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Making sense of a “complete mess”: A study of reading comprehension in Danish

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Abstract

Various factors may impact the process of reading. The depth of the orthography influences the reading strategy for readers of shallow and deep orthographies because the complexity of the mapping between graphemes and phonemes increases with depth. In this thesis, reading comprehension in Danish, considered a deep orthography, is examined. While phonological awareness is commonly recognized as an underlying cause of reading difficulties, little is known about the effect of VAS in Danish readers. An experiment consisting of three tasks involving phonological awareness, visual attention span (VAS) skills and reading comprehension respectively is conducted with 22 adult L1 Danish readers. It is investigated which of the two reading subskills of phonological awareness and VAS skills has the highest contribution to reading comprehension. The results show that phonological awareness is low in declared dyslexic readers as well as in those with the poorest reading comprehension in general but that these groups on average perform well on VAS tasks. It is also found that those with the best VAS accuracy exhibit the best reading comprehension.

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1. Introduction

Reading is an everyday activity in the modern world – an activity which is rarely attributed much attention, at least not by those who read effortlessly. However, those who struggle with making sense of letters and sounds often find the activity of reading cumbersome and unattractive. Which skills are required to become a good reader and how do deficits in these skills manifest themselves in those who read with difficulty? Coming closer to finding answers to those questions is the focus of this thesis.

While producing and comprehending speech sounds for the purpose of communication has been a natural activity for mankind for presumably over 100,000 years, writing and thus reading is a relatively new invention dating back no further than 5,000 years. Writing can be seen as a somewhat artificial process of mapping speech sounds to arbitrary symbols (e.g. letters) that are then in turn combined to form words (Sedivy, 2020). Some languages may, even though they use the same alphabet, use different letters to represent the same sound, and across writing systems, such as the Japanese syllabic system or the logographic system used in China, that same sound may be expressed in a multitude of graphical shapes. While the process of converting speech sounds to symbols takes place for the purpose of producing written communication, the reverse process of mapping symbols to speech sounds is required for reading. Due to the artificial nature of writing systems, the skills required for reading may differ depending on language and orthography, and it can thus not be assumed that reading as such is a skill that is acquired in a one-size-fits-all approach irrespective of the language.

This thesis focuses on the approach for reading in Danish. Danish is a language that is known to cause many of its L2 learners frustration in the acquisition process, but they are not the only ones to struggle. L1 speakers of Danish may also experience obstacles when attempting to master its orthography and convert letters into sounds in the process of reading (Jørgensen, 2019). These difficulties may be caused by different deficits in skills involved in the reading experience. Phonological awareness, the ability to map letters to sounds, has traditionally been proposed as the most important skill for reading acquisition and fluency but in later years, a focus on visual attention has emerged. The aim of this thesis is to investigate which skills differentiate individuals with a high level of reading comprehension in Danish from those who struggle when reading in Danish. Measuring these skills in linguistic tasks may lead to greater knowledge about their importance and impact on reading comprehension. Such knowledge may then in turn lead to a more differentiated approach in the teaching of reading and a higher focus on the improvement of the particular skill from which the person with reading difficulties would gain the largest benefit.

The background section of this thesis describes orthography in general and hypotheses in the field of orthography and reading. It contains subsections on reading comprehension as well as dyslexia and reading deficits which are thought to be potential causes of dyslexia and reading difficulties. The remaining part of the background section zooms in on Danish, particularly Danish orthography and approaches to teaching reading acquisition and ensuring early detection of dyslexia and reading difficulties in the Danish school system. Based on the background chapter, the research question and the expected findings are formulated followed by a description of the method applied. The main results are then presented and discussed to answer the research question.

To ensure readability and comprehension, various typographical conventions have been applied. In the examples given in this thesis, words in other languages than English are written in italics. The English translation is written in single quotes immediately following the non-English word, however, left out if the English translation is identical to the original word. Grammatical information about tense is indicated in parentheses after the English translation. An example may thus be presented as follows: *høre* ‘hear’ (infinitive). Graphemes are written in angle brackets e.g. <e>, and phonemes are indicated inside a set of forward slashes e.g. /ɛ/. All phonetic transcriptions originate from Den Danske Ordbog and are represented by square brackets e.g. [ˈkigs]. As described at Den Danske Ordbog (2026), these transcriptions reflect a simplified form of the International Phonetic Alphabet (IPA).

2. Background

In this chapter, some important components of reading will be described. After an introduction to orthography, reading comprehension and hypotheses about the deficits that may cause reading difficulties or dyslexia in general, the focus will be specifically on the characteristics of Danish orthography and on reading acquisition and difficulties in Danish.

2.1. Orthographies

Orthography describes the relationship between a set of symbols and a language. In the process of reading, the mapping between symbol and speech sound is a fundamental component. In all alphabetical writing systems, a process of phonological decoding takes place in which readers attempt to deduce the phonology from orthographic strings (Lallier & Carreiras, 2018). This process is most often referred to as grapheme-phoneme conversion (Warren, 2013) or grapheme-to-phoneme correspondence (Venagli et al., 2025), both abbreviated GPC. Van den Bosch et al. (1994, p. 178) define a grapheme as “a letter or a cluster of letters that is realized in the phonological transcription as a single phoneme”. In Warren (2013, p. 121), a phoneme is defined as “the smallest unit that when changed can result in a change in meaning by signaling a different word”. An example of a simple grapheme is <n> in the word *sun* that maps to the phoneme /n/. A complex grapheme consisting of a cluster of letters is <ng> in *song* which corresponds to /ŋ/.

The concept of orthographic depth encompasses the degree to which the mapping between grapheme and phoneme is simple or complex. An orthography where one grapheme represents exactly one phoneme and each phoneme is represented by exactly one grapheme, is called a shallow (or transparent) orthography. In other words, there is a consistent one-to-one mapping between grapheme and phoneme. Examples of shallow orthographies are Greek, Finnish, German, Italian and Spanish (Ziegler & Goswami, 2005). Orthographies may be viewed as residing on a continuum from shallow to deep. Moving from shallow to deep, orthographies exhibit an increasing degree of inconsistency in the GPC in that some graphemes may represent more than one sound, and some phonemes may be represented by more than one letter or may not exist in the orthography at all. Orthographies such as English, French and Danish are typically considered deep (or opaque) but may be so in different ways. Danish is said to be inconsistent for reading because the same grapheme can be mapped to several different phonemes which is evident from the examples in Table 1 below. French, on the other hand, is inconsistent for spelling because the same phoneme may be represented by several variants of spelling (Ziegler & Goswami, 2005). As an example of this inconsistency in French, Hoedt and Piron (2017) mention the phoneme /s/ that may be represented by the 12 graphemes <s>, <ss>, <c>, <ç>, <sc>, <t>, <x>, <z>, <th>, <sth>, <cc> and <sç>.

According to Katz and Frost (1992), societal factors such as economy, politics and culture may influence the orthography. For instance, for Icelandic orthography this was the case during its last reform in 1973-74 driven by educational concerns and supported by all teachers’ unions. Despite fierce opposition from the Icelandic parliament that demanded a rescission of the reform, the Ministry of Education proceeded with the implementation of the reformed orthography (Pind, 2006). However, phonological complexity in the spoken language is a factor that more consistently than societal factors drives the process of differentiation. Phonological complexity refers to the relationship between phonology and morphology. Languages where the phonological core of morphologically-related words is common and invariable are considered less complex. This means that morphologically related words share a word stem which not only sounds the same in those words but is also spelled the same way resulting in a transparent orthography. In German, examples include *mieten* ‘to rent’, *mieten* ‘they rent’ and *die Miete* ‘the rent’ that share the same word stem and spelling. At the other end of the spectrum, in phonologically complex languages, the spelling of a word stem remains invariable even though the pronunciation varies, resulting in a deep orthography with an opaque mapping between grapheme and morpheme. In Danish, the word *havde* 'have' (past tense) is pronounced [ˈhæːðə] with no audible trace of the /v/ sound. The grapheme <v> remains as part of the invariable spelling of the word stem because the conjugated form is derived from *have* 'have' (infinitive). Elbro (2014) refers to the phenomenon of invariable spelling of word stems as "the principle of meaning" (in Danish "betydningsprincippet") because the principle enables readers to recognize the meaning of a word more easily. On the other hand, the principle impedes the spelling of the word because the pronunciation is removed from its orthographic form.

2.1.1. Reading strategies and orthography

Different degrees of orthographic depth seem to demand different strategies for reading. In the dual-route model outlined in Coltheart et al. (2001), two possible routes exist. One route relies on GPC where each grapheme is mapped to a phoneme enabling the reader to assemble the phonemes into the pronunciation of the word. Once the pronunciation has been established, the reader accesses the word in the mental lexicon. The reader deploys a non-lexical (or sublexical) reading procedure and focuses on just small elements (also referred to as grains), not larger chunks of graphemes grouped together (Ziegler & Goswami, 2005). The other route runs more directly from written input such as an entire word or large parts of a word to the mental lexicon with no need for conversion of graphemes to phonemes. Readers recognize the visual pattern of the chunk of graphemes and associate the pattern directly with its sound. Taking this route, a person makes use of a lexical reading procedure focusing on larger grains.

The orthographic depth hypothesis presented in Katz and Frost (1992) is connected to the dual-route model and proposes that "the differences in orthographic depth lead to processing differences for naming and lexical decision." (Katz & Frost, 1992, p. 71). In a shallow orthography, it is easier for the reader to recognize a printed word's phonology based on GPC because the connection between grapheme and phoneme is simple and consistent. This type of non-lexical analysis can reliably be applied in transparent orthographies because of the high degree of consistency in the mappings. Readers of deeper orthographies, on the other hand, must process many written words lexically because the non-lexical GPC strategy would be too "costly" in the sense that it might lead to incorrect pronunciations. It is important to state, though, that regardless of orthographic depth, both routes are deployed during the reading process. Studies referred to in Ziegler and Goswami (2005) have shown that the phonological process of converting graphemes to phonemes is not limited to shallow orthographies.

However, the degree to which the non-lexical route is utilized does seem to decrease the deeper the orthography.

