, they clarified that their inner self-talk (self-voice) is in Norwegian. Similarly, they reported expressing emotions in Norwegian. Dreams appear to be in both languages. In the final part of the questionnaire, the pupil struggled specifying the number of years or months spent in specific linguistic environment. They reported having lived eight years in Norway and spending summer holidays in England. They have attended six years of primary school in an English-speaking environment, after one year of a Norwegian kindergarten. In terms of factors contributing to their linguistic development, the pupil gave, overall, similar answers to both Norwegian and English. However, they felt that school and education was a more contributing factor to their learning of English. In the section concerning dialect and accent, the pupil struggled responding whether they spoke with a Norwegian dialect; therefore, the author of this work discussed this question further with the mother, who admitted that they came from a different region than the one they live in, so they neither speak the local dialect nor the one the mother was brought up with. The pupil does not have a regional English accent. Finally, the pupil admitted to mixing words or sentences from the opposite language when speaking English or Norwegian.

Based on the pupil's responses, they can be considered to represent simultaneous bilingualism (Bialystok and Hakuta, 1994 in Harley, 2008), which is defined by having learnt both languages about the same time. However, several important points must be noted with regard to their use of Norwegian and English. As the pupil was a student at a school where the medium of instruction was English, in terms of subject-specific vocabulary, they were more proficient in English. In social interactions, the pupil tended to use Norwegian, with the exception for their brother with whom they spoke English. The pupil claimed to know more English words, but they thought and expressed emotions in Norwegian. The pupil also felt Norwegian because they are "used to the cold". With regard to the pupil's dyslexia difficulties, they perceived English as "one percent more difficult than Norwegian because of the secret letters".

Regarding the above information, it can be concluded that the pupil is close to a balanced bilingual in terms of their speaking and reading skills. As they use English throughout the day in a school context, there is a slight advantage for that language in terms of academic-related vocabulary development and exposure to a variety of text on different topics in English. Their English writing skills cannot be assessed on the basis of the questionnaire; however, it can be anticipated that due to having formal education in English, the pupil is more proficient in English. Overall, English appears to be a slightly more dominant language in the case of this participant.

6.2. Dyslexia assessments

Diagnosis history

The pupil was diagnosed with dyslexia in 4th grade when they were nine. They had normal vision and normal hearing. They did, however, suffer from a somewhat rare condition, which caused them to lose most of their teeth, and during the study, the pupil was undergoing a denture fitting process. This circumstance affected their articulation slightly; therefore, the study does not investigate the details of their articulation and pronunciation of speech sounds. This condition also had an impact on the pupil's confidence, which had already been affected by the attention they had been receiving due to their dyslexia. While the pupil appeared cheerful and did not show a lack of self-confidence, it was important to be aware of these circumstances while collecting data.

While the pupil was diagnosed with dyslexia in the 4th grade, their reading difficulties had started appearing already in the 2nd grade where they struggled to decode texts and tried to sound out the letters comprising the words. Their reading comprehension was, however, consistent with what is typically expected at that age. At that time, their reading skills in Norwegian were within grade level expectation for 2nd grade. Nevertheless, it was observed that the pupil needed to put a significant amount of effort to decode the words, and they tended to mix Norwegian vowels in spelling and reading. In the 3rd grade, the pupil was assessed within grade level expectations in their listening and speaking skills, but in their writing and reading skills, they were below grade level expectation. The pupil was initially screened for dyslexia in English at their school by means of commonly used screening tools, i.e., Nessy (www.nessy.com/uk) and LASS (www.gl-assessment.co.uk/assessments/products/lucid-lass-8-11). They were then referred to the Pedagogisk Psykologiske Tjeneste (PPT), which is the Norwegian municipal advisory service responsible for diagnosing children who demonstrate difficulties in their academic performance. After being tested with a Norwegian diagnostic tool – Logos (Logos.no) and receiving dyslexia diagnosis, the pupil started receiving additional support from specialised teachers and assistance during lessons. The structure and results of these initial diagnostics tests are summarized below.

LASS and NESSY

Prior to dyslexia assessment in Norwegian, the pupil was tested by means of two screening tests designed for English speaking students. Both tests were administrated at the pupil's school in November (LASS) and December (Nessy) 2018. LASS is a dyslexia screening test developed and provided by GL Assessment, which is a leading provider of formative assessments in the United Kingdom. It is an assessment of literacy and cognitive skills for two age ranges, i.e., 8-11 and 11-15 years. Eight tests of reasoning, reading, phonic decoding, spelling, memory (visual and verbal), and phonological awareness are included. It is a research-based test, which has been psychometrically validated and standardized on a national level. LASS is available in a digital form, and the duration of the test ranges between 30 to 45 minutes. It is considered simple to administer and requires minimum supervision. It is commonly used to identify weakness and strengths in students who demonstrate high probability of dyslexia (www.gl-assessment.co.uk). The test consists of nine subtests presented and described in table 3. The test has recently changed, so the version taken by the student differs slightly from the most recent version. However, all the subtests taken by the student are included in the current version and described in table 4 (see Appendix 2 for a more detailed report of the LASS test).

Tabe 4

The LASS subtests

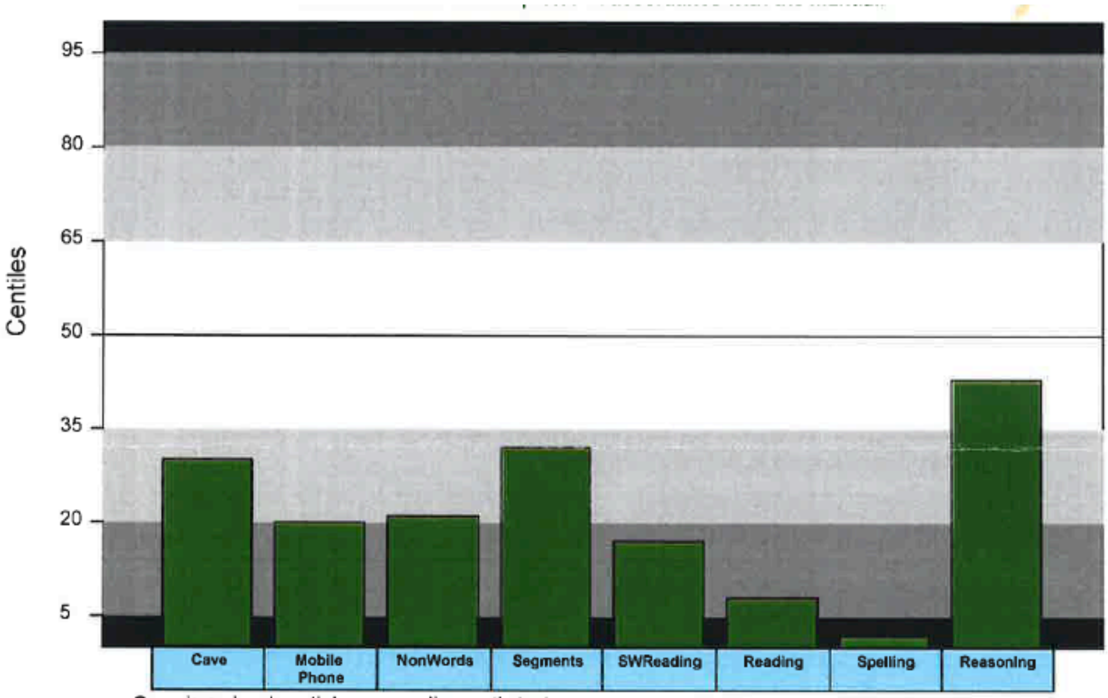
Table 1. The LASS 8–11 subtests

TEST	CATEGORY	TYPE	DESCRIPTION
Sentence reading	Attainment	Adaptive	Close reading – completing sentences by identifying the missing word from a choice of five alternatives. No spoken assistance is given.
Single word reading	Attainment	Adaptive	Reading individual words out of context – identifying the printed word, from a choice of five alternatives, that corresponds to a spoken word.
Spelling	Attainment	Adaptive	Spelling individual real words that are spoken by the computer.
Non-verbal reasoning	Ability	Adaptive	Non-verbal intelligence – analogical reasoning where the correct item, from a choice of six alternatives, has to be selected in order to complete a spatial matrix.
Verbal reasoning	Ability	Adaptive	Verbal intelligence – conceptual similarities where the correct word, from a choice of six, has to be selected that provides the best conceptual link between two pictures.
Mobile phone	Diagnostic	Progressive	Auditory sequential memory (digit span) – recall of between two and nine digits in correct (forwards) sequential order, and recall of between two and seven digits in reverse order.
Sea creatures	Diagnostic	Progressive	Visual memory – immediate recall of objects and their spatial positions, beginning with two items and progressing to seven items.
Funny words / Non-words	Diagnostic	Adaptive	Reading individual non-words – a pure measure of phonic decoding skills. For each non-word there is a choice from four spoken alternatives.
Word chopping / Segments	Diagnostic	Adaptive	Phonological processing ability – segmentation and deletion of syllables and phonemes in real words. For each item there is a choice from four spoken alternatives.

Note. Retrieved from: Horne. J. 2019. User Manual. LASS. London: GL Education

LASS is an adaptive test, which refers to a technique that modifies the nature of the test in response to the performance of the test-taker. Due to that the test is more dynamic as the computer can screen performance as the test unfolds, and as a result, modify it accordingly to the individual.

The results of the LASS test are shown in Figure 10. As can be seen, the student scored particularly low on reading and spelling tests. Single word reading subtest, Non-words subtest as well the Mobile Phone subtest (which measures auditory sequential memory) indicated a score of percentile 21 or below which indicate that the student has significant difficulties with phonological and orthographic reading. Their auditory short-term memory is not strong which is common in dyslexic readers.



Cave is a visual spatial memory diagnostic test.
Mobile Phone is a measure of auditory sequential memory involving digit span (diagnostic test).
NonWords is a diagnostic test of phonic decoding skills.
Segments is a test of syllable and phoneme deletion identifying phonological processing ability.
Single Word Reading is an attainment test involving the reading of individual words out of context.
Reading is an attainment measure involving a cloze reading task (finding the missing word in a sentence).
Spelling is an attainment task which involves the spelling of single words.
Reasoning is an ability test giving a measure of non-verbal intelligence.

Figure 10. LASS Graphical profile

Nessy is a game-based test designed to identify children at risk of dyslexia. The test includes rapid automatic naming (RAN), working memory, phonemic and phonological awareness skills subtests. (www.nessy.com/uk). The results of the test are presented in Figure 11. As can be seen from the graph, the results support the outcomes of the LASS test. The student scored significantly low on the Phonological awareness subtest, which indicate challenges related to phonological decoding skills. Also the scores achieved in the Working Memory and Auditory Sequential subtests provide additional proof of the student's weaker short-term memory abilities.

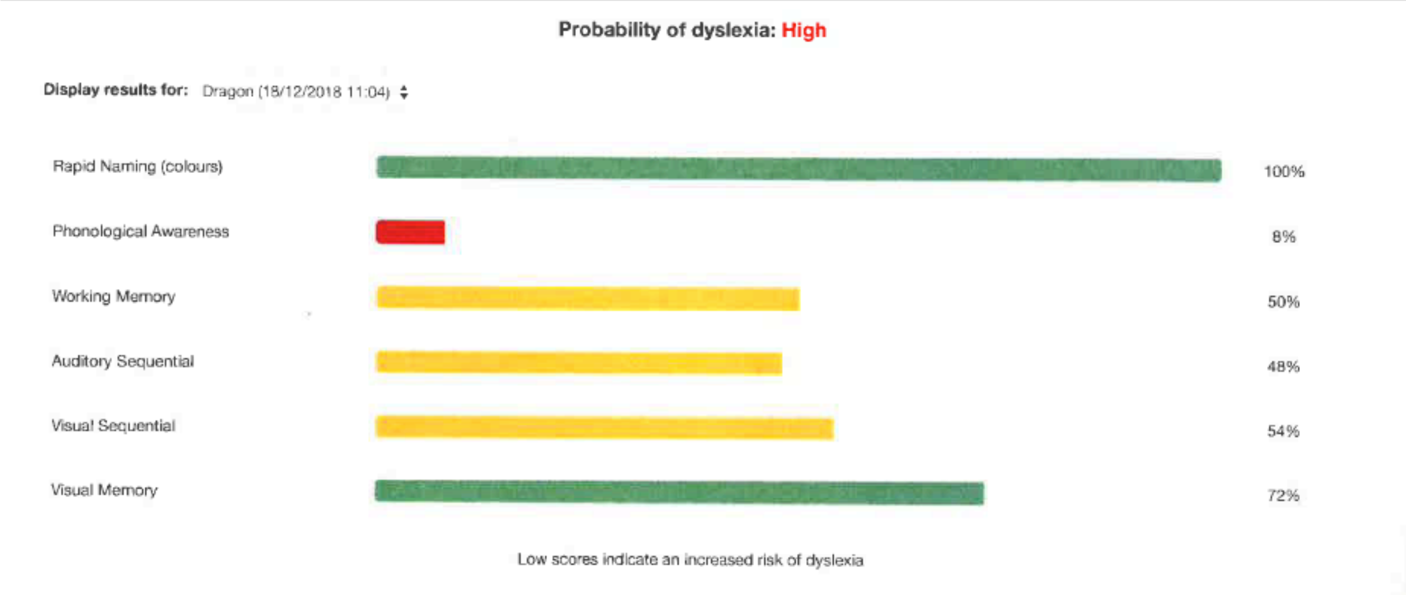


Figure 11. Nessy Student report

Based on the results from both tests, it can be observed that the student has particular challenges related with phonological decoding skills, orthographic reading skills and short-term memory. The Nessy and LASS tests, therefore, provide a reliable indication for dyslexia; however, they cannot be used as formal diagnostic tools.