2.2. Reading comprehension

As explained in the introduction, this thesis investigates phonological awareness and visual attention and their contribution to reading comprehension. Oakhill et al. (2019, p. 3) define successful reading comprehension as "the construction of an integrated representation of the overall meaning of the text" – a meaning that cannot be deduced without word and language knowledge combined. In order to achieve good reading comprehension, word decoding skills must be combined with language comprehension abilities. While the former are most often not developed until the age at which formal reading acquisition is begun, language understanding may be built from a very early age. The speed at which words and knowledge are activated in the brain is an important factor in reading comprehension. If the activation is slow, comprehension may be impaired because the meaning of one word is not accessed fast enough before the next one is encountered (Oakhill et al., 2019).

To correctly infer the message that a text is meant to convey, the ability to understand explicit as well as implicit clues in the text must be present. Explicit clues include pronouns that bridge two sentences e.g. 'Helen heard the alarm clock. She realized that it was Monday morning'. Understanding that 'Helen' and 'she' refers to the same person is an example of a local cohesion inference. A global coherence inference, on the other hand, requires background knowledge because the text does not contain explicit clues that aid the understanding. For readers to comprehend the two example sentences and how they are to be understood as a whole, they must infer that Helen knows that it is Monday morning and not Sunday because many people do not use alarm clocks on the weekend. While local inferences connect sentences and contribute to coherence at sentence level, global inferences contribute to the overall coherence of the text, and both types of inferences are typically required for successful reading comprehension.

Reading comprehension may be tested in various ways. Readers are typically presented with one or more coherent texts of the type that they are likely to encounter in everyday reading situations and asked to answer questions related to the content of the texts (Jensen et al., 2015). Though not traditionally considered an appropriate method for testing reading comprehension, Gellert and Elbro (2013) argue that the time-efficient format of a cloze test may substitute the traditional time-consuming question-answering tests if the cloze test is carefully constructed to match the same criteria of reliability and validity. In a cloze test, words in a text are omitted at a fixed ratio such as every fifth, seventh or tenth word or in more deliberately selected locations to test for local and global inference abilities. A word such as a pronoun may be omitted at intersections of sentences to test for local cohesion inferences while testing for global inferences requires carefully placing the gap so that the word can be restored only by drawing on background knowledge. Cloze tests may be presented with gaps for the omitted words with no clues for the reader or with proposed options from which the reader must choose. For the reader to select the correct word from an example such as this one “In autumn, leaves may cover the ground. Be careful not to [sing – slip – read] if you go for a run in the rain”, the logical relationship between sentences must be evaluated for the text to be understood. Studies have shown that poor performance on a cloze test may not necessarily be explained alone by poor decoding skills at the word level or failure to understand sentences in isolation (Gellert & Elbro, 2013). It is necessary to understand more than just individual words and sentences, and the ability to deploy logical reasoning and background knowledge, in the case of global inferences, is thus also important.

2.3. Dyslexia

Most readers occasionally experience difficulties in reading comprehension e.g. when encountering an unknown word or reading in a second language that is not yet mastered. For some, these difficulties are more profound and persistent. In that case, the underlying cause may be dyslexia. Two types of dyslexia exist: acquired and developmental dyslexia. Acquired dyslexia typically occurs in people with brain damage either as a result of an accident causing a blow to the head or a stroke (Warren, 2013). Developmental dyslexia, on the other hand, is not caused by head traumas or other singular events and cannot be explained by psychiatric disorders, abnormal schooling or a low IQ. It is characterized by an unexpected and persistent low reading proficiency (Lallier & Carreiras, 2018). For this thesis, only developmental dyslexia will be considered.

Because orthography affects the reading strategy, different orthographies may have different impacts on the difficulties encountered by people with dyslexia. These differences may explain why the statistics and approaches to developmental dyslexia vary significantly between countries. Some countries such as Bulgaria and Croatia have no official government definition nor policy concerning dyslexia. Greece has only recently begun to acknowledge and research reading difficulties, and Italy largely underestimates dyslexia according to citations in Broadbent (2018). Common for the orthographies of the languages primarily spoken in those countries is that they are considered relatively shallow orthographies. For countries where the percentages of dyslexics are estimated, the numbers range from around 5% in Luxemburg, 8% in France and 10% in Spain, Ireland and the UK. Finland and Sweden both estimate that 5-15

% of their populations suffer from reading and writing difficulties. The numbers indicate that definitions and measurement methods vary across countries and languages and that they are not necessarily related to the depth of the orthography. Finland with Finnish, a language characterized by a shallow orthography, spoken by 84% of its population (Tilastokeskus, 2026) is thus estimated to have more dyslexics than France with its primary language of French (spoken by 93% of the population according to WorldData.info (2026)), already mentioned above as having a deep orthography. The difference in numbers and estimates is hardly surprising given the statement by Ziegler and Goswami (2005, p. 4) that "It is still not agreed whether developmental dyslexia is the same phenomenon across different languages". While Elbro (2014) writes that boys more often exhibit reading difficulties than girls, Broadbent (2018) states that there is no gender imbalance in dyslexia. Consensus is, however, generally present in the literature about dyslexia being hereditary (Broadbent, 2018; Elbro, 2014; Arnbak, 2019). Elbro (2014) writes that twin studies and chromosome research document the genetic differences in dyslexics and non-dyslexics and that the risk of dyslexia is 2-6 times higher for children of dyslexic parents. In general, though, defining dyslexia and aligning on how to measure the extent of it in a population seems to be no easy task.

Defining whether an individual suffers from dyslexia may be an even more complex task. In pre-school children, certain characteristics such as lack of interest in language games or lack of exhibition of phonological awareness may early on indicate future reading and writing difficulties such as problems with reading comprehension. For older students, a lack of interest in voluntary reading or slow or hesitant reading as well as difficulties in reading unfamiliar words may be an indication of dyslexia (Arnbak, 2019). In adults, difficulties arise when determining whether reading difficulties are indeed persistent or if they are caused by a mere lack of opportunity and willingness to read. Adults who do not feel confident reading may be less inclined to do so and may thus acquire fewer new vocabulary items. This in turn may lead to even greater difficulties and reluctance to read. However, determining if the difficulties in adults are caused by dyslexia or lack of reading experience is complex (Elbro et al., 1994). For all age groups, a general challenge is to define exactly where to draw the line between having dyslexia and not having dyslexia. Such a line may e.g. determine if a student is or is not allocated extra resources and time extension on exams. Some students may exhibit reading and writing difficulties but not to an extent that may be defined as dyslexia according to the threshold defined in dyslexia tests. As a consequence, they may not receive the special aid that would enable them to improve their reading skills and may thus be left to cope on their own compared to their peers who tested positive in the dyslexia test (Vilien, 2025). A diagnosis of dyslexia may thus have a substantial positive impact of a person's reading journey, however, the path to arriving at such a diagnosis may be marked by obstacles and complexity.

Developmental dyslexia is not a homogenous phenomenon as dyslexics are not at all equal in the manner in which their difficulties manifest themselves. Coltheart et al. (2001) explain how the strategies used in the dual-route model may determine the type of difficulty encountered. Some dyslexics may be able to take the lexical route at the same rate as non-dyslexics in that they recognize larger clusters of graphemes with relative ease but show difficulty in assembling individual components when taking the non-lexical route. This is referred to as *developmental phonological dyslexia* and may be expressed in problems with reading pseudo-words. Dyslexics showing signs of the opposite i.e. having problems with the lexical route but not the non-lexical one are said to suffer from *developmental surface dyslexia*. For such readers, it may cause difficulties to read irregular words aloud. Designing an experiment in which participants must read irregular words and pseudo-words thus allows researchers to determine if a person has developmental phonological dyslexia (a low score on pseudo-words) or developmental surface dyslexia (a low score on irregular words). While the underlying cause of dyslexia has generally been viewed as related to a phonological deficit, i.e. the lack of phonological awareness and decoding skills when mapping graphemes to phonemes, a visual attention span (VAS) deficit is being suggested as another potential cause in various studies (Perry & Long, 2022). According to studies reviewed by Valdois (2022), between 54 and 69% of dyslexic children examined showed either a phonological or a VAS deficit but not both. It thus seems relevant to consider both deficits when investigating the potential causes of dyslexia and reading difficulties to be able to target their specific learning needs and customize the approaches to overcoming these difficulties. The following sections describe phonological awareness and VAS and how these deficits may potentially be elicited.

2.4. Phonological awareness

Phonological awareness is most often defined as "the conscious ability to detect and manipulate language sounds" (Sodoro et al., 2002, p. 225). A reader with a strong phonological awareness is able to accurately and fluently identify words and map graphemes to phonemes in unfamiliar words to decipher their pronunciation. Phonological awareness is thus a prerequisite for successfully applying the non-lexical approach in the dual-route model and for ensuring accuracy in the reading process. Phonemic awareness is a distinct aspect of phonological awareness that specifically encompasses the notion that "every spoken word can be conceived as a sequence of phonemes" (Sodoro et al., 2002, p. 225). Phonemic awareness in children at the pre-school age has been shown to be a strong predictor of how a child develops literacy skills later on (Juul & Sigurdsson, 2005), however, it is a skill that may be improved with literacy instruction, and improved phonemic awareness then in turn typically leads to improved reading acquisition (Bosse & Valdois, 2009). Studies have shown that phonological abilities play a particularly important role for beginning readers because these readers are unfamiliar with the orthographic inputs that they encounter and thus need to assemble each word based on GPC via the non-lexical route (Lallier & Carreiras, 2018).

Phonological awareness may be tested by means of a variety of tasks. Some of these include the ability to rhyme words, distinguish the different phonemes included in a word and to tell the syllables of a word apart (Sodoro et al., 2002). The ability to read and correctly pronounce pseudo-words has also been documented to have a strong link to phonological awareness (Bosse et al., 2007). If readers do not possess a strong awareness of how graphemes map to phonemes, they are simply unable to conclude on a correct pronunciation of a pseudo-word. As mentioned in 2.3, this inability is characteristic of developmental phonological dyslexia.

2.5. Visual attention span (VAS)

There is increasing evidence that visual attention skills are of importance in reading acquisition (Lallier & Carreiras, 2018). The visual attention span (VAS) is one element often under investigation. It is defined in Bosse et al. (2007, p. 198) as "the amount of distinct visual elements which can be processed in a multi-element array". In terms of reading, this may be translated into the number of distinct graphemes that a reader can process in one fixation. The VAS required for reading may depend on the route selected. When reading lexically i.e. focusing on a larger cluster of elements, a larger VAS is naturally required for it to extend over the whole sequence. On the other hand, for non-lexical processing in which the reader focuses on single graphemes, the required VAS is smaller. Readers learning to read in an L1 of shallow orthography, in which the non-lexical route may more often be used, have been shown to exhibit a narrower VAS than those acquiring reading skills in an L1 orthography of less transparent nature (Lallier et al., 2016). The depth of the orthography determines how large a window size (number of graphemes) is needed for optimal processing of words. According to Perry and Long (2022), studies have shown that the window size is three for Italian, four for Dutch and five for English. Consequently, a VAS deficit seems to be less critical in a shallow orthography like Italian than in a deeper orthography like English.

As stated in 2.4, phonological awareness is strongly linked to difficulties in reading pseudo-words. Nevertheless, a VAS deficit may also constitute a factor in pseudo-word reading independently of phonological awareness (Bosse et al., 2007). For deep orthographies, VAS must be wider than a single-letter window because chunks of graphemes must be recognized in order to associate the grapheme pattern with the corresponding sound as described in 2.1.1. A reader with a reduced VAS cannot easily identify several graphemes in one fixation and thus may not recognize the entire pattern necessary for identifying the pronunciation from the pattern. In pseudo-words, where readers cannot rely on taking the lexical route by purely recognizing clusters of graphemes or entire words, the only possible route is the non-lexical one. However, if VAS skills are impaired, readers cannot reliably convert the reduced number of letters which they are able to identify into a pattern and will thus fail to assemble these letters into a pronounceable word. This explains why a VAS deficit may be a factor in pseudo-word reading independently of a phonological awareness deficit.

The speed of reading seems to be correlated with VAS, thus the wider the VAS, the faster the reading speed regardless of orthography depth (Bosse et al., 2007; Bosse & Valdois, 2009; Lallier et al., 2014). Age has also been shown to influence VAS skills. Bosse and Valdois (2009) write that this is most likely a reflection of the impact of reading experience on the visual attentional processing system.

Studies have indicated that some dyslexics exhibit poor VAS capacities as they are limited in the number of elements which they can process simultaneously in multi-elements arrays. This is known as the VAS deficit hypothesis (Bosse et al., 2007). The VAS deficit has been found in dyslexics who showed a good level of phonological awareness, and this suggests that the deficit may be an independent underlying cause of developmental dyslexia (Valdois, 2022).

One method commonly used for testing VAS relies on whole and partial report conditions in which participants are tasked with focusing (and reporting) on a whole string (whole report) or just one letter in a string (partial report). Such tasks enable the studying of how letter information is processed during a single fixation (Bosse et al., 2007). In alphabetic orthographies, tasks involving the two conditions are typically designed around a string of five letters presented on a screen for 200 ms. The short duration ensures that no eye movements take place and that the stimuli are processed parallelly within a single fixation (Valdois, 2022). Performance on whole and partial report tasks may reflect participants' ability to distribute their visual attention across the string of letters while at the same time identifying individual letters. In a whole report task, participants are asked to report the whole string with no order constraint. Often this reporting is done verbally. In a partial report task, on the other hand, the focus is on one of the letters only. One variant of a partial report task is the presentation of the string of five letters for 200 ms. after which immediately follows a probe in the shape of a bar below one of the letters. Participants are tasked with reporting back verbally the cued letter only (Bosse et al., 2007). Another variant applied by Lallier et al. (2016) does not rely on oral reporting. Instead, it presents the five-letter string for 200 ms followed by a 100 ms. white screen and then a single target letter on a screen with no time limit. Participants must indicate either by mouse or keyboard input if the target letter was included in the five-letter string. Constructing a non-verbal partial report task removes the potential phonological interpretation of the VAS deficit. As oral reporting unavoidably involves an element of phonological processing, doubts have been raised that a VAS deficit may be an expression of phonological difficulties rather than a purely visual one (Valdois, 2022). Such doubts may safely be rejected in report tasks with no verbal elements. Advantages of testing VAS using the described set-ups include the ease and speed of use as well as the predictive ability with the data. Furthermore, significant effects of using whole and partial report conditions have been found in many studies involving quite disparate participant populations (Perry & Long, 2022). It thus appears to be a reliably applicable test approach almost regardless of the intended target group.

In the design of whole and partial report tasks, the visual characteristics of the letters and their presentation are of importance. According to Valdois (2022), three factors may impact the accurate recognition of individual letters within a string. First, the complexity of the characters plays a role as some orthographies are represented by more complex letters than others. This is e.g. the case with Arabic. Second, visual similarity between letters such as N and M may delay the recognition of the individual letter. A third factor is the phenomenon of crowding in which the visual system excessively integrates objects. In VAS tasks, this may be controlled for by increasing inter-character spacing in a string. When designing a task, the orthography in question (alphabetic etc.) and the selected letters/symbols as well as their presentation must thus be carefully considered.

The position of each character also impacts its identification. Grainger et al. (2016) write that crowding, regardless of inter-character spacing, may still negatively impact the identification of the second and fourth consonants in the VAS task because those consonants are surrounded by characters on each side. It is thus common to observe a lower accuracy rate for those positions compared to the surrounding characters. Furthermore, the highest accuracy rate is typically found for the consonant in the left-most position regardless of the depth of the orthography. This is known as the "first-letter advantage" (Grainger et al., 2016). The closer a consonant is to the fixation point in the task, the more visible it is. This is referred to as acuity resulting in the central (third) letter frequently being accurately identified. With the first and fifth letter benefiting from the least crowding and the third character being the most visible, a typical accuracy graph from a VAS task has a W-shape as illustrated in Figure 1 (though usually asymmetrical with regards to the first and last positions because of the expected highest accuracy rate of the first character).

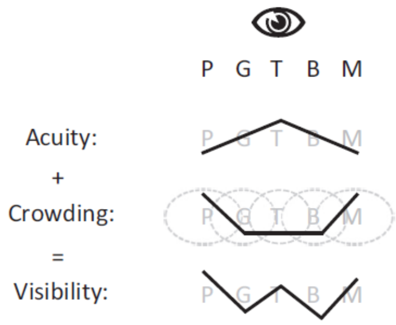

Figure 1: Serial position function for letter-in-string identification (Grainger et al., 2016)

2.6. Danish

Following the descriptions of factors influencing and contributing to reading comprehension in general, the Danish orthography and reading in Danish are explained in this section.

2.6.1. Orthography

The language in scope for this thesis is Danish which, as mentioned above in 2.1, is considered to have a deep orthography. According to Juul and Sigurdsson (2005), it is deep with regards to inconsistency of sound-to-letter correspondences for two reasons. First, one Danish spelling may often be mapped to more than several phonemes and vice versa. Examples displayed in Table 1 below include the grapheme <o> that maps to the phonemes /o/, /ɔ/ and /ʌ/ and the phoneme /ɔ/ which is represented by the graphemes <o> and <u> . Second, the orthography is deep because the frequency with which the principle of "one sound per letter" deviates is high. A deviation in this context is defined by Juul & Sigurdsson (2005, p. 266) as "relative to maximally distinct standard pronunciations". In their study of the 500 most frequent words in Danish, 190 exhibited deviations from the one-sound-per-letter principle as opposed to Icelandic, a shallower orthography, which had only 34 deviations for the same number of words.

Already from the establishment of a national norm for Danish around the year 1200, Danish orthography included obsolete pronunciations. Elbro (2006) writes that this discrepancy between orthography and pronunciation may potentially be attributed to the fact that the scribes responsible for the first national Danish spelling norm wanted to avoid basing the orthography on one single variant of spoken Danish given the number of dialects and regional variants that existed at the time. As spoken Danish over time has moved further away from its East Nordic root than most other Germanic languages, the distance between writing and speech has only become more pronounced. Furthermore, orthographic complexities have been imported with loanwords of which Danish, according to Elbro (2006), has been more welcoming than other Scandinavian languages. The spelling of loanwords in Danish is regulated by *Bekendtgørelse om Retskrivning* 'regulation on spelling' from 1892 which focuses mainly on French and German loanwords and includes little about the spelling of English loanwords as they played no role at the time. However, only relatively few loanwords have been adapted to Danish spelling by means of the rules described in the regulation (Hansen & Lund, 1994). Few attempts have been made to reform the spelling of loanwords to comply with established spelling conventions of Danish. In 1986, during what is commonly referred to as *majonæsekrigen* 'the mayonnaise war', The Danish Language Council proposed to accept spelling variants especially for loanwords of French origin such as *mayonnaise/majonæse* and *ressource/resurse* 'resource' in *Retskrivningsordbogen* 'The Danish Spelling Dictionary'. The proposal was met with considerable opposition and heated debates in the media and among politicians. The main purpose was to provide writers of Danish with the choice between the original spelling and a simpler variant in compliance with Danish spelling conventions, and it was thus not a matter of removing original variants from the dictionary. Eventually, the debate ebbed away, and most variants are still found as entries in the dictionary, though corpus searches reveal that the simplified variants are rarely used (Dansk Sprognævn, 2010). As a result of changes to spoken Danish and the imported spelling peculiarities of loanwords, present day Danish orthography is characterized as "complicated" by Jørgensen (2019) who describes some elements of Danish orthography as a "complete mess". Jørgensen (2019) highlights four areas of Danish orthography that he refers to as "troublemakers". Unless otherwise indicated, the descriptions in the following are based on his observations.

2.6.1.1. Plosives

The syllable position of the graphemes <p>, <t> and <k> determines their pronunciation. Only when these graphemes occur at the onset of a syllable does the standard pronunciation correspond to the voiceless plosives /p/, /t/ and /k/. If the graphemes occur in a cluster of consonants, the pronunciation instead corresponds to the voiced plosives /b/, /d/ and /g/ respectively. One example illustrating both phenomena is *kasket* 'cap' pronounced [kaˈsgɛd].

2.6.1.2. Short vowels

All Danish vowel phonemes cannot possibly be represented by a separate letter each. There are simply too few letters in the Danish alphabet to achieve that, even after adding the special letters <æ>, <ø> and <å> to the Latin alphabet. According to Elbro (2006), a single vowel letter corresponds to at least two different short-vowel phonemes and at least one long one. Jørgensen

(2019) provides tabular overviews over grapheme-phoneme conversions for short vowels in Danish. Table 1 combines the overviews into a single table.