Logos

Method

There are three versions of Logos test tailored to different age groups. The tasks in each version vary in terms of complexity and type (see Table 3). Correctness and accuracy are expressed in percentage (%), and time is measured in seconds (sec.). Efficiency targets are calculated as quotient of accuracy and time (%/sec.). Logos results are expressed in percentiles, which represent how well the student performed in comparison to a standardised group of a 100 participants. This means that, e.g., if a participant receives 5 percentile in listening comprehension task, 5% of students within the particular task set received the same or lower results. Two thresholds are of critical importance: percentile value of 30 or below is considered an indication of moderate difficulties, and a percentile value of 15 and below indicates significant difficulties.

The test consists of tasks that, among others, assess phonemic awareness, phonological decoding skills, word identification skills, phonological short-term memory, reading and listening comprehension, reading fluency and spelling. These skills are assessed through a battery of tasks designed to address these different areas. All task sets in Logos begin with two practice example activities, which allow the student to become familiar with the particular task. The result of the practice activities is not included in the interpretation of the task. Depending on the task set, Logos ranges from 13 to 18 tasks (subtests; see Table 4). Six tasks are considered to be the main indicators of dyslexia and will be discussed here first.

Table 5

The subtests of Logos task set 2 and Logos task set 3

	Logos task set 3
1. Reading fluency and reading comprehension	1. Reading fluency and reading comprehension
2. Listening comprehension	2. Listening comprehension
3. Word identification	3. Word identification
4. Phonological reading	4. Phonological reading
5. Orthographic reading	5. Orthographic reading
6. Letter reading	6. Phonemic awareness
7. Graphem-phoneme encoding	7. Phonological short-term memory
8. Phoneme synthesis	8. Working memory
9. Phoneme analysis	9. Distinguishing between words and homophonic nonwords
10. Phonological short-term memory	10. Quick naming of known objects
11. Distinguishing between words and homophonic nonwords	11. Visual short-tem memory
12. Visual analysis	12. Understanding concepts
13. Phonological discrimination	13. Oral reaction time
14. Quick naming of known objects	14. Manual response time
15. Understanding concepts	15. Dictation
16. Oral reaction time	
17. Manual response time	
18. Dictation	

Subtest 1 Reading fluency and reading comprehension

This subtest maps reading fluency and reading comprehension. The student's task is to read aloud a text that consists of five sections, while the test leader registers reading errors. The reading time is measured from the moment the paragraph appears on the screen until the test administrator presses the M key on the keyboard when the child has finished reading. The reading flow (WCPM) refers to the number of correctly read words per minute. The test administrator must, in addition, assess intonation and stress as well as monitor whether the student takes into account the punctuation during reading. Students with decoding difficulties often spend a long time reading the text aloud, in addition to having more decoding errors. Difficulties with word decoding often lead to reduced reading comprehension. Accuracy, reading time and reading flow are registered. Reading comprehension is calculated based on the sum of correct answers after each paragraph of text. The student is given three questions for each paragraph, which amounts to 15 questions for the whole text. Here only accuracy is measured. The test leader registers incorrect answers.

Subtest 3 Word identification

This subtest measures the participant's ability to read single words with a long presentation time. The student is presented with a series of words on the screen, one word at a time. The words remain on the screen for up to five seconds. The relatively long presentation time allows the participant to choose freely which decoding strategy they want to use. The words are presented in random order and vary in length, frequency and complexity. A cross analysis of the linguistic dimensions provides important information about which strategy the participant is using. The use of longer time to read by the participant indicates that the participant uses a phonological decoding strategy (i.e., they use the grapheme to phoneme rules to decode the word). In this case, short words and simple words are mastered faster than long and complex ones. The frequency dimension, on the other hand, has little significance, as most words will be low-frequency for a phonological reader. On the other hand, a participant who uses an orthographic decoding strategy (i.e., they reads through the lexical route which allows a quick identification of words stored in the mental lexicon) tends to decode relatively quickly. Inadequate orthographic word recognition is characterized more by an increased number of reading errors than by using longer time. Students who read orthographically read high-frequency words better than low frequency ones. On the other hand, word length and word complexity have little meaning for an orthographic reader. Thus, a cross analysis of the linguistic dimensions of word length, complexity and frequency provides important information about the student's strategy use. An analysis of the participant’s reading errors provides additional information about the type of strategy used and the participant’s mastery of that strategy. In the test instruction, the student is told to read each word as quickly and correctly as possible. The subtest is answered orally. Both correctness and time use (R2) are registered. The test leader must register reading errors.

Subtest 4 Phonological reading

This subtest measures the student's ability to read using a phonological decoding strategy. The participants are presented with non-words (i.e., pseudowords, e.g., *vun*, which is a unit of text that resembles a word in a specific language, as it follows the phonotactic rules of the language but, in fact, carries no meaning), and the ability to read them is considered a valid test for the phonological decoding strategy. Using non-word prevents an orthographic recognition, and the reader is forced to use a phonological decoding skills. The non-words are constructed in a way that they contain as little as possible known orthographic patterns. The non-words are presented one at a time. Each non-word is displayed on the screen for up to five seconds. This gives the reader enough time to analyse the letter series phonologically. They are presented in random order and vary in length and complexity. The task for the student is to decode the non-words correctly and as quickly as possible. The participant provides the answer orally. Both correctness and time use (R2) are registered. The test leader registers errors.

Subtest 5 Orthographic reading

Subtest 5 measures the student's ability to read using an orthographic decoding strategy. The student is introduced to a series of words that appear individually on the screen. Every word stays on the screen for 0.2 seconds. The words are presented in random order and vary in length and frequency. Most of the words are irregular, which means that they cannot be decoded following conventional grapheme-to-phoneme correspondence rules. The short exposure time and the irregularity of the words limit the possibility of using a phonological decoding strategy. The student is instead forced to focus on the whole word and, thus, relies on orthographic recognition. The task is to recognize the words correctly and as quickly as possible. The subtest is answered orally. Both correctness and time use (R2) are registered. The test leader registers errors.

Subtest 18 (15) Dictation

This subtest assesses the participant's spelling skills. The dictation consists of a number of sentences read aloud one at a time by the test leader. Each task consists of one sentence, and in each sentence, there is one word the participant is expected to write. The participant writes on the back sheet of the notebook. The subtest contains both regular and irregular words, but most are irregular. It is not expected for the participant to be able to spell all the words in the test, and the subtest can be completed after five consecutive errors. An analysis of the student's spelling errors will provide important information about the spelling difficulties and the need for further follow-up. The participant answers the assignment in writing. The test leader assesses spelling skills and registers the result in Logos afterwards. Only accuracy is considered.

Subtest 2 Listening comprehension

Subtest 2 maps the participant's ability to complete an auditive text comprehension task. The participant listens five sections of one text. Each section is followed by three question related to the text. The participant's task is to answer the questions as correctly as possible. The text and questions are constructed in the same way as in the subtitle *Reading fluency and reading comprehension*. Students with decoding difficulties tend to have better listening comprehension than reading comprehension skills, because a large part of the student's cognitive resources are tied up in the work with word decoding. Questions are answered orally. Only correctness is registered. The test adminstrator registers incorrect answers.

Apart from the main indicators, Logos has the following tests, which help diagnose dyslexia and understand the student's specific challenges.

Subtest 6 Letter knowledge

The subtest measures the participant's knowledge of the names of the letters. The letter knowledge is mapped by presenting the participant with letters on the screen, one at a time. Each letter appears on the screen for up to two seconds. Letter knowledge is a prerequisite for both phonological and orthographic decoding. The task requires the participant to name each letter correctly and as quickly as possible. The subtest is answered orally. Both correctness and time use (R2) are registered. The test leader registers errors.

Subtest 7 Grapheme - phoneme decoding

The subtest measures the participant's knowledge of graphemes and what phonemes represent them. A series of simple and compound graphemes appear on the screen. The participant's task is to name the graphemes. Each grapheme is displayed on the screen for up to two seconds. The subtest is answered orally. Both correctness and time use (R2) are registered. The test leader registers errors.

Subtest 8 Phoneme Synthesis

The subtest measures the participant's ability to connect phonemes into words. The participant hears a number of phonemes and their task is to indicate which word the phonemes constitute. The phonemes are presented with a time interval of 0,5 second between each sound. The tasks have increasing difficulty. If the participant has problems with phoneme synthesis, it makes it difficult to use a phonological decoding strategy. Any problems with the phonological short-term memory make the synthesis process difficult. The student answers orally. Both accuracy and time use (R2) registered. The test leader registers errors.

Subtest 9 Phoneme Analysis

The subtest maps the participant's ability to identify and analyze a word and its respective phonemes. The subtest contains two types of tasks: finding the last phoneme in a spoken word and stating all the phonemes that make up a word. The ability to name phonemes is important for the development of a good phonological decoding strategy. The participant answers the task orally. Both correctness and time (R2) is recorded. The test administrator registers all errors.

Subtest 10 Phonological short-term memory

Participant's ability to remember and repeat a series of numbers is tested in this part of Logos. The numbers must be repeated in the same order in which the participant hears them. Between each number there is a time interval of 0.5 seconds. There is an increase in difficulty as the test progresses. The task begins with three numbers. Then the tasks are expanded to 6 numbers. The task can be interrupted after three subsequent errors. The phonological short-term memory test provides information about how many sound segments a student can hold in memory for a short while. Participants who read using phonological decoding must keep more phonemes in the short-term memory, until the entire letter series is recoded and the synthesis is completed. Difficulties with phonological short-term memory make it particularly difficult to use one phonological decoding strategy.

Subtest 11 (9) Distinguishing between words and homophonic non-words

This subtest maps orthographic recognition skills. The participant is presented with two stimuli on the screen - a word and a homophonic non-word (e.g., *glue* and *glew*). The task is to decide which of the two stimuli represent a correctly spelled word. A homophonic non-word is pronounced in the same way as the corresponding target word. The correct answer, therefore, presupposes orthographic recognition. If the participant uses a phonological decoding strategy, both words result in the same audio package so that they cannot be distinguished. The subtest is answered manually by pressing either the M or Z key on the keyboard. The student gives an answer by pressing the key that is on the same side as the word that is spelled correctly. Short time in combination with several errors indicates guessing. Long time use, on the other hand, is a sign that the student has tried to solve the task and answered to the best of his/her ability. Both accuracy and time (R1) are registered automatically.

Subtest 12 Visual analysis

The subtest measures the ability to analyse two visually related rows of letters. One row of letters appears above the other. Each row consists of five consonants. In one part of the task the rows of letters are identical. In the other part, the rows differ from each other by one letter - the first, the middle or the last. The questions are presented in random order. The participant's task is to determine if the letter rows are equal or different. The subtest requires the ability for both holistic and analytical processing. Long time use may indicate that the participant uses a sequential, analytical processing strategy. Short time usage indicates holistic processing. In combination with a high number of errors, using a long time might indicate a failure in the visual analysis. The subtest is answered manually. If the letter rows are the same, the participant must press the M key. If they are different, the student must press the Z key. Both accuracy and time use (R1) are registered automatically.

Subtest 13 Phonological discrimination

The subtest measures the ability to distinguish between two words that are phonologically similar. The words are either exactly the same phonologically (homophones; e.g., *hour* and *our*) or they differ slightly from each other, for example *glemme* (forget) – *klemme* (hug). The participant's task is to indicate whether the words are the same or different. The participant answers the task by pressing the specified keys on the keyboard. Using long time indicates that the student has tried to solve the task to the best of his or her ability. Difficulties with phonological discrimination may be due to hearing difficulties; however, the difficulties may also be due to problems with auditory processing or uncertain phonological identifications of the words in the long-term memory. In the latter case, the student will typically also have difficulties with phoneme analysis and with correct pronunciation of words. If the words are the same, the participant must press the M key. If they different, the student must press the Z key on the keyboard. Both accuracy and time use (R1) are registered automatically.

Subtest 14 Quick naming of known objects (Rapid automatized naming)

The subtest maps the student's ability to quickly name a number of known objects. The participant is presented with a series of 40 pictures representing five objects randomly repeated. The participant’s task is to name the items from top left to bottom right. Before the task begins, the test leader goes through the pictures with the participant, and they agree on what the pictures illustrate. The goal is to measure the naming speed, not whether the student knows the object. Students with phonological difficulties may have difficulty naming all the objects continuously and with a smooth flow. They usually manage the first pictures relatively well, but then decrease the pace, and one can often observe that they begin to have difficulty retrieving the objects' names once more, even if they know what word to say. The time is registered manually and measured from the moment the pictures appear on the screen till the test leader presses the M key. Only time use is recorded.

Subtest 15 Understanding of concepts

The subtest measures the participant’s knowledge of the meaning of a number of words. The student is presented with a word, and the task is to provide an explanation or definition of that word. Examples of correct answers are stated in the notebook. The goal is to observe whether the student knows the meaning of the concepts presented. The task must be scored as correct if the student uses the word correctly in a sentence or points to a specified object. Only correctness is registered. The test leader registers incorrect answers.

Subtest 16 Oral reaction time

The student is presented with a dice on the screen. The dice show either one or two dots. The participant’s task is to quickly say of there is one or two dots presented. The subtest measures only response time R1.

Subtest 17 Manual reaction time

The student is presented with an arrow on the screen. The arrow points either to the left or to the right. The task is to press the Z or M key on the keyboard to indicate which direction the arrow is pointing towards. The subtest measures only response time R1.