Table 1: Grapheme-sound correspondences for short vowels

Grapheme	Sound	Examples
I	/i/	*pisk* (whip), (mini-)*Risk* (name), *mild* (mild), *sild* (herring), *vild* (wild), *skidt* (dirt)
	/e/	*disk* (counter), *fisk* (fi sh), *pil* (arrow), *vil* (vb. will), *midt* (middle)
E	/ɛ/	*fest* (party), *hest* (horse), *bedst* (best)
Æ	/ɛ/	*læst* (shoe tree), *næst* (next to)
A	/a/	*and* (duck), *hat* (hat), *fald* (fall)
	/ɑ/	*Anders* (name), *kaffe* (coffee), *kam* (comb) and in connection with -r-: *kram* (hug), *skrald* (garbage)
Y	/y/	*bytte* (exchange), *dytte* (honk), *hytte* (hut), *lytte* (listen), *pyt* (puddle), *dysse* (soothen), *hysse* (hiss, silence), *Sysse* (name)
	/ø/	*nytte* (be of use), *spytte* (spit), *kysse* (kiss)
Ø	/ø/	*bøtte* (bucket)
	/œ/	*bønne* (bean), *stønne* (groan)
U	/u/	*bul* (treetrunk), *bulle* (official letter), *skulle* (inf. of ‘shall’), *tulle* (mess around), *kulle* (bald mountain)
	/ɔ/	*kul* (coal), *hul* (hole), *nul* (zero), (*for*-)*kulle* (turn into coal), (*gennem*-)*hulle* (to get filled with holes)
O	/o/	*mor* (mother), *foto* (photo)
	/ɔ/	*bombe* (bomb), *plombe* (dental filling)
	/ʌ/	*rhombe* (rhombe), *hekatombe* (hekatombe)
Å	/ɒ/	*tårn* (tower), *år* (year), *hår* (hair)
	/ʌ/	*bånd* (ribbon), *hånd* (hand)

2.6.1.3. Vowel length

Danish orthography provides some indications of when to pronounce short and long vowels. In general, vowels are long in syllables ending in a vowel and in syllables where the vowel is proceeded by only one consonant e.g. *kyse* ‘bonnet’ [ˈkyːsə] as opposed to syllables with two post-vocalic consonants e.g. *kysse* ‘to kiss’ [ˈkøsə]. However, a number of exceptions to this rule exists which means that the orthography, in many cases, does not guide the reader to the right pronunciation.

2.6.1.4. Glottal stop

The glottal stop is a prominent feature of Danish pronunciation. Nevertheless, nothing in the Danish orthography consistently indicates the glottal stop, and Jørgensen (2019) is of the opinion that it is so complex to correctly identify the position of the glottal stop orthographically that it would be worthless to attempt to teach these complexities to learners of Danish (including L1 speakers). The glottal stop requires certain conditions to be present but does not automatically occur when those conditions are in place. Readers can thus not base their assumptions about pronunciation solely on encountering a word in those conditions. The orthography does provide guidance in some cases e.g. when a word ends in *d* as in *mand* 'man' [ˈmanˀ] versus *man* 'one' (pronoun) [ˈman]. However, in a noun like *spil* 'game' [ˈsbel] compared to the verb with the same spelling *spil* 'play' (imperative) pronounced [ˈsbelˀ], the spelling provides no indication of when to apply a glottal stop.

2.6.2. Reading acquisition in Danish

Four principles underlie the teaching of reading acquisition in the Danish school system. They are described here (based on Elbro (2006) and Elbro (2014)) in the order in which they are acquired. First, the alphabetic (or phonematic) principle is applied which corresponds to the non-lexical route in the dual-route model. In this phase, the focus is on GPC i.e. the association of one grapheme with one sound and one sound with one grapheme. This principle is explicitly taught in the Danish school system. However, given the number of deviations from 1-1 mappings between graphemes and phonemes in Danish, this simple principle accounts only for a subset of conversions. For this reason, children must, secondly, learn the principle of grapheme to phoneme patterns with conditional pronunciations. Examples include the pronunciation related to vowel length described in section 2.6.1.2 and 2.6.1.3. Elbro (2014) argues that Danish orthography is indeed more predictable than expected as rules exist for many of these patterns. However, these rules are not taught explicitly but merely learned with reading practice and most Danish L1 speakers are thus not consciously aware that they exist. A fact that may contribute to the impression of the "complete mess" mentioned in 2.6.1. The third principle builds on morphemic orthographic knowledge that is needed in order to determine the spelling of homophones such as *køre* 'drive' (infinitive) and *kører* 'drive' (present tense). Only by performing a morphemic analysis does the reader know which ending corresponds to which verb form. Other examples include a word such as *sagde* 'say' (past tense) which is pronounced

[ˈsæː] but contains the grapheme <g> because it is derived from *sige* ‘say’ (infinitive). As mentioned in 2.1, this principle is also referred to as “the principle of meaning” because only by being aware of the root and its meaning is it possible to understand the orthography. Nevertheless, only the distinction between homophones of verbs in the infinitive (e.g. *lære* ‘learn’) and present tense (e.g. *lærer* ‘(he/she/it) learns’) by means of their endings is taught explicitly. The fourth and last principle is related to learning the orthographic patterns of words that cannot be explained by the previous three principles. These words can be learned only by means of the lexical route because of their unique pronunciation or inconsistent spelling patterns. Though some high-frequency words adhering to this last principle are most often learned early in the reading acquisition process e.g. *de* ‘they’ pronounced [ˈdi] and *af* ‘of’ pronounced [ˈæˀ], most words for which this principle is applied are learned late in the process and due to the sheer number of such words, it is an ongoing task for readers of Danish.

2.6.3. Reading difficulties in Danish

The depth and complexity of the Danish orthography taken into consideration, it is hardly surprising that dyslexia is an area that receives substantial attention in the Danish school system. In 2015, the Ministry of Education launched a national dyslexia test (*den Nationale Ordblindetest*) that aims to identify dyslexic readers of Danish. Participants are placed into three color-coded categories according to their results i.e. red meaning *ordblind* ‘dyslexic (litt. ‘wordblind’)’, yellow indicating *usikker fonologisk kodning* ‘uncertain phonological coding’ and green for *ikke ordblind* ‘not dyslexic (litt. ‘not wordblind’)’. The test may be used from the third grade of primary school (when children are approximately nine years old) and onwards and may thus also be applied for adolescents and adults. However, the language abilities of all children are systematically evaluated already in pre-school, and it is mandatory to screen all school children in the first grade for reading difficulties. Those showing difficulties must be offered a risk test for dyslexia (*risikotest for ordblindhed*) that same school year. Children of dyslexic parents must also be offered the same test unless the school and the parents decide that it is not needed (Børne- og Undervisningsministeriet, n.d.). According to numbers from the Ministry of Children and Education, approximately 20% of all school children had been tested by means of the national dyslexia test by the time that they reached the end of their mandatory schooling in 2025. Out of that group, approximately 13% tested positive (Børne- og Ungeministeriet, 2025). Even though the national dyslexia test is applicable to adults as well, only few are tested because the test is administered exclusively in the realms of the educational system. Consequently, less than 1% in the age group from 30 to 64 are tested. The estimates for dyslexia among adults are thus mainly based on self-reporting, which has been shown to correlate only weakly with actual reading abilities. Elbro et al. (1994) write that in 1994, approximately 7% of adults in Denmark considered themselves dyslexic. However, out of those, about half did not exhibit signs of difficulties when reading everyday texts. One plausible explanation for this discrepancy could be that these adults were diagnosed as children and still consider themselves dyslexic even though they, with time and training, have overcome their reading difficulties. The numbers for Denmark are thus in line with other European countries (section 2.3). The uncertainties may be reduced in the future as more data will automatically become available given the continued and increased focus on helping children overcome reading difficulties from the onset of their schooling.

3. Research questions

Reading comprehension is based on a combination of decoding skills and language knowledge. Speed of word activation is an important factor. While decoding skills and accuracy are commonly linked to phonological awareness, reading speed and thus implicitly word activation speed are related to VAS. In the literature consulted for this thesis describing research in reading abilities and difficulties in Danish, phonological awareness is mentioned exclusively as the cause of reading difficulties and dyslexia. However, research in VAS in other languages has shown that limited VAS skills may also be an independent underlying cause. The aim of this thesis is to test the two subskills in relation to reading comprehension. The research questions to answer in this thesis are as follows:

RQ1: Do the two reading subskills of phonological awareness and VAS influence reading comprehension? And if so, do they equally contribute to reading comprehension?

RQ2: Are there any detectable patterns regarding phonological awareness and VAS that distinguish different levels of reading comprehension regardless of dyslexia?

RQ3: Is there a difference between dyslexic and non-dyslexic readers in terms of the two subskills and their influence on reading comprehension?

Concerning RQ1, the expected finding is that a deficiency in one of the reading subskills may lead to poor reading comprehension even though the other subskill is strong. Studies described in (Valdois, 2022) found that a majority of dyslexics exhibit a deficit in only one of the subskills, i.e. phonological awareness or VAS, which then uniquely contributes to deficiencies in reading performance. However, one of the tasks of the experiment of this thesis consists of the identification of pseudo-words. Bosse et al. (2007) state that a VAS deficit may negatively affect pseudo-word reading. It would thus not be unexpected to observe a correlation between the results of the pseudo-word task (traditionally used for testing phonological awareness as stated in 2.4) and the results of the VAS task.

With regards to RQ2, the expectation is that poor phonological awareness may be found in the participants who exhibit poor reading comprehension skills regardless of dyslexia. As reading comprehension relies on a combination of word decoding and language skills (Oakhill et al., 2019), a phonological awareness deficit may be associated with low reading comprehension. However, a wider VAS could be expected to contribute positively to reading comprehension because increased VAS is associated with increased reading speed (Bosse et al., 2007; Bosse & Valdois, 2009; Lallier et al., 2014), and it would thus not be unexpected to find higher VAS accuracy rates in the group of participants with the best reading comprehension scores.

As for the difference between dyslexics and non-dyslexics (RQ3), the expectation is that dyslexics score lower than non-dyslexics on the phonological awareness task (Center for Læseforskning, n.d.b). Studies such as those of Bosse et al. (2007) and Venagli et al. (2025) have also found that some dyslexics exhibit a VAS deficit, and dyslexics are expected to score lower on the VAS task of this study.