Initial Logos test:

Procedure

The study participant took Logos test for the first time at the age of nine when she attended 4th grade. According to her age, she was given Logos set 2 (grade 3-5) with 18 tasks. A certified person from PPT administrated the test at the student's school. More details of the procedure are not known as the test was given to the student before she became the participant of the study.

Results and discussion

The results from the original Logos test are shown in Figure 12. Considering the limitations of the Master thesis project, only the core subtests together with those indicating significant results will be discussed in detail. The results demonstrate that there are several areas where the student scored between 15 and 30 percentile range which is defined as moderate difficulty, and five areas where the participant scored below the 15 percentile threshold indicating significant difficulties.

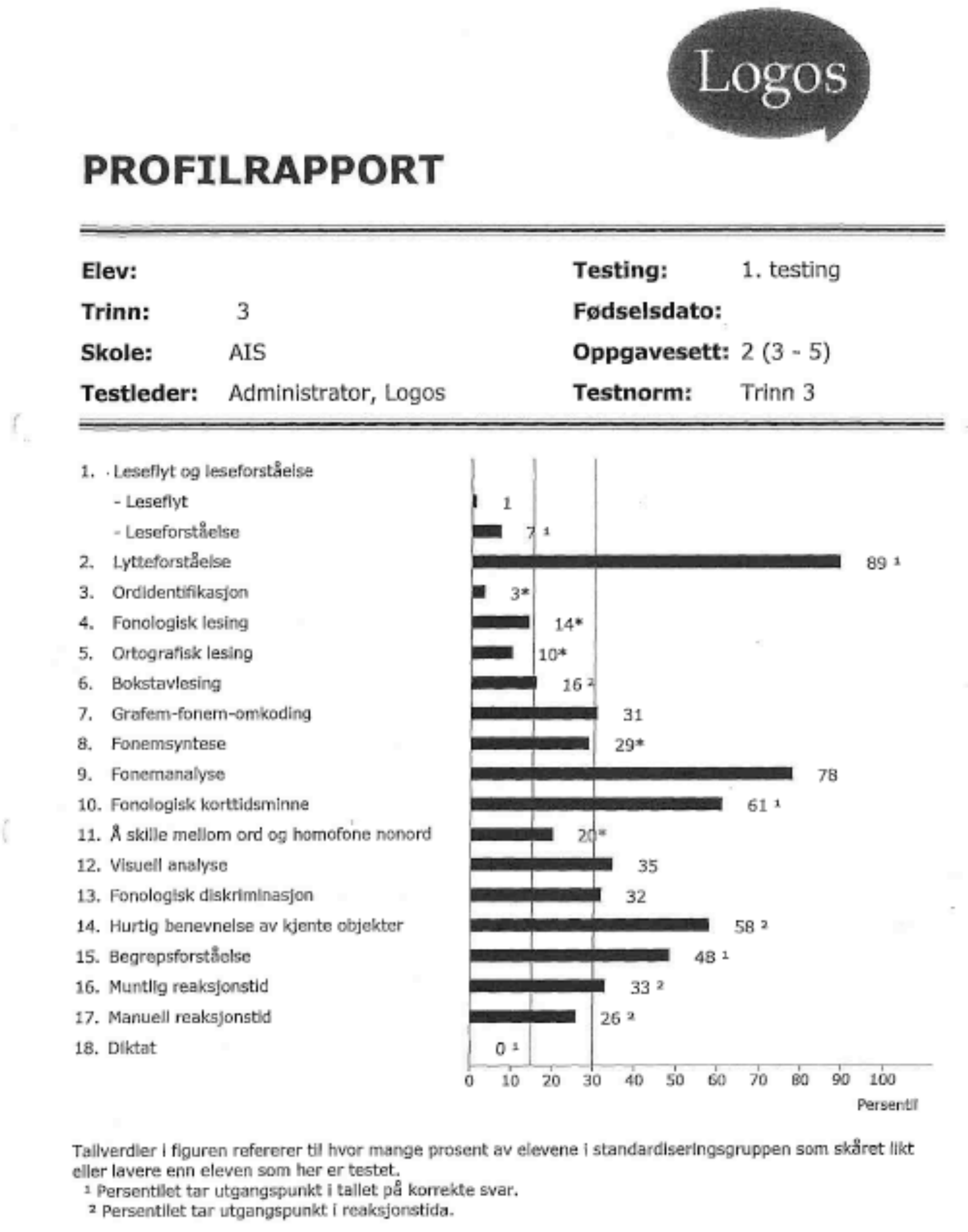


Figure 12. Logos initial test results. This figure illustrates the percentile scores the participant of the study achieved during the initial Logos testing in 4th grade.

The areas that show significant difficulties concern reading fluency, reading comprehension, word decoding and phonological and orthographic reading, as well as dictation, which are the core indicators of dyslexia. The pupil scored 1 percentile in Reading fluency. A more detailed report of this subtest (Appendix 3) indicates that the pupil took 15.37 minutes to read the text (average is 5.01min.) and her reading flow (WCPM, words correct per minute) indicates a score of 17.31 WCPM, while the mean for this task is 79.55. As the student used a significantly longer time to read the text, it indicates that they exhibit decoding difficulties. These, in turn, lead to reduced reading comprehension, which is consistent with the student's results, as they scored 7 percentile in her reading comprehension part of this test.

In contrast, the pupil's listening comprehension results (89 percentile) are impressive as they scored above average (78.62) achieving 93.33 correct answers. This contrast between the results in reading comprehension and listening comprehension signifies that the student had to use large parts of their cognitive resources on word decoding during reading which hindered their ability to concentrate on the content. In the Word identification subtest, the student scored 3 percentiles. A more detailed report shows that they used more time to read the words than an average reader their age (Average: 2.03 sec. compared to 1.58sec.). The use of longer time indicates that the participant used a phonological decoding strategy. Short words are mastered faster than long and simple words better than complex ones. However, their naming speed is much closer to average in the case of high frequency words (1.66 sec. compared to 1.51 sec.). At the same time, they used on average 2.55 sec. to read low frequency words, while the average time is 1.46 sec.) Since the frequency dimension has little significance for a phonological reader, the scores might indicate that the student has mastered orthographic word recognition for high frequency words. Similarly long words took longer time to name 2.73 sec. (average: 1.86), than short words (1.63 sec. in comparison to 1.33 sec.) and surprisingly, complex words took a similar amount of time to read as simple words. However, after looking at correctness, it is evident that the student might have been guessing as most complex and long words are incorrect. The results, thus, indicate that the student had mastered orthographic reading of high frequency words, but attempts to apply phonological reading skills as the main strategy, while resorting to guessing when the words become too long or too complex.

In the phonological reading subtest, the student had a score of percentile 14. They read correctly 58.33% percent of words, while the average result is 84.46%. Longer and more complex words were read incorrectly much more often than the mean score (33.33% in comparison to 77.33% average for long words, and 50% in comparison to 82.49% on average). However, the time use does not show a large difference (average of 2.23 sec. in comparison to 2.12 sec.). In the orthographic reading subtest, the student scored 10 percentile, and similarly to the phonological reading test, long and low frequency words posed a more significant difficulty for the student. They read 16.67% long words correctly (compared to average of 67.61%) and 38.89% low frequency words (compared to 75.81% average). The student used more time to name the words than an average participant. One more test in which the student scored below 30 percentile was the subtest *Distinguishing between words and homophonic non-words*. The more detailed report (Appendix 3) reveals that the student has difficulty in particular with vowels (e.g., *å* and *o* are often confused as in the pair *over/åver*, e and æ as in *stærk/sterk*) and silent letters (e.g., *hjelpe/jelpe* or *gjennom/jennom* where in both cases, the h and g in the first words are silent). As the homophonic non-words are pronounced in the same way as the corresponding target words, it is difficult for a phonological reader to recognize the correct orthographic representation of the sound pattern of the word. If the participant uses a phonological decoding strategy, both words result in the same audio package so that they cannot be distinguished. In the subtest *Understanding of concepts*, the student scored above average, i.e., 81.82% in comparison to 81.13%. This is particularly significant as the student is bilingual and attends an English speaking school; thus, her understanding of concepts in Norwegian would be expected to be weaker.

Finally, the dictation part is particularly indicative, as it is clearly visible that the participant was spelling phonetically, mixing both Norwegian and English spelling systems (Table 4). As this is particularly relevant to this study, a more detailed analysis of this subtest is presented in table 6.

Table 6

Illustration of the participant's spelling of dictated words.

Norwegian word	Pupil's spelling	Phonetic transcription	Observation/ comment	Meaning
Jul	<u>y</u>ul	/ɟʊɭ/	The /ɟ/ sound in English is represented by [y]	Christmas
Morsomt	mo<u>sh</u>omt	/ˈmɔʂɔɱʈ/	The articulation of the English /ʃ/ sound is very close to the Norwegian retrofleks /ʂ/. They only differ in terms of place of articulation.	funny
kylling	<u>shu</u>ling	/çi:liŋ/	Both /ç/ and /ʃ/ are fricatives; however, they differ in terms of place of articulation. /ç/ is palatal, while /ʃ/ is postalveolar.	chicken
sjeldent	<u>sh</u>eldent	/ʂɵɭɗɵn/	[sj] is pronounced as /ʂ/ in Norwegian, which is very close to the English /ʃ/ sound.	rare
gutt	gu<u>t</u>	/gut/	Double consonants are more common in Norwegian and they indicate that the preceding vowel is pronounced as short.	boy

verst	vasht	/væʃt/	[rs] differs depending on the dialect. The student does not have a dialect, but she is exposed to her mother's dialect from eastern Norway, where [rs] is pronounced like /ʃ/. The arae where the student lives, i.e, southern Norway tends to pronounce [rs] like [r-s] as in *Mars*.	worst
kolliderte	kolidete	/kɔli:dertə/	Double consonants are more common in Norwegian and they indicate that the preceding vowel is pronounced as short.	collided
kommand oen	komandoen	/kɔmændʊən/	Double consonants are more common in Norwegian and they indicate that the preceding vowel is pronounced as short.	command
gjerne	yane	/ʝænə/	[g] in [gj] consonant cluster is silent. [j] in Norwegian is pronounced like [y] in English. Depending on the dialect, the [r] can be unperceivable in *gjerne*.	with pleasure, gladly
nysgjerrig	nushari	/nɪʂeri/	The consonant cluster [sgj] is pronounced like /ʂ/, which is a sound close to the English /ʃ/ sound, often corresponding to the grapheme [sh]. [g] is often silent at the offset of Norwegian words.	curious
jorda	yora	/jʊra/	The [d] in *jorda* is silent, and [j] is pronounced like the English [y] sound in *yellow*.	earth
butikken	butiken	/bʊtɪ:kən/	Double consonants are more common in Norwegian and they indicate that the preceding vowel is pronounced as short.	shop

In summary, the Logos data show quite clearly that the pupil exhibits obvious difficulties in reading and spelling, which are indicative of dyslexia. The most striking results concern the spelling (diktat) subtest, which reveal a significant influence of English spelling on Norwegian. Interestingly, the errors are consistent with English spelling rules, and they concern sounds that share some similarities, such as place or manner of articulation. For example, the consonant cluster [sj] in *sjeldent* is pronounced as /ʂ/ in Norwegian, which is very close to the English /ʃ/ sound. Both sounds are fricatives, but they place of articulation differs, as /ʂ/ is a retroflex, while /ʃ/ is a postalveolar. These observations indicate that in the case of a dyslexic bilingual speaker, the types of errors are of a cross-linguistic nature.

Second Logos test

As two and a half years had passed since the Logos test was administrated, a selected number of tasks from Logos were given to the student prior to the experiments of the current study. For the repetition of Logos test, only a subset of the tasks were selected. The selection process involved including only core dyslexia diagnostic tasks, as well as excluding Subtest 14 Quick naming of known objects, i.e., Rapid Automatized Naming task, as well as Subtest 11 Distinguishing between words and homophone non-words as they have been chosen as blueprints for designing the tests for the study's experiment in order to observe the influence of bilingualism on dyslexia. The tasks the participant completed as part of the study were taken from Logos task set 3 (grade 6-10) as the student was two years older and fell into task set 3 category of Logos test. It is important to note that tests in Logos set 3 are more challenging as they are tailored to an older group of participants (i.e., from grade 6 student up to adults). Therefore, score in some results might be lower than in the initial test. Furthermore, Logos task set 3 includes a subtest that is not part of Logos set 1 and set 2, i.e., Phonemic awareness. This subtest measures the student's ability to identify and manipulate phonemes in words. The participant's task is to listen to a word presented auditorily, and then indicate what sound pattern would be left after a specific phoneme has been deleted. For example, after hearing the word *house*, the student is asked to say the remaining sound pattern after the phoneme /h/ is removed. The correct answer would be /aʊs/. Students with dyslexia often have significant difficulty with this type of task. The difficulties are commonly revealed either through an incorrect answer or in the form of a long time use. The student answers orally. The test leader registers incorrect answers. Both correctness and time use (R1) are registered.

Procedure

The test took place at the student's home in a comfortable location. The student sat in front of the screen at a comfortable reading distance. A certified and experienced Logos administrator conducted the test with the student. The administrator spoke to the student in Norwegian from the moment they met as Logos is a Norwegian diagnostic test, and the student needed to be in the Norwegian mind-set. The student was informed by the administrator of the procedure, and she was reassured that they could take breaks in between the different parts if she felt that she was becoming tired or was losing focus.

Results

The results are shown in Figure 13. As can be seen, the areas that show significant difficulties are reading fluency, phonological and orthographic reading, as well as dictation.