A general expectation of the experiment is to find participants identifying targets in all five positions in a VAS task. The expectation is based on the nature of the Danish orthography which forces readers to distribute their attention wider to find clues to pronunciation. This is as opposed to shallower orthographies where readers can rely on GPC and smaller window sizes and thus typically are more biased towards the left-most characters in VAS tasks because they do not need to consider graphemes in context. As mentioned in 2.6.2 based on Elbro (2006) and Elbro (2014), in the Danish reading acquisition process, readers relatively soon learn about conditional pronunciation based on patterns of graphemes, not one-to-one GPC, and thus they learn to focus on clusters of graphemes. Despite the expected distributed VAS of Danish readers, there is still an expectation that the accuracy score for the first position will be the highest due to the "first-letter advantage" and that the accuracy graph will reflect the typical W-shape described in 2.5 based on Grainger et al. (2016).

4. Method

The following sections detail how the experiment was designed and implemented.

4.1. Tool

For the sake of flexibility and to allow as many participants as possible to take part in the experiment, it was important to find a method that did not require participants to perform the tests in a laboratory setting. It was thus decided to create the experiment using the online platform Gorilla Experiment Builder (Cauldron Science, 2026). As described in Anwyl-Irvine et al. (2020), Gorilla is a tool which removes the obstacles often faced by researchers who would like to construct easily accessible experiments but lack the complex programming skills that may otherwise be required for setting up browser-based experiments. Gorilla offers an experiment design tool in which it is possible to design the entire flow from finish to end and combine questionnaires and tasks without the need for coding. In this experiment, the Gorilla components Task Builder 2 and Questionnaire Builder 2 were used.

4.2. General design and layout decisions

To ensure a consistent layout across the experiment, some general decisions regarding design and layout were made for the tasks and questionnaires created in Gorilla. First, instructions were kept in relatively simple terms to ensure that they were understood by all participants, including those less proficient in reading. Second, feedback in the practice rounds was also kept simple and included emoticons depicting a happy or a sad face to indicate a correct or incorrect response. Third, no audio instructions or feedback were incorporated in the elements created in Gorilla. Fourth, the experiment was designed to be executed on a screen larger than a standard mobile phone. Gorilla does offer the possibility to preview the layout of different elements on large and small monitors, laptop, tablet and phone, and it is thus possible to anticipate the user experience on different devices. It was, nonetheless, clearly stated in the instructions for the experiments and when recruiting participants that it was best performed on a computer. Finally, with regards to the format of the responses given by the participants, none of the tasks contained elements of pronunciation. Some dyslexics suffer from speech motor control problems (Elbro et al., 1994), and an oral component might have been considered an obstacle to those.

4.3. Experiment flow

The experiment consisted of the following components which are all described in detail in the sections below:

- Questionnaires:
    - Consent form
    - Did not consent
    - Participant questionnaire
- Tasks:
    - Find the Word
    - VAS
    - Self-test

The flow of the experiment can be seen in Appendix A. The participant's decision to consent or not to the conditions presented in the consent form determines the flow. If participants do not consent, the experiment branches out into a page ("Did not consent") which simply contains a short message explaining to the participant that it is not possible to proceed with the experiment without the required consent.

If participants consent, they proceed to the participant questionnaire and then further on to the three tasks. The order of the tasks was established so that participants first test their phonological awareness in Find the Word, then their VAS and then lastly obtain a score for their reading comprehension in a reading test at an external website (selvtest.nu) – a score that they must input in the Selvtest task in Gorilla.

4.3.1. Consent form

As the consent form questionnaire is the entry point of the experiment, the first screen contains a short introduction of the experiment as well as instructions regarding the recommended device type and the approximate duration of the experiment. Secondly, participants are presented with a page containing a short description of the purpose of the experiment, their right to withdraw at any time and the e-mail address of the author in case of questions regarding the use and storage of data (see Appendix 0). Four questions are then asked which participants must answer to proceed with the experiment. The instructions clearly state that only by selecting the Yes option for the first three questions is it possible to continue. The questions are as follows:

- Is Danish your mother tongue?
- Are you willing to perform the experiment online?
- Do you consent to having your data stored in a database?
- Do you consent to your data being used anonymously in future research?

4.3.2. Did not consent

This page does not allow for any responses but simply states that the participant cannot participate in the experiment due to the lack of consent (Appendix C). By pressing a button, the participant terminates the experiment. In the branching set-up in the experiment flow in Gorilla, it is not possible to return to the consent form if participants change their minds about the consent given. However, they are free to use the hyperlink to the experiment again and start anew.

4.3.3. Participant questionnaire

The questionnaire (see Appendix D) first surveys the age, gender and highest completed level of education of the participants and their parents. Gorilla allows age to be input as date of birth using day, month and year dropdowns or as month and year and includes an option for automatically calculating age based on that data. Arguably, obtaining such precise data about the birthday of the participants may be crucial in studies of infants and toddlers but less so in experiments involving adults and, in this experiment, it would have sufficed to include a year dropdown only. That is, however, not possible in Gorilla. The gender dropdown contains the options “Female”, ”Male”, ”Other” and “Do not want to answer” to limit the number of possible choices while at the same time allowing for more than the gender binary. Educational levels range from “No formal education”, “Primary school” and “Secondary school” to “(Professional) bachelor’s degree” and “Master’s degree or above”. Two questions relate to the educational level of the participant’s parents. The selectable levels are the same as for the participant, however, the options of “Don’t know” and “Do not want to answer” allow for more flexibility in answering.

In the section that follows, participants indicate in which languages they can read from a pre-defined list of languages and their self-evaluated proficiency level for each language. The list contains the languages that are either mandatory at public primary school level in Denmark, i.e. English and French or German, or generally offered at secondary school level according to Børne- og Undervisningsministeriet (2021). Swedish and Norwegian are also included. They are not taught as separate courses, but both languages are included in the syllabus for Danish at the primary school (Børne- og Undervisningsministeriet, 2019). A comment field allows participants to enter additional languages and their levels. Participants are asked specifically about their perceived reading level and not about their general competences in a specific language.

The final section of the questionnaire concerns dyslexia. Participants are asked to indicate if they are dyslexic or not and whether their dyslexia has been confirmed by a formal test. If the answer is yes, an additional field is displayed asking them to indicate if they have received remedial instruction or not. If that is the case, a comment field is displayed in which participants are encouraged to elaborate on the kind of remedial instruction.

4.3.4. Find the Word

This task tests phonological awareness by asking participants to identify pseudo-homophones. Participants are presented with four pseudo-words and must select the word that phonologically resembles a real Danish word the most. The design of the task is based on the description given by Center for Læseforskning (n.d.a). For this thesis, 40 new stimuli consisting of four pseudo-words each (Appendix 0) were created based on the GPC in Danish described in 2.6 and comparable to those of the formal test. The task does not involve audio, nor does it involve reading production.

After an example explaining the principle of the task where four pseudo-words are shown and the one that sounds like a real word is highlighted, participants proceed to a practice round with three stimuli. Feedback is received after each try and is presented in the shape of an emoticon and a text (Figure 2).

Figure 2: Feedback for correct and incorrect response

The stimuli are presented one at a time, as shown in Figure 3, with each individual pseudo-word presented in a clickable box. No time limit is set per screen, and participants can thus choose to advance at their own pace. However, there is a time limit of five minutes for the entire task to ensure a steady pace and to enable comparison with the results previously obtained by Center for Læseforskning (n.d.b). A progress bar and a timer are displayed on the screen. Participants are not informed about the total number of stimuli.

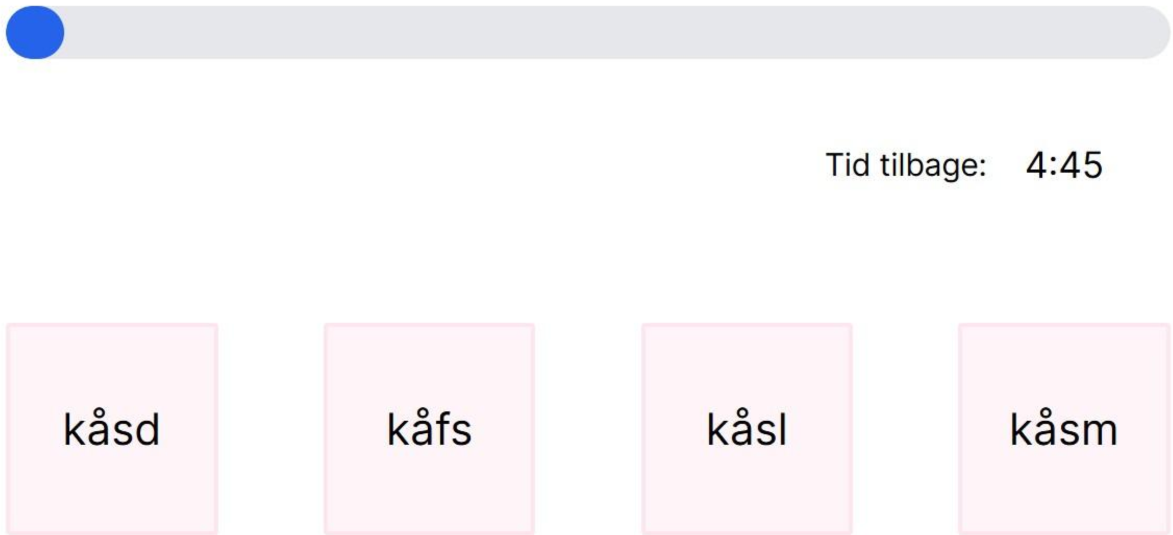

Figure 3: Find the Word stimulus example

Upon completion of this task, participants are encouraged to take a short break and look away from the screen before continuing the experiment.

4.3.5. VAS (Visual Attention Span)

The second task tests the visual attention span of participants. It is a partial report task (see section 2.5) in which five consonants are presented on the screen for 200 ms. Subsequently, one consonant is shown, and the task for the participant is to evaluate if that single consonant was part of the five-consonant string. Venagli et al. (2025) kindly allowed the reuse of the stimuli developed for the experiment described in their article. The considerations listed here with regards to the stimuli were thus all done in the design of the VAS task described in Venagli et al. (2025) and do not originate from the author of this thesis. The task contains 80 strings of five consonants and one target consonant. The strings are combinations of the ten upper-cased consonants B, C, F, H, N, Q, S, T, V and Z thus avoiding orthographically similar consonants such as M and N to allow for easier recognition of the individual letters. Out of the 80 strings, 30 are fillers in which the target consonant is not part of the consonant string. The stimuli can be found in Appendix 0.