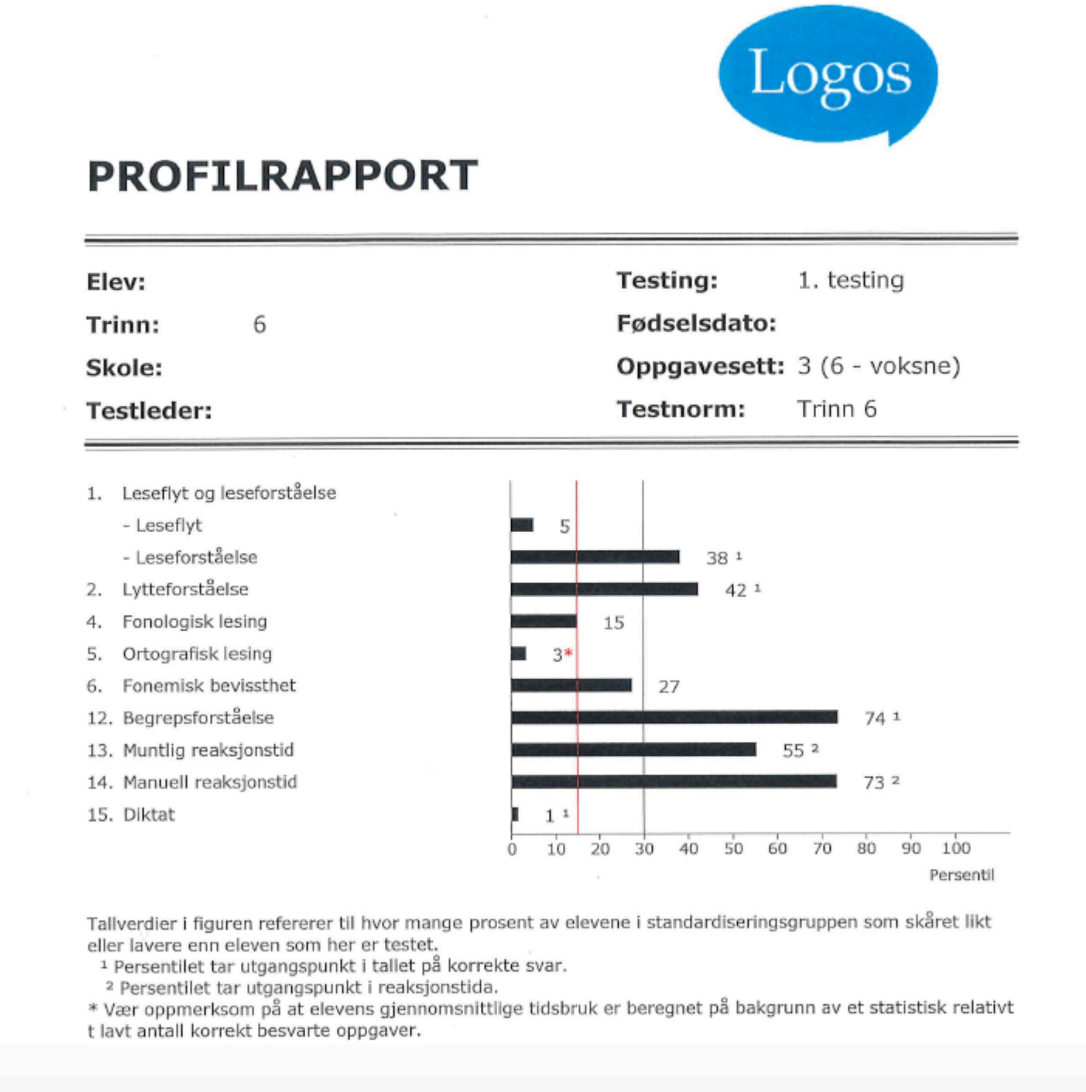


Figure 13. Logos second test results. This figure illustrates the percentile scores the participant of the study achieved during the second Logos testing in 6th grade when the study was conducted.

The student scored percentile 5 in Reading fluency. A more detailed report of this subtest (Appendix 4) indicates that the student took 7.6 minutes to read the text (average is 4.85min.) and their reading flow (WCPM) indicates a score of 42.24 WCPM, while the average is 80.38. As the student used more time to read the text, it indicates that they exhibit decoding difficulties. They managed to read correctly 88.43% of the text correctly; however, the average is 95.68%, which indicates that her score is still significantly low. Their reading comprehension is much stronger than their reading fluency as they scored percentile 38. Her listening comprehension results, (percentile 42) does not show any significant difficulties.

In the phonological reading subtest, the student scored 15 percentiles. They read correctly 85.71% of words, while the average result is 90.60%. A more detailed report reveals that the student read correctly 92.86% of words, while the average score is 94.10%. Longer words were read incorrectly more often than the average score (78.57% in comparison to 87.10% average). The student did not show a significant difficulty in reading correctly complex words, as they read 85.71% complex words correctly in comparison to 89.14% on average; thus, they scored 38 percentile in this category. The time use shows a somewhat significant difference (average of 2.23 sec. in comparison to 1.64 sec.). In the orthographic reading subtest, the student scored 3 percentile. On average, the student read 58.33% words correctly, in comparison to 86.06% average. Long words were considerably more difficult for the student. They read 33.33% long words correctly (compared to a mean of 78%). Both high and low frequency words appeared challenging as the student read 66.67% high frequency words correctly (compared to a mean of 90.22%), and 50% low frequency words (compared to an average of 81.90%); both of which resulted in a score of percentile 7. The student used 1.55 sec on average to read the words, while the mean was 1.16 sec. In the phonemic awareness task, the student scored percentile 27, which is below the threshold indicating moderate difficulty. The student could identify 73.33% of sound patterns correctly, after a phoneme was removed from the word she had been presented with. The mean for this subtest was 84.24%, which signifies that the student scored 25 percentile for correctness. Their use of time was quite close to the mean (1.05 sec.), as they used on average 1.13 sec. to provide an answer. This resulted in a score of 37 percentile for time. In the subtest Understanding of concepts, the student scored above average, i.e., 74 percentile in comparison. The dictation subtest reveals significant challenges as the student scored 1 percentile. The most common errors concerned missing out silent letters (e.g. *kveld*, *fargeblind* – [d] is silent), and not including double consonants (e.g., *annonser* or *fartskontroll*).

In summary, the follow-up logos test confirmed the results from the first Logos test. They show a strong indication that the student has dyslexia, as well reveal similar transference of spelling patterns between English and Norwegian.

6.3. Bilingual processing tests

RAN

Method and design

In order to evaluate the student's visual, verbal and motor systems as well as her ability to retrieve phonological information a RAN test has been designed. As previously explained, the rapid automatized naming task (RAN; Logos Subtest 14 Quick naming of known objects), maps the student's ability to quickly name a number of known objects presented visually. The RAN test designed for this investigation has been modified in a way, which would allow observing differences and similarities in the two languages the student uses. Therefore, the test was administered in both Norwegian and English, and the cognate status of the words to be produced was manipulated. Therefore, four different scenarios were created; i.e., objects representing Norwegian cognates, English cognates, Norwegian non-cognates and English non-cognates. The visuals were presented in a grid (see Figure 14). Each scenario consisted of two sets with the visuals presented in different orders to obtain an average based on two attempts with varied order. In total, eight grids were constructed for the test (see appendix TTT). Each grid represented five stimuli repeated in six rows of eight visuals.

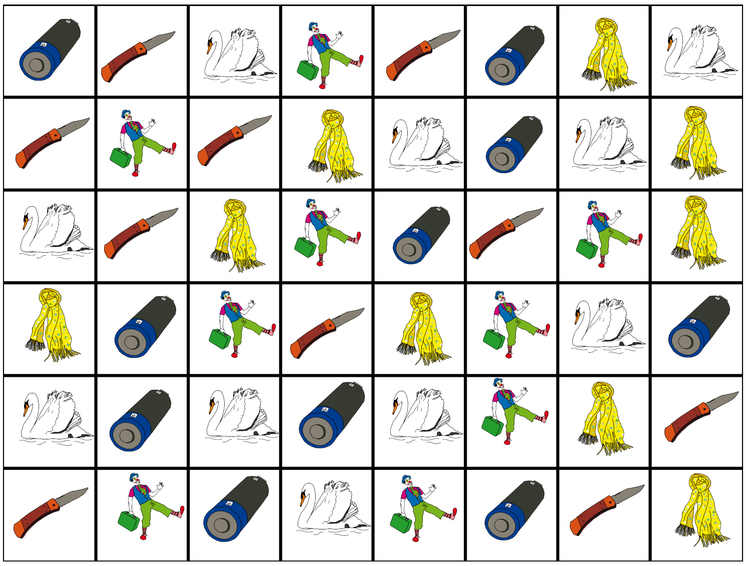


Figure 14. Example of a grid. English cognates

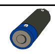
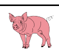
In order to construct the grids, a total of 20 pictures were selected from the MultiPic Database (Duñabeitia et al. in press. See Table 7 below). The cognate status was the primary variable that was manipulated in this experiment. The pictures were selected from a variety of semantic categories, and each set contained visuals from distinct categories to avoid semantic priming (i.e., facilitation of responding, in the form of a faster response time, which occurs when a stimulus is preceded by a semantically related stimulus, e.g., *nurse* facilitates *doctor*; Wagner & Koutstaal, 2002). Table 4 shows the stimuli and which variables were controlled for. Word frequency (fpm), word length (number of syllables, phonemes and letters), onset and rimes of words as well as visual complexity of the stimuli were the major variables which were matched in a way that ensured that there were no significant differences between the four groups (Norwegian cognates, English cognates, Norwegian non-cognates, English non-cognates). As the speed of naming words increases proportionally to the increase in frequency, it was important that both cognates and non-cognates were matched on frequency. The word frequency for the English entries was retrieved from Subtlex-UK database, and a mean of 4.01 and 4.14 were calculated for the English cognates and non-cognates respectively. The word frequencies for the Norwegian entries have been retrieved form the Norwegian Web as Corpus database (NoWaC), and the mean for the Norwegian cognates and non-cognates were 3.94 and 3.74, respectively. Values of 4 -7 are considered high frequency on the Zipf scale.

Similarly to word frequency, the number of syllables, letters and phonemes was controlled to obtain a matching mean between the four scenarios (table 7). The word onset and rime were controlled in each set in order to avoid phonological priming effects across objects. Repeating onsets or rhymes across spoken words can affect the speed with which they are produced (e.g., Wheeldon, 2003). Finally, the visual complexity of the stimuli was controlled, and a mean of 2.6 for all sets except English non-cognates (2.5) was calculated. The result is based on a 1 (very simple) to 5 (very complex) scale (Duñabeitia et al., in press). As previously explained, the selection criteria involved choosing phonologically and semantically dissimilar items to avoid semantic and phonological priming effects between items.

Table 7

An overview of the cognates and non-cognates used for the RAN experiment with details concerning their frequency, number of syllables, phonemes, letters, and visual complexity

	Freque ncy (fpmw)	**frequency (Zipf) from SubtlexUK &** NoWaC	**syllables**	**phonemes**	**letters**	**visual complexity**
Group 1 - English cognates						

Knife 	30,8	4,5	1	4	5	1,84
Swan 	9,6	3,98	1	4	4	2,94
Scarf 	5,8	3,8	1	5	5	3,1
Clown 	7,9	3,9	1	5	5	3,1
Battery 	7,4	3,87	3	6	7	2,27
	12,3	**4,01**	**1,4**	**4,8**	**5,2**	**2,65**
Group 2 Norwegian cognates						
Kaffe 	35,6	4,6	2	4	5	3,09
Bombe 	9,2	4	1	4	4	1,95
Skjell 	2,7	3,4	2	4	5	2,72
Sverd 	4,3	3,6	1	5	5	2,3
Mus 	12,7	4,1	1	3	3	3,15
	12,9	**3,94**	**1,4**	**4**	**4,4**	**2,642**
Group 3 English non-cognates						
Chair 	45,3	4,7	1	3	5	2,3
Pig 	32,5	4,3	1	5	5	2,8
Carrot 	12	3,4	2	5	6	2,41
Witch 	11,4	4,2	1	3	5	3,2
Envelope 	12,5	4,1	3	4	8	1,7
	22,74	**4,14**	**1,6**	**4**	**5,8**	**2,482**
Group 4 Norwegian non-cognates.						
Blad 	21,9	4,3	1	4	4	2,5

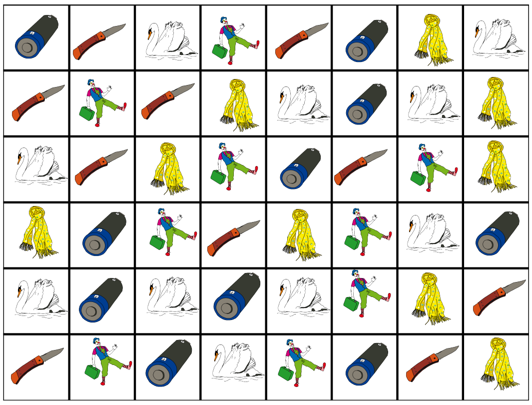
Sitron 	2,8	3,4	2	6	6	2,7
Hjul 	9,2	4	1	4	4	2,4
Paraply 	1,8	3,3	3	7	7	2,4
Kanin 	5,4	3,7	2	5	5	3,2
	8,22	**3,74**	**1,8**	**5,2**	**5,2**	**2,64**

Procedure

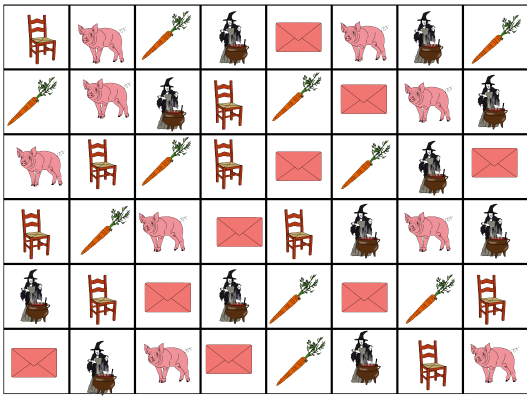
The RAN test was administrated at the student's school in a quiet test room without any distractions. The RAN test was administrated by the author of the study and was voice-recorded. As the student is exposed to English in the academic context and spends most of her day using English, it is expected that English is her stronger language. While the linguistic advantage in not markedly significant, the test began with the English sets of visuals. Following the cognates facilitation effect, it is expected that cognates will be easier to name; hence, starting with them will prevent the possibility of confounding the results with practice effect; therefore, the first part of the test involved English cognates (Grid 1). This would be followed by the English non-cognates (Grid 2), after which the student will be presented with the Norwegian cognates (Grid 3) and non-cognates (Grid 4) respectively. This procedure would be repeated after a few days to obtain an average of two attempts.