Initially, participants are presented with a short introduction to the task. An example string is shown followed by a screen showing a target consonant and Yes and No buttons for responding. The introduction is followed by a practice round of four strings. Each string is presented for 2000 ms., which is ten times longer than during the real trial to allow participants to get accustomed to the task without the stress of the shorter time limit. The instructions highlight that the practice round takes place at a slower pace than the real experiment. Apart from the difference in time limit, the layout of the practice round is identical to the trial. A fixation cross is presented for 500 ms. followed by a blank screen of 100 ms. After the display of the consonant string for 200 ms., another blank screen follows for 100 ms. after which the target consonant is shown without a time limit. Feedback is provided for each string in the practice round in a format identical to that shown in Figure 2.

Before initiating the trial, participants are reminded that the pace will be significantly faster than during the practice round. There is no time limit to the task, and its duration depends on the speed at which participants click Yes or No to evaluate the target consonant. Information is not given about the number of stimuli. However, a progress bar at the top of the screen indicates to participants how far they have progressed in the trial. Please refer to the illustration in Figure 4.

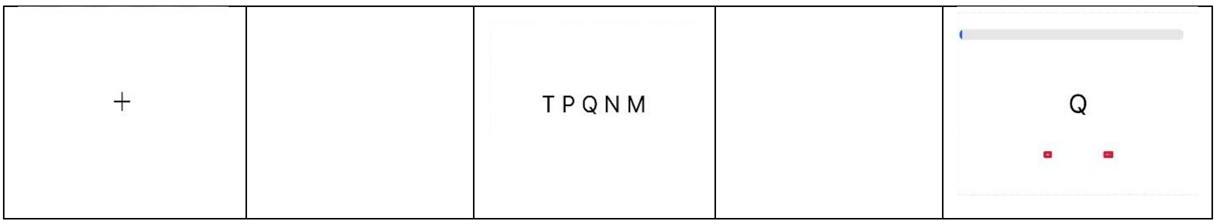

Figure 4: VAS task set-up

Upon completion of this task, participants are once again encouraged to take a short break and look away from the screen before continuing the experiment.

4.3.6. Self-test

The third part of the experiment directs participants to the external website selvtest.nu with the purpose of completing a reading comprehension test. The score from this test is to be entered in the Gorilla web interface subsequently. The sections below describe selvtest.nu and the Gorilla set-up respectively.

4.3.6.1. Selvtest.nu

The self-test at selvtest.nu is a publicly available test of reading comprehension in Danish. In 2012, the Danish government approved a budget of DKK 16.5 million to provide enhanced support for unemployed individuals with dyslexia and others with reading and writing difficulties. Research had shown that this target group was underrepresented at courses for adult learners because its members tend to overestimate their reading abilities. The purpose of developing a publicly available self-test was to allow for an easily accessible informal evaluation of actual reading abilities and to encourage more adults to take the appropriate measures to improve reading and writing deficiencies (Mploy, 2016).

The development was done by researchers from Center for Læseforskning at the University of Copenhagen and is described in detail in Jensen et al. (2015). To keep the self-test short enough to realistically attract target group participants, the test focuses exclusively on reading comprehension. The design of the test builds on the cloze format described in 2.2. Three different variants of cloze tests are used in combination. The standard variant leaves out every fifth word of a sentence and presents the participant with four options to choose from to fill the gap (Figure 5).

Figure 5: Cloze test – standard

A second variant makes use of local inferences where the user must infer which word is the correct one out of the four options, based on the local context (Figure 6).

Figure 6: Cloze test - local inference

The third variant requires the use of global inferences. To select the correct word, the participant must make inferences based on background knowledge having a broader scope than the sentence itself (Figure 7).

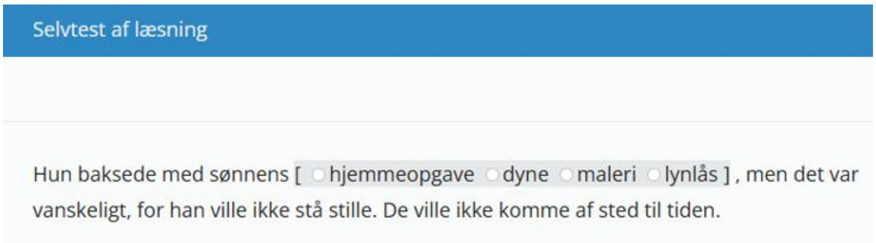

Figure 7: Cloze test – global inference

The target group of selvtest.nu is adults. The test takes ten minutes to complete and is accessible by means of a web browser. The instructions state that the test should be taken on a computer or a tablet. Taking the test on a mobile phone may impact the validity of the result according to Institut for Nordiske Studier og Sprogvidenskab (n.d.). All instructions regarding the task itself are provided by means of audio and are not accompanied by instructions in writing. It is, however, possible to repeat the oral instructions as many times as possible. In addition to taking the test, participants are also asked to answer two questions for which a positive answer indicates potential reading difficulties. In the first question, participants are asked if they have previously been enrolled in special education due to reading or writing difficulties. In question number two, participants are asked if they themselves experience spelling difficulties in their everyday lives.

The self-test stops automatically after ten minutes or earlier if the participant has exhausted the stimuli. The result is presented as a floating number. A bar below the number serves as a legend for interpreting the result along with a text explanation. Please refer to the illustration below in Figure 8. A result in the red interval is presented with the heading *Mange tekster kan være svære og tage tid* ‘Many texts may be difficult and take time’. A result in the yellow zone has the heading *Nogle tekster kan være svære og tage tid* ‘Some texts may be difficult and take time’, and in the green zone participants see the heading *Du har gode* *læsefærdigheder* 'You have good reading skills'. The results are presented with caution regardless of the score to emphasize that while the test gives an indication of reading comprehension, it does not reflect possible spelling difficulties. The answers to the two questions mentioned above also impact the feedback text. If participants answer positively to at least one of them, the feedback text includes a paragraph saying that their answer(s) indicate(s) possible spelling difficulties. The wording of the feedback is kept deliberately simple and does not provide any rigid conclusions about the participants' reading abilities but rather indicate tendencies based on the score and the questions. All feedback texts, regardless of the result, contain a paragraph emphasizing that anyone has the right to further testing. For convenience, hyperlinks are provided to relevant websites.

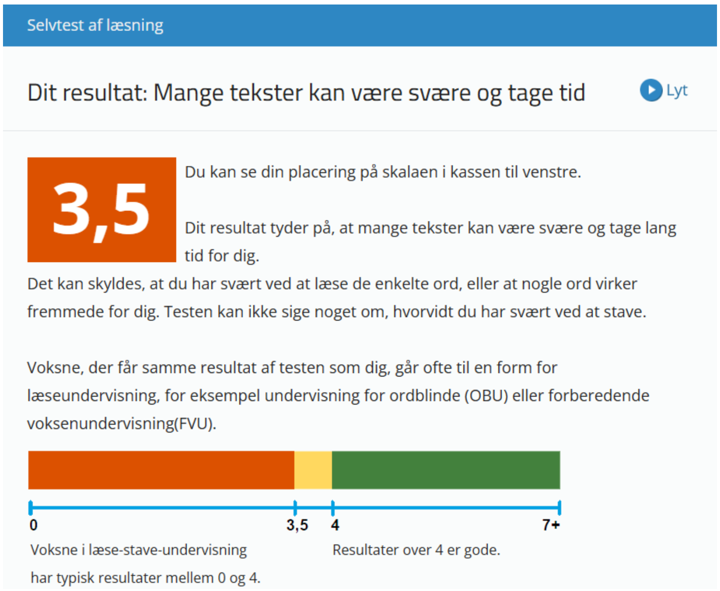

Figure 8: Illustration of test score at selvtest.nu

The self-test is not intended as a tool to diagnose dyslexia because it tests for reading comprehension only, and some dyslexics have received enough reading training and practice to compensate for their reading deficiencies as mentioned in section 2.6.3. They may thus score relatively high on the self-test even if they still exhibit difficulties when reading new words or spelling. The use of the self-test in this experiment is thus not a means to draw conclusions about dyslexia but rather an investigation of reading comprehension and potential correlations with phonological awareness and VAS.

Jensen et al. (2015) describe how the results from the self-test matched with those of more established reading comprehension tests during the development phase. It was a requirement for the developed test to be considerably more time-efficient than traditional reading comprehension tests to realistically expect adults to complete the test. The comparable results of the cloze test format with the traditional test format justified the use of the former in the setting of an online test. While the authors in Jensen et al. (2015) present their arguments for where to place the thresholds of the different categories (red, yellow and green) based on empirical studies, they emphasize that the thresholds were in the end not purely objectively decided. It was a political decision how many and which readers should statistically be encouraged to seek further professional assessment of their reading abilities based on their test results. The aim was to avoid too many false positives, i.e. overwhelming the educational system with proficient readers thinking that they needed help based on the result of the test. At the same time, it was equally important to ensure that the appropriate message was conveyed to those who would indeed benefit from an additional assessment.

The choice of using selvtest.nu to test for reading comprehension in this experiment was made for the two reasons. First, a publicly available test, based on academic principles and empirically tested, enabled easy access for all participants and second, time efficiency was of the essence to prevent the experiment in its entirety from becoming too time-consuming.

4.3.6.2. Gorilla set-up

In Gorilla, the result obtained at selvtest.nu is entered in a task which initially shows several screens containing instructions about how to proceed. Most importantly, participants are told to keep the browser tab containing the Gorilla experiment open and to return to that tab to report the score obtained at selvtest.nu. The link to selvtest.nu provided in the instructions opens in a new browser tab, and a screenshot in the task highlights exactly this to underline the importance of keeping both tabs open (Figure 9).

Figure 9: Screen with instructions about how to keep two tabs open

Upon completion of the test at selvtest.nu, participants enter their score in the Gorilla task. They also indicate if they were already familiar with selvtest.nu or not (Figure 10).

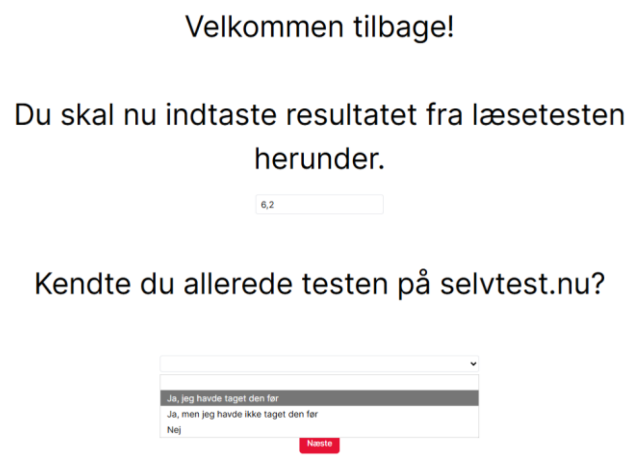

Figure 10: Screen for entry of score from selvtest.nu

This part of the experiment is deliberately placed last. Obtaining a low score at selvtest.nu might discourage participants from proceeding with the experiment or affect their performance on the other tasks if selvtest.nu was placed first. The last screen, which concludes the entire experiment, provides a brief description of the purpose of the experiment. It also gives participants the option to enter comments about the experiment or anything else that they would like to communicate to the author.

4.4. Test procedure

The experiment was accessible by means of a hyperlink to the Gorilla platform. The recruitment policy chosen in Gorilla was of the type "simple link" that logs in participants automatically. Consequently, participants are not asked to log in using their personal credentials. The advantage is anonymity, the disadvantage is that the same person may log in an unlimited number of times. For ethical reasons, anonymity was rated higher than the certainty of having only unique participants. Given the estimated duration of the experiment (30 minutes), the assumption was made that the risk of the same person wanting to complete the experiment several times was low. A pilot study was conducted with one participant, a fellow linguistics student. Based on the feedback from the pilot study, tasks and instructions were revised to ensure as smooth an experience as possible for the real participants.

4.5. Recruitment of participants

The target group of the experiment was adults with an L1 of Danish. The initial idea was to target only dyslexics. However, it was deemed unrealistic to obtain a sufficient number of participants for two reasons. First, most adults in Denmark were never formally tested for dyslexia during their years of schooling. As mentioned in section 2.6.3, less than 1% of adults between 30 and 64 have been tested. Therefore, demanding a formal proof of dyslexia as an entry criterion for participation would drastically reduce the number of potential participants. Second, the assumption was made that people with reading difficulties or dyslexia may be less willing to participate in a linguistic experiment because they would expect themselves to perform poorly and thus be discouraged from the onset. Participants were recruited through the author's network on Facebook and LinkedIn as well as through personal communication. In the recruitment process, the duration of the experiment was emphasized (30 minutes) as well as the requirement of completing the experiment on an audio-enabled computer (for the task at selvtest.nu) to manage participants' expectations. No compensation was offered. The experiment was launched on March 23 and ended May 3, 2026.

4.6. Ethical considerations

Personal data was collected and managed in accordance with the guidelines of the Joint Faculties of Humanities and Theology at Lund University (Humanistiska och teologiska fakulteterna, 2025). All participants provided written informed consent prior to participating in the experiment (Appendix 0). Participants were informed of the purpose of data collection and that they were allowed to leave the experiment at any point. It was also explained that they had the option of not allowing the storage of their data for future use. In addition, participants were clearly informed about the contact person for the experiment. Categories of personal data that required particular consideration in the process of data collection by means of the questionnaire (Appendix D) included age, first language and health information in the form of questions regarding dyslexia. Collecting data such as e-mail addresses that could directly or indirectly be used to uniquely identify a physical person was avoided even though not collecting this type of information enabled participants to participate more than once because of the lack of a system-external unique identifier as explained in 4.4.

5. Results and analyses

5.1. Participants

In total, the experiment was accessed 53 times via the shared link. Gorilla provides dashboards showing the recruitment progress, making it possible to follow the flow of each anonymized participant as they are assigned an ID which links data from questionnaires and tasks in the resulting data sets. For those that do not reach the status of completion, Gorilla shows the exact point at which the participant stopped. 21 participants did not proceed beyond the consent form. Initially, participants were required to provide a confirmative answer to all the four questions shown in 4.3.1 to proceed. Speculations can only be made as to whether the fourth question of allowing the use of data for future research was the cause of participants leaving the experiment at that point. Considering that they, at that point of the experiment, had no knowledge about the type of data that would be collected, it is possible that some were reluctant to continue because of this requirement. It was thus decided to add more details to the consent form, explaining the type of data to be collected and when the collected data would be deleted if it could not be used for future research. Furthermore, the consent to the fourth question was made optional. Six participants abandoned the experiment during the Find the Word task, while one stopped at the participant questionnaire, another at the VAS task and two arrived at the self-test task without completing the required data entry and thus not properly finishing the entire experiment. Due to the anonymity of the participants, it was not possible to proactively investigate the reasons for the early exits, but a few did communicate having technical issues in general or more specifically at selvtest.nu. The 53 log-in attempts resulted in 22 completed experiments in total on which the data analyses described in the following sections were based.

5.2. Data and data analysis tool

Data was exported from Gorilla in the format of two semicolon-separated files for questionnaire and task data respectively. It was imported, combined, analyzed and visualized in the web-based interactive computing platform Jupyter Notebook using Python version 3.14.0 and the libraries Polars, Plotnine and Great Tables. Summary statistics were calculated using the describe() method or the std() and mean() functions. The standard deviation used was the sample standard deviation. Summarized data as well as a visualization of the results per participant can be found in Appendix G.

5.3. Data quality

The quality of the data was verified before the analyses were initiated. The verification was performed by means of summary statistics as well as visualizations. One issue was detected in the process where one participant was found to be registered with 43 responses in the Find a Word task though there were only 40 stimuli. Out of the three extra responses, two were duplicates of other responses and one contained the value “End”. The “End” value was also present in the data for the 14 participants who did not complete the entire task and indicated the point at which the five-minute time limit was reached. However, it cannot be the case that the participant registered with 43 responses reached the time limit because the task should automatically have terminated after the presentation of the 40 stimuli. After careful investigation of the data to ensure that the remaining responses were valid and unique, the

"End" responses as well as the duplicates were removed from the dataset before the data analysis.

5.4. Participant questionnaire

All 22 participants were adult Danish L1 speakers aged 19-75 years with an average age of 47.6, mostly female (59%) and 50% with a Bachelor's degree. There were no participants in the age group 30-39. Figures 11-13 below show the distribution of participants.

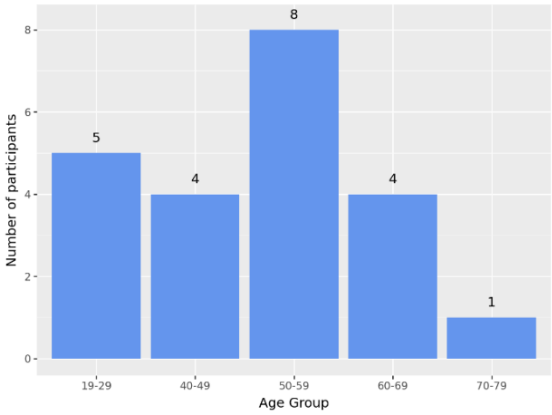

Figure 11: Age group distribution

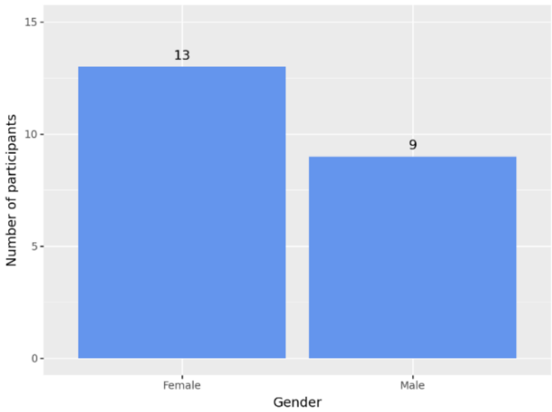

Figure 12: Gender distribution

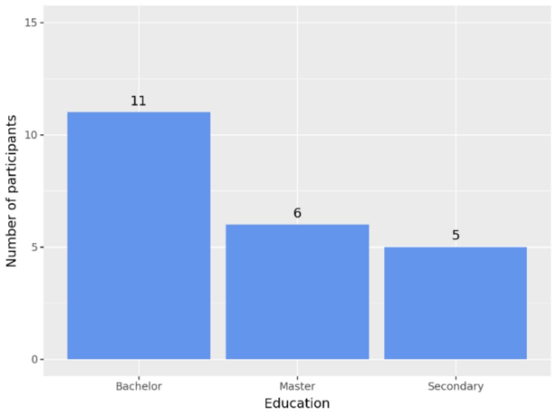

Figure 13: Educational levels

Out of the 22 participants, four indicated that they were dyslexic. Two of them answered that they were dyslexic though not based on a formal test, while the other two had been formally tested. Dyslexic participants thus made up 18% of the participants, which is a higher proportion than in the Danish population in general. Phakiti (2015) writes that the suggested minimum of participants for quantitative data analysis is 30. Given the limited total number of participants, the results from this experiment cannot be converted into conclusions in general about reading abilities and difficulties in Danish L1 speakers. Nonetheless, tendencies in the data will be described and comparisons between dyslexic and non-dyslexic results will be made to illustrate the findings.

5.5. Phonological awareness

For the Find the Word task, only eight managed to complete all 40 stimuli within the timeframe of five minutes. The results of the task were analyzed in terms of number of correct responses regardless of the number of completed stimuli to allow for immediate comparison with the standards published by Center for Læseforskning (n.d.b). Summary statistics of correct responses are shown in Table 2.