The procedure for each part of the experiment involved presenting the student with the stimuli before giving her the test. This ensured that the student could recognise the stimuli and name them in the relevant language. After that, the student was presented with the set of stimuli on a A3 paper and was asked to name them across from left to right as quickly as they could. Time was recorded, and the student repeated the procedure for Grids 2, 3 and 4. The test was administrated within two weeks on four different days. On the first day, the student was presented with English cognates and non-cognates, and on the second day, the student was presented with Norwegian cognates and non-cognates. After a week, the procedure and order of Grids were repeated, but the visuals in each set were presented in a different order (see Figure 15).

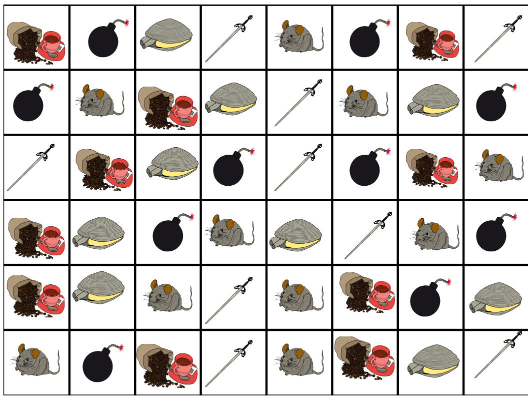
Set 1



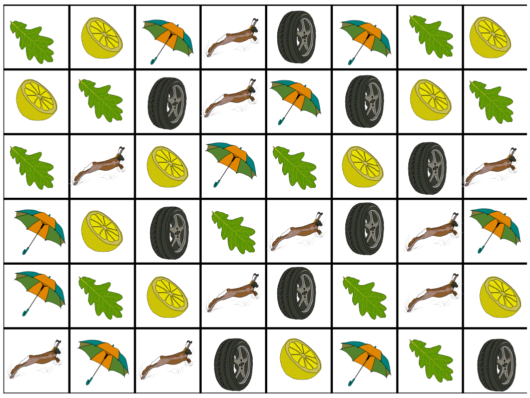
Grid 1 English cognates



Grid 2 English non-cognates

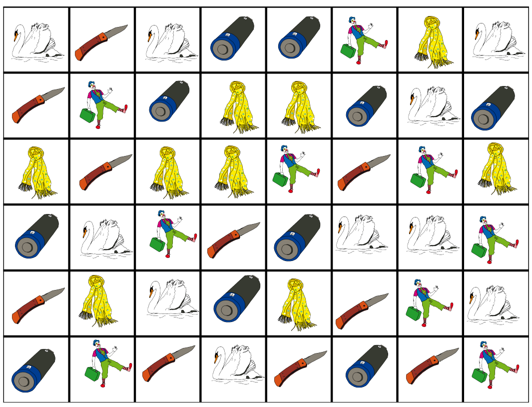


Grid 3 Norwegian cognates

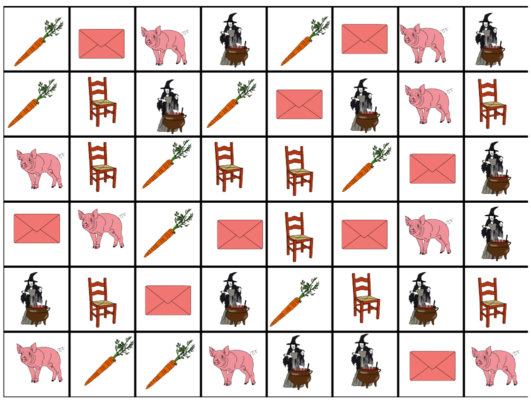


Grid 4 Norwegian non-cognates

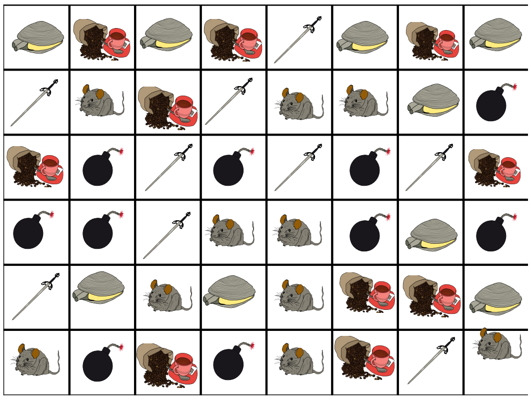
Set 2



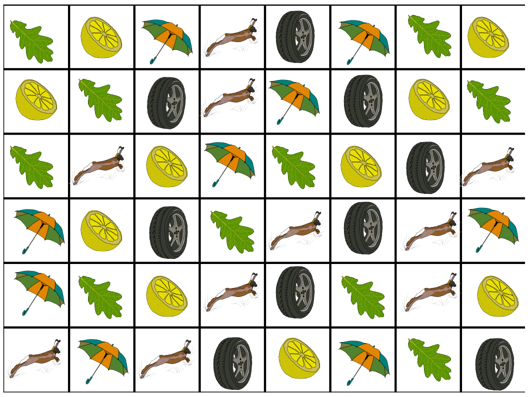
Grid 5 English cognates



Grid 6 English non-cognates



Grid 7 Norwegian cognates



Grid 8 Norwegian non-cognates

Figure 15. Presentation of stimuli in the RAN test

Results and discussion

The results of the RAN experiment are presented in Table 8. They show that Norwegian cognates were named the fastest (mean of 39.7 sec.), while Norwegian non-cognate took the participant more time to name than any other set (mean of 55.3 sec.). The difference between Norwegian grids is more visible than the difference between the English grids. On average, it took the participant 15.6 sec longer to name Norwegian non-cognates than Norwegian cognates, while naming English non-cognates took on average 6.35 sec more than naming English cognates. The number of pauses is reduced in the second attempt for all grids apart from Norwegian non-cognates, which shows a significant increase from 0 (set 1) to 6 (set 2). While the participant named some pictures with the incorrect name, in the majority of cases (i.e., 12 out of 13), the errors were corrected. For the English cognates grid, the number of errors increased in the second attempt; however, the student took less time to respond.

The results indicate a cognate facilitation effect for the Norwegian cognate grids as this it has been named the fastest. This might mean that the cognitive effect is more prominent in the more transparent language.

Table 8

Results of RAN experiment

		Time	Average	Number of Pauses	Number of Errors
English cognates	Set 1	50	**47.75**	6	0
	Set 2	45.5		4	4 (4 corrected)
English non-	Set 1	42.33	**41.4**	8	2 (1 corrected)

cognates	Set 2	40.5		1	1 (corrected)
Norwegian cognates	Set 1	42.37	**39.7**	5	1 (corrected)
	Set 2	37.1		2	2 (corrected)
Norwegian non-cognates	Set 1	58.8	**55.3**	0	1 (corrected)
	Set 2	51.7		6	1 (hesitated) 1 (corrected)

WORD SPOTTING

Method and design

For the purpose of this study, the word-spotting task (discussed in the introduction) has been modified to include both Norwegian and English homophones to observe the effect of bilingualism on dyslexia. Therefore, the student was presented with three stimuli, as opposed to two, as it is common in a monolingual word-spotting task. Similarly to the RAN test, cognates and non-cognates have been used to observe the bilingual influence on the pupil's performance. Another modification to this task was that the participant heard the word as the stimuli appeared on the screen. Native speakers of the respective languages read the words out loud. At an attempt to minimize the risk of sequence effect in within-subject design, the stimuli were presented in a non-linear (triangular) way, and the position of the target word was altered for each stimulus. An example can be seen in Figure 16. Only accuracy was measured.

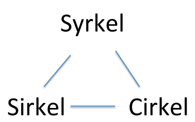


Figure 16: An example of the presentation of the word spotting task stimuli

60 target words were chosen for the task in total. Each target word was matched with two homophonic foils simulating Norwegian and English sounds (total of 120 pseudo-words). 40 of these words were grouped into the following 4 sets of 10 words: English cognates, English non-cognates, Norwegian cognates, and Norwegian non-cognates. The words chosen for the

word spotting task had been matched on word frequency, number of letters, number of phonemes and number of syllables (see Table 9).

Table 9

Overview of the words and foils chosen for the word spotting task with information regarding word frequency, number of letters, number of phonemes and number of syllables.

Norwegian cognates	foil 1 (Nor)	foil 2 (Eng)	Zipf	word frequency (fpmw)	No. Letters	No. Phonemes	No. Syllables
Skjorte	kjorte	shorte	3,5	3	7	5	2
eple	eble	aple	3,7	4,8	4	4	2
bjelle	bjele	belle	3,1	2.51	6	5	2
sirkel	syrkel	seerkel	3,8	5,8	6	6	2
skulder	skølder	shulder	3,6	4,4	7	6	2
Krystall	kristall	krystal	2,9	0,8	8	7	2
jakke	jake	yakke	3,7	4,8	5	4	2
traktor	traktår	tractour	3,5	6.68	8	6	2
diamant	damant	diamante	3,3	4.01	7	7	2
tunnel	tunel	toonel	3,6	4,3	6	5	2
Average			3,47	4	6,4	5,5	2
Norwegian noncognates	foil 1 (Nor)	foil 2 (Eng)	Zipf	word frequency (fpmw)	No. Letters	No. Phonemes	No. Syllables
veske	veskke	vesce	3,6	3,8	5	5	2
agurk	agørk	agourk	3,3	2.72	5	5	2
kylling	kyling	shylling	3,9	7,4	7	6	2
hanske	handske	hansque	3,2	1,5	6	6	2
kirurg	kirørg	shirurg	3,2	1,4	6	6	2
blyant	bliant	bleant	3,2	1,6	6	6	2
kjole	tjole	shule	3,9	7,7	5	4	2
hjerne	jarne	yerne	3,7	3.20	6	5	2

pølse	**polse**	**pilse**	**3,5**	3,4	5	5	2
skinke	**kinke**	**shinke**	**3,4**	2,3	6	5	2
Average			**3,49**	3,6375	5,7	5,3	2
English cognates	**foil 1 (Eng)**	**foil2 (Nor)**	**Zipf**	**word frequency (fpmw)**	**No. Letters**	**No. Phonemes**	No. Syllables
reduce	**redeus**	**redus**	**3,5**	3,2	6	5	2
ethics	**ethicks**	**etics**	**3,4**	2,6	6	5	2
bladder	**blather**	**blædder**	**3,4**	2,6	5	4	2
defect	**difect**	**difekt**	**3,2**	1,7	5	4	2
implant (noun)	**implent**	**implænt**	**3,3**	1,9	6	6	2
totem	**toteme**	**tåtem**	**3,2**	1,7	5	4	2
trumpet	**drumpet**	**trampet**	**3,8**	6,6	4	3	2
gothic	**ghotic**	**gotic**	**3,8**	6,5	7	7	2
thermal	**thermel**	**termal**	**3,5**	3,2	7	6	2
beaver	**beefer**	**biver**	**3,5**	3,2	5	4	2
Average			**3,46**	3,32	5,6	4,8	2
English noncognates	**foil 1 (Eng)**	**foil 2 (Nor)**	**Zipf**	**word frequency (fpmw)**	**No. Letters**	**No. Phonemes**	No. Syllables
disrupt	**disrup**	**disrapt**	**3,4**	**3,4**	7	5	2
obey	**aubey**	**åbey**	**3,5**	3,2	4	4	2
parrot	**parot**	**parret**	**3,4**	2,6	6	6	2
redeem	**redeam**	**redim**	**3,2**	1,7	6	6	2
wizard	**wizerd**	**wyzard**	**3,3**	1,9	7	5	2
cushion	**qushion**	**kushion**	**3,6**	3,8	6	5	2
prison	**pricen**	**prisonn**	**3,4**	2,6	6	5	2
delete	**deleet**	**delit**	**3,3**	2,7	6	4	2
parcel	**barcel**	**parsel**	**3,5**	3,2	5	5	2
pencil	**penscil**	**pensyl**	**4**	9,5	6	6	2
Average			**3,46**	3,46	5,9	5,1	2

All words were between 4 and 8 letters long. The average length of words was 6.4 and 5.7 for the Norwegian cognates and non-cognates, respectively; and 5.6 and 6.9 for the English cognates and non-cognates. The number of phonemes was between 3 and 7, with an average of 5.5 and 5.3 for the Norwegian stimuli and 4.8 and 5.1 for the English ones. All words were disyllabic. English stimuli word frequency has been retrieved from Subtlex-UK database, whilst the Norwegian stimuli word frequency has been obtained from NoVaC. The word frequency (fpm) in both English and Norwegian was between 3 and 4 occurrences per million. The pseudo-words had been controlled for the place and manner of orthographic and phonological change (see Table 9). 20 words and 40 pseudo-words have been included in the task as filler words to avoid overwhelming the student with the more challenging examples. Each word had two corresponding foils / pseudo-words, which were matched with the target word in terms of phonological and orthographic similarities. Both foils resembled the word but one foil had an orthographic or phonological alteration that is typical of the target language, while the other foil has an alteration that resembles the other language. For example, in the Norwegian cognates set, for the word "skjorte", the first foil was "sjorte". Both graphemes *skj* and *sj* represent the retroflex [ʂ] sound in Norwegian. There is only one orthographic change in the initial consonant cluster. The second foil was "shorte" with an English grapheme *sh*, which corresponds to the phoneme [ʃ]. Both retroflex [ʂ] and postalveolar [ʃ] have the same manner of articulation. Both of these sounds are sibilant fricative. In terms of place of articulation, they are both coronal, which makes them very similar. All the target words in the experiment were matched with their corresponding foils in a similar manner. The Norwegian part of the test comprised 10 Norwegian cognates, 10 Norwegian non-cognates, 10 filler words and 60 corresponding pseudo-words. The second part of the experiment consisted of 10 English cognates, 10 English non-cognates, 10 filler words and 60 pseudo-words.

Procedure

The Word-spotting task was presented to the student at her school in a quiet test room without any distractions. The test was voice-recorded. The participant was verbally informed about the procedure (instructions in appendix). The experiment was divided into two separate parts. One part was administrated by a Norwegian native speaker, and the second part of the experiment was administrated by an (American) English native speaker. The participant had to listen to the administrator read out loud the words in a random order. As each word was read out loud, the participant was shown a stimulus on the computer screen consisting of three items, i.e., the correctly-spelled word and two foils /two pseudo-words, which were matched with the target word in terms of phonological and orthographic similarities. The participant was asked to point to the item they believed corresponded to the sound they heard and represented the word pronounced by the administrator.

Results and discussion

The test errors and proportions are shown in Table 10. As can be seen, the highest number of errors was in the Norwegian cognates set. The student selected four incorrect items, three of which were English foils. The English cognate set included two incorrect answers, both of which were the English foils. One incorrect answer was given in the English non-cognates set, with the English foil being selected, and no incorrect answers were given in the Norwegian non-cognates set.

Table 10

An overview of the errors in each set of the word spotting task

Target word (Norwegian cognates)	Answer	Target word (Norwegian non-cognates)	Answer	Target word (English cognates)	Answer	Target word (English non-cognates)	Answer
Skjorte	shorte			reduce	redeus	redeem	redeam
skulder	shulder			gothic	ghothic		
Krystall	kristall						
jakke	jake						
Error percentage							
40%		0%		20%		10%	

All the incorrect answers were English foils both for the Norwegian and the English sets. The results indicate that the participant seems to rely on or be more familiar with the English spelling system. The fact that the spelling of cognates was more identified incorrectly more is consistent with the cognate effect, which implies more cross-linguistic interference or cognates as opposed to non-cognates. Strikingly, Norwegian cognates were identified incorrectly twice as often as English cognates, which demonstrates a stronger cognate effect for the more transparent language.

7. Summary of findings

Logos and Screening tests LASS and Nessy

Based on the results from the two dyslexia screening tests in English, i.e., LASS and Nessy, as well as the results obtained from the Norwegian dyslexia diagnostic test Logos, it can be observed that the pupil's challenges are similar across the two languages. Both English screening tests and Logos reveal significant difficulties in reading skills, phonological and orthographic reading skills, auditory short-term memory, as well as spelling difficulties. The analysis of the spelling tasks reveals that there is a cross-linguistic interaction between the two languages, with the spelling of the opaque language (English) clearly influencing the answers in the test intended for the transparent language (Norwegian). This, however, does not necessarily indicate that the influence is only one-directional, as the notes from the spelling task from the English screening tests are not accessible. An additional spelling test in English might shed some light on whether the cross-linguistic transfer of spelling is mutual. There are two possible explanations for the effect of English spelling on Norwegian: 1. English is the language of literacy instruction at the pupil's school, and while the pupil is a bilingual speaker, they receive the majority of education in English. Only four lessons a week are specifically focused on the Norwegian language. The student is exposed to Norwegian text during the day (receptive language), but does most of their writing in English (productive language); 2. After being diagnosed with dyslexia in grade 4, the pupil started receiving special educational needs support in English. This support involved developing her phonological awareness skills, spelling and reading skills in English. The same provision was not in place for the Norwegian language, which might indicate that the pupil had more exposure to and practice with English spelling rules than with Norwegian. Finally, it can be observed that the transfer of spelling patterns between the two languages also support the non-selective nature of the bilingual mental lexicon.

With regards to the second prediction concerning the cognate effect, the experiments revealed an interesting pattern. While the Norwegian cognate set showed a strong cognate facilitation effect, the English cognate set did not reveal such effect. These results confirm the results obtained by Costa and Caramazza (2000) who observed that language dominance contributes to the cognate effect. The less dominant language (Norwegian) is linked to a stronger cognate effect than the more dominant language (English). These results do not confirm the second prediction of this thesis that both languages would show a cognate effect.

Finally, the prediction concerning an increased amount of errors made by the study participant in the more opaque language (English) have not been confirmed by the experiments' results. More errors were made, in fact, in the more transparent language (Norwegian). This, however, can be explained by tow major factors (i.e., language of literacy instruction and special education needs provision in only one language) that could have affected the results. First, the pupil's language proficiency and use is academically stronger in the language of literacy instruction, i.e., English. This means that the pupil is more familiar and more exposed to the English writing system on a daily basis. Second, the pupil received special education provision in English where they practised phonological skills, English spelling rules and reading. The same provision was not provided in Norwegian.

Whether these results can provide evidence for the orthographic depth hypothesis is questionable, as more factors played a role in this particular case. Another possible explanation for the fewer errors in English might be related to morphological complexity. As discussed previously, morphological awareness becomes increasing more important for reading throughout the school years (e.g., Casalis & Colé, 2004; Carlisle 2000 in Borleffs et al., 2019), while the knowledge of morphology continues to develop (Berninger et al., 2010 in Borleffs et al., 2019). Furthermore, morphological awareness is linked to an increase in reading achievement (Casalis & Colé, 2004). As readers of opaque language use the morphological structure of words (Schiff and Raveh, 2007 in Borleffs et al., 2019) and the orthographies of these languages are controlled both by phonology and morphology, this might contribute to the advantage in the word spotting task observed in this study.

Weaknesses and Future research

A study with more participants could provide a more reliable set of results. A case study is somewhat limited in terms of observing a phenomenon across a population. It is, however, true that within a population there are quite significant individual differences that would need to be taken into consideration. Furthermore, to explore whether the advantage of English over Norwegian in the word spotting task was related to language of literacy instruction, it would be useful to compare a group of dyslexic bilingual students from a mainstream Norwegian school with children from an International school. This could shed some light on the potential influence of the language of instruction.

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Appendices

Bilingual profile questionnaire

Demographic characteristics

1. What is your age?
2. What is your gender?
3. Do you have normal vision or vision that is corrected to normal with glasses or contact lenses?
4. Do you have normal hearing or hearing that is corrected to normal?
5. What is your country of birth?
6. What is your current country of residence?

Language background:

1. Is Norwegian the only language you speak at home (aside from perhaps English)?
2. Are you a reasonably good speaker of English?
3. Please list all the languages you speak in order of DOMINANCE (up to 5).
4. Please list all the languages you speak in order of ACQUISITION (up to 5).
5. Please list what percentage of the time you are on average exposed to each language (e.g. exposure in terms of talking, listening, and reading, including TV, films and music). (All your answers should add up to 100)
6. When choosing a language to speak, with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time.
7. What cultures do you identify with (e.g., Norwegian or British)? Please list each culture below (up to 5) and use the scale from 0-10 to rate the degree of identification, whereby 0 = no identification, 5 = moderate identification, 10 = complete identification.
8. In which language do you usually do the following tasks?
   - Simple math (count,add)
   - Dream
   - Express anger or affection
   - Talk to yourself

Norwegian and English Proficiency:

1. Please list the number of years and months you have spent in each language environment:

	Norwegian	English
A country where this language is spoken		
A family where this language is spoken		
A school where this language is spoken ALL of the time		
A school where this language is spoken SOME of the time		

2. Please rate how much the following factors contributed to your learning of each language on a scale of 0-10 whereby 0 = not a contributor, 5 = moderate contributor and 10 = most important contributor.

	Norwegian	English
Interacting with friends / colleagues		
Interacting with family		
Reading (e.g., books, magazines, online material)		
School and education		
Self-instruction (e.g., language learning videos or apps)		
Watching TV / streaming		
Listening to music/media		

Dialect and Accent

3. In your opinion how strongly regional is your spoken Norwegian on a scale of 0-10 (whereby 0 = not at all, 5 = moderately, 10 = very much)?

4. What kind of accent do you think your spoken English has (e.g., British / American / other / none in particular)?

5. When you are speaking do you ever find yourself accidentally mixing words or sentences from Norwegian and English?

- If yes, how often does English accidentally intrude in your Norwegian on a scale of 0-10 (whereby 0 = never, 5 = half of the time, 10 = all of the time)

- And how often does Norwegian accidentally intrude into your English on a scale of 0-10 (whereby 0 = never, 5 = half of the time, 10 = all of the time)?

6. When you are speaking with a person who also knows both Norwegian and English do you ever find yourself intentionally mixing words or sentences from Norwegian and English

- If yes, how often do you intentionally use English words when speaking Norwegian on a scale of 0-10 (whereby 0 = never, 5 = half of the time, 10 = all of the time)?
- And how often do you intentionally use Norwegian words when speaking English on a scale of 0-10 (whereby 0 = never, 5 = half of the time, 10 = all of the time)?

Individual LASS Summary Table and Graphical Profile

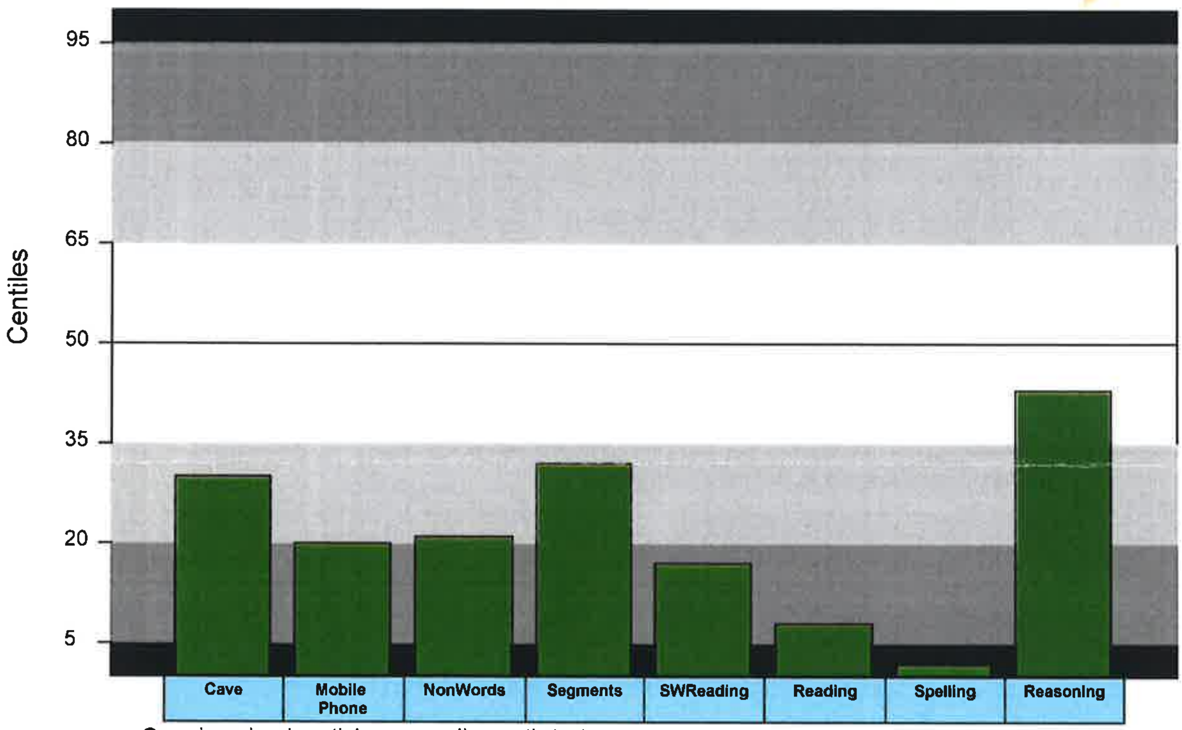
LASS ID: I

D.O.B: ´

Date printed: 19/11/18

Module	Score	Centile	Std Score	Z Score	ZScore difference	Discrepancy	Test date	Test age	Age equiv. range
Cave	20	30	92	-0.525	0.35	Not significant	19/11/18	9 y 7 m	8y 0m - 8y 5m
Mobile Phone	6	20	87	-0.842	0.67	- (p < 0.05)	19/11/18	9 y 7 m	8y 6m - 8y 11m
NonWords	14	21	88	-0.807	0.63	Not significant	19/11/18	9 y 7 m	8y 0m - 8y 5m
Segments	23	32	93	-0.468	0.29	Not significant	19/11/18	9 y 7 m	8y 6m - 8y 11m
SWReading	41	17	86	-0.954	0.78	- (p < 0.05)	19/11/18	9 y 7 m	Not applicable
Reading	42	8	79	-1.405	1.23	- (p < 0.01)	19/11/18	9 y 7 m	8y 0m - 8y 5m
Spelling	36	2	70	-2.054	1.88	- (p < 0.001)	19/11/18	9 y 7 m	< 8y 0m
Reasoning	34	43	97	-0.176	-	-	19/11/18	9 y 7 m	8y 6m - 8y 11m

Profiles should be interpreted in accordance with the manual.



Cave is a visual spatial memory diagnostic test.
Mobile Phone is a measure of auditory sequential memory involving digit span (diagnostic test).
NonWords is a diagnostic test of phonic decoding skills.
Segments is a test of syllable and phoneme deletion identifying phonological processing ability.
Single Word Reading is an attainment test involving the reading of individual words out of context.
Reading is an attainment measure involving a cloze reading task (finding the missing word in a sentence).
Spelling is an attainment task which involves the spelling of single words.
Reasoning is an ability test giving a measure of non-verbal intelligence.

Assessor's comments

Logos

DETALJERT RAPPORT

Elev:		**Testing:**	1. testing
Trinn:	3	**Fødselsdato:**	
Skole:	AIS	**Oppgavesett:**	2 (3 - 5)
Testleder:	Administrator, Logos	**Testnorm:**	Trinn 3

1. Leseflyt og leseforståelse (22.03.2018)

Leseflyt

	Ord Korrekt			Lesetid			Leseflyt		
	Prosent	*Snitt*	Persentil	Minutter	*Snitt*	Persentil	WCPM	*Snitt*	Persentil
Total skår	**80,36**	***95,84***	**1**	**15,37**	***5,01***	**1**	**17,31**	***79,55***	**1**

Leseforståelse

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**53,33**	***83,37***	**7**

Oppgave	Korrekte svar	Korrekt leste ord
1	0	56
2	2	56
3	1	39
4	3	56
5	2	59

2. Lytteforståelse (22.03.2018)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**93,33**	***78,62***	**89**

Oppgave	Korrekte svar
1	3

* Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt t lavt antall korrekt besvarte oppgaver.

2	3
3	2
4	3
5	3

3. **Ordidentifikasjon** (22.03.2018)

	Korrekt			R2			R2-R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**45,00**	***91,42***	**0**	**2,03**	***1,58***	**17 ***	**0,68**	***0,68***	**38**	**3 ***
Kort	55,00	*92,80*	1	1,69	*1,33*	14	0,32	*0,52*	74	5
Lang	35,00	*90,04*	1	2,73	*1,86*	11	2,43	*0,87*	2	1
Høyfrekvent	40,00	*94,27*	0	1,66	*1,51*	29	0,29	*0,64*	92	3
Lavfrekvent	50,00	*88,57*	1	2,55	*1,66*	9	0,75	*0,73*	33	3
Enkel	50,00	*92,20*	0	2,42	*1,46*	5	0,75	*0,63*	24	1
Kompleks	40,00	*90,64*	1	1,76	*1,72*	36	0,57	*0,74*	59	4

* Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt lavt antall korrekt besvarte oppgaver.

Oppgave	Stimuli	R/G	R2	R2-R1
1	tre	R	1,69	0,23
2	ble	R	1,57	0,08
3	skje	G	1,64	0,16
4	slik	G	4,27	2,75
5	januar	G	4,97	3,59
6	ost	R	1,99	0,67
7	gjennom	G	3,32	2,20
8	musikk	R	4,74	3,66
9	mai	R	2,08	0,70
10	mer	R	1,10	0,27
11	faktisk	R	5,93	4,91
12	tvil	G	4,59	4,57
13	pris	G	1,35	0,30
14	ansvar	G	2,59	1,32
15	fra	R	1,84	0,32
16	vei	G	5,99	4,42
17	feil	R	3,50	2,27
18	høy	R	2,37	0,23
19	vann	R	1,28	0,05
20	kanskje	G	2,81	1,43
21	gjorde	G	1,59	0,33
22	familien	R	1,85	0,20

23	kroner	G	2,42	1,25
24	ønsker	R	2,23	1,29
25	alt	R	1,64	0,69
26	mellom	G	1,61	0,63
27	sammen	R	2,48	2,47
28	får	G	4,15	3,72
29	ligger	R	4,10	2,43
30	startet	G	2,70	1,02
31	tilbake	G	7,57	6,05
32	skjedde	G	3,47	2,52
33	slo	R	1,64	0,47
34	direkte	G	3,43	2,60
35	tak	G	1,40	1,39
36	kan	G	1,87	0,17
37	derfor	G	5,18	3,89
38	behov	G	2,97	1,82
39	var	G	3,15	1,39
40	venner	R	2,73	0,80

4. **Fonologisk lesing** (22.03.2018)

	Korrekt			R2			R2-R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**58,33**	***84,46***	**6**	**2,29**	***2,12***	**34 ***	**1,00**	***1,04***	**42**	**14 ***
Kort	83,33	*91,60*	24	1,66	*1,64*	38	0,71	*0,68*	33	30
Lang	33,33	*77,33*	5	2,58	*2,84*	52	1,62	*1,60*	38	11
Enkel	66,67	*86,45*	11	2,02	*2,03*	41	0,87	*0,97*	49	23
Kompleks	50,00	*82,49*	8	2,46	*2,22*	30	1,17	*1,11*	36	10

*** Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt lavt antall korrekt besvarte oppgaver.**

Oppgave	Stimuli	R/G	R2	R2-R1
1	eru	R	1,13	0,21
2	kly	R	2,40	1,02
3	reidårø	G	2,61	1,62
4	skroble	G	3,64	2,50
5	repak	G	2,57	1,93
6	rys	R	2,92	1,33
7	jen	R	1,82	0,99
8	ukt	G	1,58	0,26
9	trymery	R	2,52	1,49
10	føs	R	1,15	0,15

11	klyfist	G	2,61	1,47
12	tubør	R	2,64	1,07
13	skjåluto	G	1,87	0,16
14	trun	R	1,50	0,23
15	kait	R	2,23	0,67
16	lemfæt	G	3,76	1,99
17	tjorhøs	G	4,42	3,29
18	skif	G	3,69	2,96
19	fry	R	1,32	0,22
20	pintås	R	2,36	1,75
21	gratusk	R	4,80	2,86
22	ritmalit	G	5,55	2,68
23	plit	R	3,92	1,33
24	gum	R	1,32	0,75

5. Ortografisk lesing (22.03.2018)

	Korrekt			R2			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**44,44**	***78,83***	**8**	**1,74**	***1,40***	**17 ***	**10 ***
Kort	72,22	*90,04*	11	1,60	*1,24*	16	12
Lang	16,67	*67,61*	9	4,05	*1,73*	1	3
Høyfrekvent	50,00	*81,85*	9	1,60	*1,33*	21	10
Lavfrekvent	38,89	*75,81*	9	2,64	*1,50*	6	5

* Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt lavt antall korrekt besvarte oppgaver.

Oppgave	Stimuli	R/G	R2
1	de	R	1,16
2	bord	G	4,55
3	hvordan	G	5,04
4	over	R	1,60
5	hånd	G	5,08
6	godt	R	2,29
7	omgang	G	5,73
8	bildet	R	4,05
9	utenfor	G	4,83
10	mennesker	G	4,89
11	gikk	R	2,60
12	komme	R	1,65
13	land	G	2,20
14	begynte	G	4,01

15	hjem	R	1,04
16	kirken	G	4,48
17	der	R	1,29
18	forslag	G	2,48
19	millioner	G	2,61
20	lov	R	1,83
21	opptatt	R	4,41
22	midt	G	2,24
23	gjerne	G	5,35
24	alvorlig	G	4,43
25	nord	R	3,42
26	fortsatt	G	2,40
27	norske	G	5,28
28	stod	G	2,17
29	forskjellige	G	4,13
30	jeg	R	0,91
31	mindre	G	2,56
32	glad	R	2,64
33	verdig	G	3,18
34	hva	R	1,56
35	født	R	2,22
36	hvor	R	1,60

6. **Bokstavlesing** (22.03.2018)

	Korrekt		R1		
	Prosent	*Snitt*	Sek.	*Snitt*	Persentil
Total skår	**100,00**	***97,92***	**0,79**	***0,65***	**16**

Oppgave	Stimuli	R/G	R1
1	i	R	0,77
2	e	R	0,59
3	o	R	0,63
4	t	R	0,94
5	v	R	0,85
6	y	R	0,77
7	d	R	1,20
8	j	R	0,84
9	r	R	0,81
10	æ	R	1,07
11	u	R	0,88
12	a	R	0,49

13	g	R	1,11
14	k	R	0,70
15	p	R	0,24
16	s	R	0,63
17	x	R	0,85
18	å	R	0,99
19	n	R	0,82
20	m	R	0,70
21	b	R	0,76
22	f	R	0,62
23	c	R	1,16
24	h	R	0,79
25	ø	R	0,33

7. **Grafem-fonem-omkoding** (22.03.2018)

	Korrekt			R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**84,00**	***86,01***	**42**	**1,02**	***0,94***	**33**	**31**
Enkel	100,00	*93,02*	100	0,78	*0,89*	68	73
Kompleks	66,67	*78,35*	24	1,33	*1,03*	13	15

Oppgave	Stimuli	R/G	R1
1	g	R	1,32
2	t	R	0,74
3	tj	R	1,30
4	n	R	0,72
5	ai	R	0,27
6	b	R	0,99
7	hj	R	1,71
8	øy	R	1,02
9	m	R	0,59
10	kj	R	1,37
11	d	R	1,57
12	au	G	1,42
13	f	R	1,24
14	gj	G	1,66
15	skj	G	0,97
16	p	R	0,81
17	r	R	1,11
18	ng	G	1,22
19	s	R	0,14

20	hv	R	2,36
21	sj	R	1,36
22	ei	R	1,26
23	h	R	0,20
24	j	R	0,11
25	k	R	0,78

8. Fonemsyntese (22.03.2018)

	Korrekt			R2			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**50,00**	***70,21***	**22**	**1,45**	***1,66***	**62 ***	**29 ***

* Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt lavt antall korrekt besvarte oppgaver.

Oppgave	Stimuli	R/G	R2
1	bil	G	3,31
2	mye	G	4,14
3	fra	R	1,45
4	smil	R	1,46
5	lure	G	3,56
6	dame	R	1,12
7	siden	G	5,81
8	papir	G	5,94
9	tenke	R	2,47
10	politi	R	1,36
11	handle	R	2,02
12	graver	G	2,61

9. Fonemanalyse (22.03.2018)

	Korrekt			R2			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**93,33**	***92,03***	**55**	**2,02**	***2,65***	**78**	**78**

Oppgave	Stimuli	R/G	R2
1	snø	R	4,15
2	bank	R	2,27
3	prest	R	2,00
4	gras	R	4,58
5	spy	R	2,37
6	rom	R	2,39

7	mor	R	2,03
8	jul	R	1,90
9	tøv	R	1,78
10	nye	R	1,99
11	søvn	R	2,91
12	fisk	R	1,87
13	drue	R	1,83
14	jakt	R	1,73
15	hyle	G	5,34

10. Fonologisk korttidsminne (22.03.2018)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**58,33**	***58,39***	**61**

Oppgave	Stimuli	R/G
1	691	R
2	724	R
3	928	R
4	3591	R
5	4672	R
6	8395	R
7	71463	G
8	92851	G
9	47632	G
10	251946	G
11	287254	R
12	153698	G

11. Å skille mellom ord og homofone nonord (22.03.2018)

	Korrekt			R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**53,33**	***73,80***	**15**	**2,50**	***2,33***	**42 ***	**20 ***

* Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt lavt antall korrekt besvarte oppgaver.

Oppgave	Stimuli 1	Stimuli 2	R/G	R1
1	åg	og	R	1,93
2	vikkti	viktig	G	2,78
3	der	dær	G	2,61

4	hjelpe	jelpe	R	4,30
5	va	hva	R	2,43
6	meg	maj	R	1,83
7	kom	kåm	R	3,37
8	åver	over	G	3,70
9	ær	er	R	2,03
10	lakt	lagt	R	3,54
11	rundt	runnt	R	2,99
12	jerne	gjerne	R	4,17
13	derfor	dærfor	R	2,80
14	nårsk	norsk	G	5,00
15	stærk	sterk	G	2,60
16	kvell	kveld	G	5,00
17	land	lann	R	2,57
18	åffte	ofte	G	3,25
19	jelm	hjelm	G	3,22
20	hvor	vor	R	2,10
21	tadt	tatt	G	3,40
22	sopp	såpp	R	4,44
23	jennom	gjennom	G	4,66
24	nok	nåkk	G	4,21
25	sje	skje	R	1,68
26	hvem	vem	R	1,03
27	sovne	såvne	G	1,38
28	fålk	folk	G	2,53
29	sjanse	skjanse	G	3,35
30	hvilken	vilken	R	1,25

12. Visuell analyse (22.03.2018)

	Korrekt			R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**75,00**	***76,25***	**45**	**2,84**	***2,74***	**44**	**35**

Oppgave	Stimuli 1	Stimuli 2	R/G	R1
1	DPKRS	DPKRS	R	2,50
2	MTPVR	NTPVR	G	2,07
3	RSTPJ	RSFPJ	R	2,44
4	BFJNV	BFJNV	R	4,92
5	CDMGT	CDMGT	R	2,61
6	VKTBG	VKTBC	R	2,98
7	KBMVD	KBSVD	R	2,61

8	BKHSD	RKHSD	R	3,06
9	JFRHV	JFRHV	R	3,09
10	SCHLM	SCHLN	R	3,02
11	PNFGJ	PNFGJ	R	3,48
12	TJSLK	TJSLK	R	3,64
13	GBHRJ	GBHRJ	R	2,16
14	JSDPB	TSDPB	R	1,67
15	HKRVS	HKPVS	G	2,60
16	RNSVB	RNSVB	R	2,77
17	PSHVG	PSHVL	G	2,01
18	TGDCF	TGLCF	G	5,00
19	KVHMR	FVHMR	R	1,78
20	RVBMK	RVBMK	R	3,48
21	LTBKC	LTBKC	G	3,09
22	RCLBD	RCLBP	R	2,92
23	FPCTK	FPCTK	R	2,35
24	VGNMR	VGNMR	G	2,18

13. **Fonologisk diskriminasjon** (22.03.2018)

	Korrekt			R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**90,00**	***92,78***	**32**	**0,68**	***0,63***	**39**	**32**

Oppgave	Stimuli 1	Stimuli 2	R/G	R1
1	kjerne	gjerne	G	0,34
2	glemme	klemme	R	0,66
3	kunne	kunne	R	0,20
4	bære	pære	R	2,19
5	dele	tele	R	1,76
6	skjule	skjule	R	0,59
7	søt	søtt	R	0,66
8	franske	granske	R	0,55
9	grøft	tøft	R	0,61
10	kjenne	kjenne	R	1,93
11	lyse	nyse	R	0,29
12	døv	tøv	R	3,87
13	tjene	tjene	R	0,41
14	tran	tran	R	0,25
15	måke	våke	G	0,24
16	sjekke	kjekke	G	0,85
17	true	drue	R	0,90

18	kjerre	kjerre	R	0,68
19	rus	russ	R	1,06
20	skyte	skyte	R	0,27
21	vise	lise	R	0,52
22	pøse	døse	R	0,98
23	skjør	skjør	R	0,70
24	hvete	hvete	R	0,76
25	bake	bakke	R	0,69
26	lese	lesse	R	0,88
27	snike	snike	R	0,70
28	hop	hopp	R	0,89
29	visk	visk	R	0,33
30	svømme	svømme	R	0,27

14. Hurtig benevnelse av kjente objekter (22.03.2018)

	Korrekt		Lesetid		
	Prosent	*Snitt*	Minutter	*Snitt*	Persentil
Total skår	**100,00**	***100,00***	**0,86**	***0,93***	**58**

15. Begrepsforståelse (22.03.2018)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**81,82**	***81,13***	**48**

Oppgave	Stimuli	R/G
1	due	R
2	søvnig	G
3	kvist	R
4	overalt	R
5	forbudt	R
6	travelt	G
7	fjerne	R
8	trist	R
9	kåpe	R
10	gjest	R
11	koffert	R
12	ofte	R
13	invitere	G
14	yngste	R
15	ulykke	R

16	speil	R
17	adresse	G
18	bolig	R
19	spandere	R
20	ambulanse	R
21	albue	R
22	fremmed	R

16. Muntlig reaksjonstid (22.03.2018)

	Korrekt		R1		
	Prosent	*Snitt*	ms	*Snitt*	Persentil
Total skår	**100,00**	***99,57***	**637**	***600***	**33**

Oppgave	Stimuli	R/G	R1
1	to prikker	R	604
2	en prikk	R	462
3	en prikk	R	483
4	to prikker	R	101
5	to prikker	R	715
6	to prikker	R	554
7	en prikk	R	893
8	to prikker	R	1118
9	en prikk	R	822
10	en prikk	R	817
11	to prikker	R	637
12	en prikk	R	808
13	to prikker	R	584
14	en prikk	R	75
15	to prikker	R	664

17. Manuell reaksjonstid (22.03.2018)

	Korrekt		R1		
	Prosent	*Snitt*	ms	*Snitt*	Persentil
Total skår	**93,33**	***95,07***	**596**	***521***	**26**

Oppgave	Stimuli	R/G	R1
1	høyre pil	R	480
2	venstre pil	R	595
3	venstre pil	R	597
4	høyre pil	R	468

5	høyre pil	G	396
6	høyre pil	R	691
7	venstre pil	R	695
8	høyre pil	R	596
9	venstre pil	R	581
10	venstre pil	R	596
11	høyre pil	R	596
12	venstre pil	R	559
13	høyre pil	R	727
14	venstre pil	R	911
15	høyre pil	R	427

18. Diktat (22.03.2018)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**0,00**	***44,11***	**0**

Oppgave	Stimuli	R/G
1	godt	G
2	morsomt	G
3	butikken	G
4	kylling	G
5	vinduet	G
6	sjeldent	G
7	gjemme	G
8	gutt	G
9	adresse	G
10	konserten	G
11	kolliderte	G
12	gjerne	G
13	kommandoen	G
14	middels	G
15	jorda	G
16	tålmodig	G
17	spydet	G
18	hvilken	G
19	verst	G
20	ripsbær	G
21	interesse	G
22	hvordan	G
23	nysgjerrig	G

24	temperaturen	G
25	konkurransen	G

DETALJERT RAPPORT

Elev:		**Testing:**	1. testing
Trinn:	6	**Fødselsdato:**	
Skole:		**Oppgavesett:**	3 (6 - voksne)
Testleder:		**Testnorm:**	Trinn 6

1. Leseflyt og leseforståelse (24.10.2020)

Leseflyt

	Ord Korrekt			Lesetid			Leseflyt		
	Prosent	*Snitt*	Persentil	Minutter	*Snitt*	Persentil	WCPM	*Snitt*	Persentil
Total skår	**88,43**	***95,68***	**6**	**7,60**	***4,85***	**6**	**42,24**	***80,38***	**5**

Leseforståelse

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**45,00**	***53,71***	**38**

Oppgave	Korrekte svar	Korrekt leste ord
1	2	71
2	1	76
3	3	76
4	3	98

2. Lytteforståelse (24.10.2020)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**55,00**	***60,62***	**42**

Oppgave	Korrekte svar
1	2
2	2

3	2
4	3
5	2

4. **Fonologisk lesing** (24.10.2020)

	Korrekt			R2			R2-R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**85,71**	***90,60***	**27**	**2,01**	***1,64***	**17**	**0,98**	***0,90***	**33**	**15**
Kort	92,86	*94,10*	47	1,46	*1,28*	25	0,68	*0,63*	33	23
Lang	78,57	*87,10*	26	2,90	*2,10*	10	1,78	*1,26*	19	10
Enkel	85,71	*92,07*	25	1,89	*1,59*	22	0,98	*0,87*	31	15
Kompleks	85,71	*89,14*	38	2,09	*1,69*	16	1,21	*0,94*	22	17

Oppgave	Stimuli	R/G	R2	R2-R1
1	eru	R	2,01	0,97
2	kly	R	1,52	0,51
3	reidårø	G	4,73	3,73
4	skroble	G	2,96	2,09
5	repak	R	2,60	1,28
6	trinsk	R	3,53	2,54
7	ponåset	R	3,14	1,73
8	rys	R	1,45	0,76
9	jen	R	1,06	0,29
10	skilurøski	R	4,33	3,25
11	øpyli	G	2,64	1,24
12	ukt	R	1,37	0,96
13	trymery	R	2,65	1,78
14	føs	R	1,46	0,74
15	klyfist	R	3,70	2,12
16	tubør	R	1,78	0,99
17	skjåluto	G	3,49	2,51
18	trun	R	1,27	0,56
19	kait	R	1,70	0,77
20	lemfæt	R	2,90	1,82
21	tjorhøs	R	5,88	5,14
22	skif	R	1,58	0,68
23	fry	R	1,10	0,46
24	pintås	R	2,02	1,51
25	gratusk	R	2,18	1,46
26	ritmalit	R	3,05	2,40
27	plit	R	2,01	0,68

28	gum	R	1,24	0,16

5. **Ortografisk lesing** (24.10.2020)

	Korrekt			R2			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**58,33**	***86,06***	**6**	**1,55**	***1,16***	**7** *	**3** *
Kort	83,33	*94,12*	11	1,39	*1,03*	7	5
Lang	33,33	*78,00*	4	1,80	*1,37*	12	4
Høyfrekvent	66,67	*90,22*	7	1,32	*1,10*	17	5
Lavfrekvent	50,00	*81,90*	7	1,73	*1,23*	6	4

* Vær oppmerksom på at elevens gjennomsnittlige tidsbruk er beregnet på bakgrunn av et statistisk relativt lavt antall korrekt besvarte oppgaver.

Oppgave	Stimuli	R/G	R2
1	her	R	0,86
2	geni	G	1,22
3	gjennom	R	1,62
4	rips	R	1,41
5	falsk	G	1,64
6	hvis	R	1,42
7	stabilitet	R	3,15
8	bildet	R	2,43
9	farligste	G	3,94
10	selvsagt	G	2,89
11	gikk	R	1,37
12	seiret	G	5,59
13	land	R	1,18
14	skyggen	G	2,39
15	hjem	R	1,26
16	kirken	R	1,77
17	hobby	R	1,64
18	ytterste	G	1,98
19	millioner	G	2,28
20	kinnet	R	1,61
21	makt	R	1,38
22	rikt	R	1,25
23	kanskje	R	1,19
24	varsel	R	1,95
25	kjærlig	R	1,82
26	fortsatt	R	1,70
27	situasjon	G	1,78

28	gitt	R	1,27
29	forskjellige	G	4,32
30	gjest	R	2,49
31	strålende	G	3,89
32	glad	R	1,10
33	skøyter	G	3,45
34	skip	G	3,52
35	fryd	R	1,55
36	tro	R	0,92
37	trent	G	1,23
38	skjorte	G	4,32
39	sjakk	R	3,61
40	hjul	R	2,47
41	fjernsyn	G	2,47
42	kapteinen	G	2,00
43	fjern	R	1,55
44	restaurant	G	3,86
45	lyst	R	1,24
46	sprenge	G	3,79
47	fremtiden	G	2,00
48	sjuk	R	1,64

6. **Fonemisk bevissthet** (24.10.2020)

	Korrekt			R1			Effektivitet
	Prosent	*Snitt*	Persentil	Sek.	*Snitt*	Persentil	Persentil
Total skår	**73,33**	***84,24***	**25**	**1,13**	***1,05***	**37**	**27**

Oppgave	Stimuli	R/G	R1
1	nål	R	0,49
2	tøv	G	0,83
3	ris	R	1,42
4	øre	R	0,89
5	rus	R	1,13
6	ta	R	0,53
7	fil	R	2,12
8	han	R	1,15
9	se	R	1,29
10	klar	R	0,79
11	hest	G	1,28
12	mas	G	0,86
13	test	G	1,39

14	sør	R	0,25
15	danse	R	1,77

12. **Begrepsforståelse** (24.10.2020)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	***76,67***	***66,63***	**74**

Oppgave	Stimuli	R/G
1	kapittel	R
2	ufør	G
3	bevege	R
4	meny	R
5	sjonglør	G
6	dirigent	R
7	penicillin	G
8	kamera	R
9	scene	R
10	produsere	G
11	konsentrert	R
12	tradisjon	R
13	komplett	R
14	rapport	R
15	desperat	R
16	invitere	R
17	pinlig	R
18	dokument	R
19	kanal	R
20	kampanje	G
21	risiko	R
22	spandere	R
23	elegant	R
24	magnet	R
25	kombinere	R
26	stress	R
27	skeptisk	R
28	teoretisk	G
29	sjenert	R
30	streik	G

13. **Muntlig reaksjonstid** (24.10.2020)

	Korrekt		R1		
	Prosent	*Snitt*	ms	*Snitt*	Persentil
Total skår	**100,00**	***98,79***	**493**	***497***	**55**

Oppgave	Stimuli	R/G	R1
1	to prikker	R	558
2	en prikk	R	566
3	en prikk	R	569
4	to prikker	R	501
5	to prikker	R	592
6	to prikker	R	572
7	en prikk	R	445
8	to prikker	R	484
9	en prikk	R	535
10	en prikk	R	439
11	to prikker	R	446
12	en prikk	R	483
13	to prikker	R	493
14	en prikk	R	465
15	to prikker	R	408

14. **Manuell reaksjonstid** (24.10.2020)

	Korrekt		R1		
	Prosent	*Snitt*	ms	*Snitt*	Persentil
Total skår	**93,33**	***95,80***	**380**	***423***	**73**

Oppgave	Stimuli	R/G	R1
1	høyre pil	G	335
2	venstre pil	R	315
3	venstre pil	R	478
4	høyre pil	R	322
5	høyre pil	R	515
6	høyre pil	R	556
7	venstre pil	R	428
8	høyre pil	R	398
9	venstre pil	R	329
10	venstre pil	R	468
11	høyre pil	R	515
12	venstre pil	R	332
13	høyre pil	R	331

14	venstre pil	R	319
15	høyre pil	R	361

15. **Diktat** (24.10.2020)

	Korrekt		
	Prosent	*Snitt*	Persentil
Total skår	**11,43**	***62,23***	**1**

Oppgave	Stimuli	R/G
1	kveld	G
2	sprek	R
3	ydmyk	R
4	tannverk	G
5	annonser	G
6	fargeblind	G
7	gjerne	G
8	historien	R
9	kikket	G
10	tjære	G
11	sersjant	G
12	tjue	G
13	sjokoladen	G
14	hjertelig	G
15	ærend	G
16	karusell	G
17	praktisk	G
18	spisset	G
19	fartskontroll	G
20	passasjerer	G
21	effekt	G
22	dybden	R
23	komplimenter	G
24	ripsbærbusker	G
25	eiendommen	G
26	geni	G
27	journalist	G
28	gaffel	G
29	kontrollert	G
30	absolutt	G
31	ingeniører	G
32	arrangerte	G

33	departementet	G
34	restauranten	G
35	energikilder	G