Table 2: Find the Word: Summary statistics of correct responses

Dyslexia	Count	Mean	Std. Dev.	Min	25%	50%	75%	Max
Yes	4	0.29	0.06	0.20	0.30	0.30	0.30	0.35
No	18	0.57	0.17	0.15	0.48	0.60	0.70	0.80

In the standard test described at Center for Læseforskning (n.d.a), which has 38 stimuli, a result below 15 correct words (39%) in five minutes is remarkably low. Adults in dyslexia training get approximately nine words (24%) correct in five minutes whereas adults with no reading difficulties obtain more than 20 correct words (53%) according to Elbro (2014). In this experiment, as shown in Table 2, non-dyslexics managed an average of 57% correct words while the dyslexic participants found only 29% correct words on average – results which, though slightly higher, are in line with standard results. Some of the dyslexic participants reported that they found this task extremely frustrating and merely selected words randomly because they could not make any sense of the pseudo-words. However, the minimum score of 15% correct words for non-dyslexics was below the minimum score of the dyslexic group (20% correct words), which shows that not only declared dyslexics struggled in this part of the experiment.

5.6. VAS (Visual Attention Span)

The results of the VAS task were analyzed in terms of number of correct responses and location of the target consonant in the consonant string. The 30 filler stimuli were ignored in the analysis. For the 50 stimuli, the overall mean accuracy rate was 69% while rates for all participants ranged from 24% to 90%. Table 3 shows the results for dyslexics and non-dyslexics.

Table 3: VAS: Summary statistics of accuracy rates

Dyslexia	Count	Mean	Std. Dev.	Min	25%	50%	75%	Max
Yes	4	0.70	0.10	0.60	0.64	0.72	0.72	0.82
No	18	0.69	0.15	0.24	0.66	0.72	0.76	0.90

As mentioned in 2.5, age has been shown to correlate with VAS. Figure 14 shows the mean accuracy score on the VAS task per age group. The data based on the limited number of participants in this experiment do not indicate a linear increase in VAS accuracy with age.

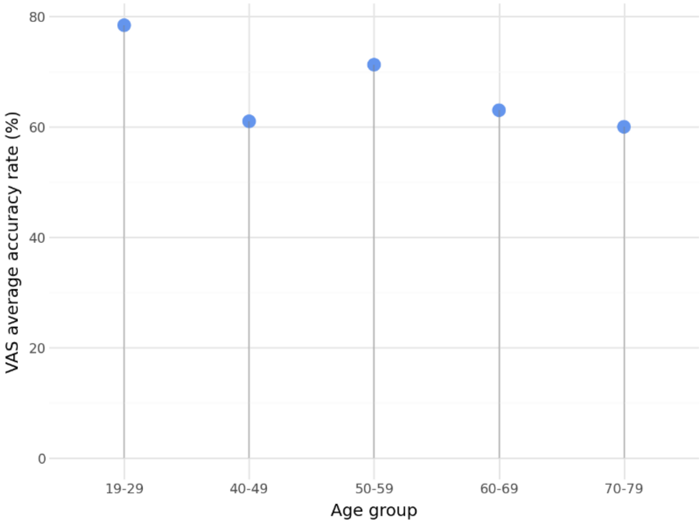

Figure 14: VAS: Mean accuracy per age group

The mean accuracy per consonant position is displayed in Figure 15 showing a large decrease in the accuracy rate between the third and fourth positions for both groups. As expected, the accuracy rate is highest for the first consonant position for both groups. The higher average score on the third position for the dyslexic participants is aligned with the expectation of higher accuracy on the central position (see 2.5). The results for the non-dyslexic participants, nonetheless, do not exhibit a similar peak at the third position, and the effect of fixation point proximity is thus not observed in this group. The graphs for both groups deviate slightly from the expected W-shape. The dyslexic group scores lowest of all on the fifth position, and the non-dyslexics have a higher accuracy on the second compared to the third position.

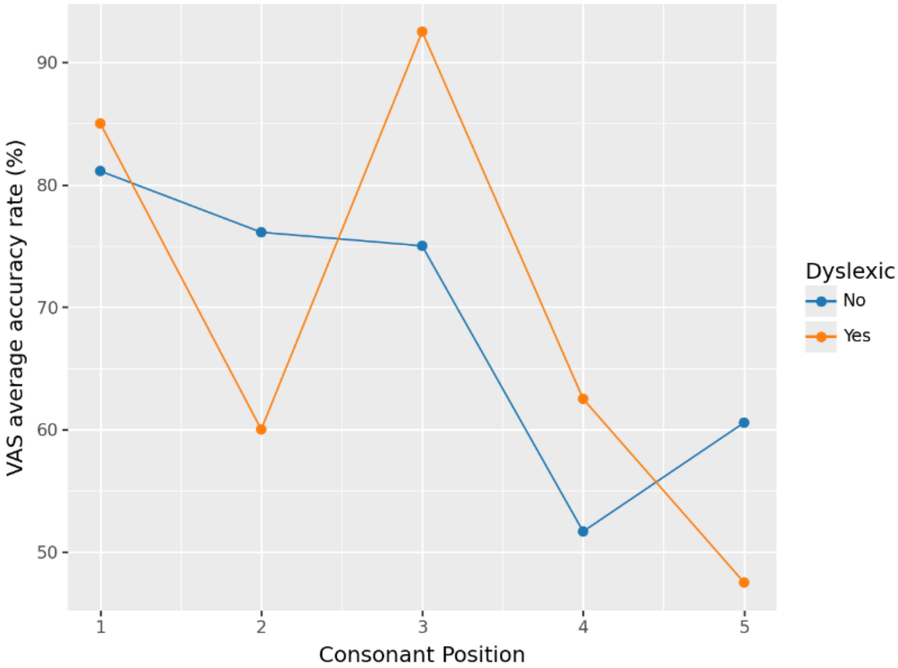

Figure 15: VAS: Accuracy per position for dyslexics and non-dyslexics

5.7. Reading comprehension

On the self-test, the reported scores ranged from 3.4 to 7.5 with a mean score of 5.12. A comparison of the scores of dyslexics versus non-dyslexics does not reveal a clear trend distinguishing one group from the other. While the scores of the dyslexic group were lower on average, they ranged from 3.4 to 6.6. As shown in the summary statistics in Table 4, at least 75% of the non-dyslexics thus scored lower than the dyslexic participant who scored the highest.

Table 4: Self-test: Summary statistics of scores in absolute numbers

Dyslexia	**Count**	**Mean**	**Std. Dev.**	**Min**	**25%**	**50%**	**75%**	**Max**
Yes	4	4.45	1.49	3.40	3.50	4.30	4.30	6.60
No	18	5.27	1.05	3.90	4.30	5.20	5.80	7.50

One participant scored below 3.5, which constitutes the limit of the red zone as shown in Figure 8 in section 4.3.6.1 for which the translated message is that "Many texts may be difficult and take time". Two scored between 3.5 and 3.9 equaling a result in the yellow zone where the message is "Some texts may be difficult and take time". The remaining participants were all in the green zone and thus saw the message "You have good reading skills". Jensen et al. (2015)

do not specify what the maximum score is on the self-test. As shown in Figure 8, the upper limit is simply indicated by "7+" (in one trial to assess the suitability of the test for this thesis, a score of 11 was obtained). Jensen et al. (2015) also specifically state that it was an active design decision to give feedback to participants by means of a score in a colored category with examples instead of a standard score or percentile. Due to the lack of specific information regarding the upper limit of the scale or the standard distribution of scores, it is not possible to relate the results achieved by the participants in this experiment to those of other users of the self-test.

5.8. Correlations

The scatter plot in Figure 16 shows the self-test score on the X-axis and the correct response rate in the Find the Word task on the Y-axis. The correlation calculated using the Pearson Product Moment test in Python is at 0.30, which suggests a positive though rather weak correlation between phonological awareness and reading comprehension. A positive correlation means that if the value of one of the variables increases, an increase is also expected in the other variable. Correlation is expressed on a scale from 0 to 1 where 0 indicates no systematic relationship between the two variables (Phakiti, 2015). There is thus a slight tendency in the data for an increase in phonological awareness to be associated with an increased reading comprehension score.

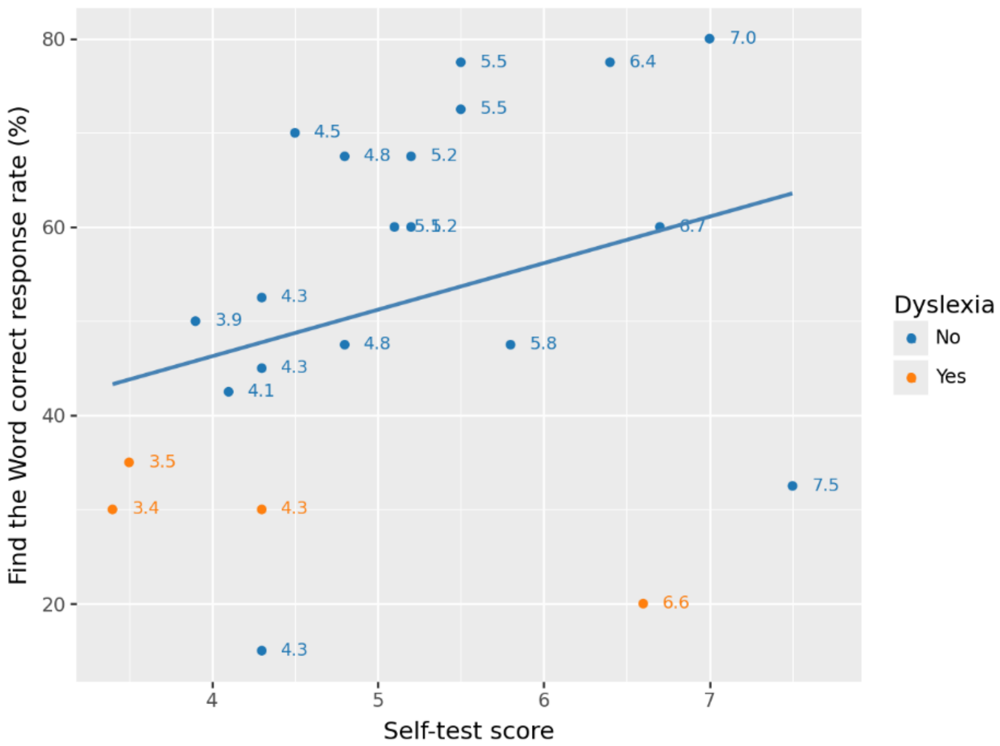

Figure 16: Scatter plot of self-test scores and Find the Word correct responses

Figure 17 displays the relation between self-test scores and VAS accuracy rates. The correlation is calculated at 0.17 showing a weaker positive correlation between VAS skills and reading comprehension than the correlation in Figure 16 for Find the Word and reading comprehension.

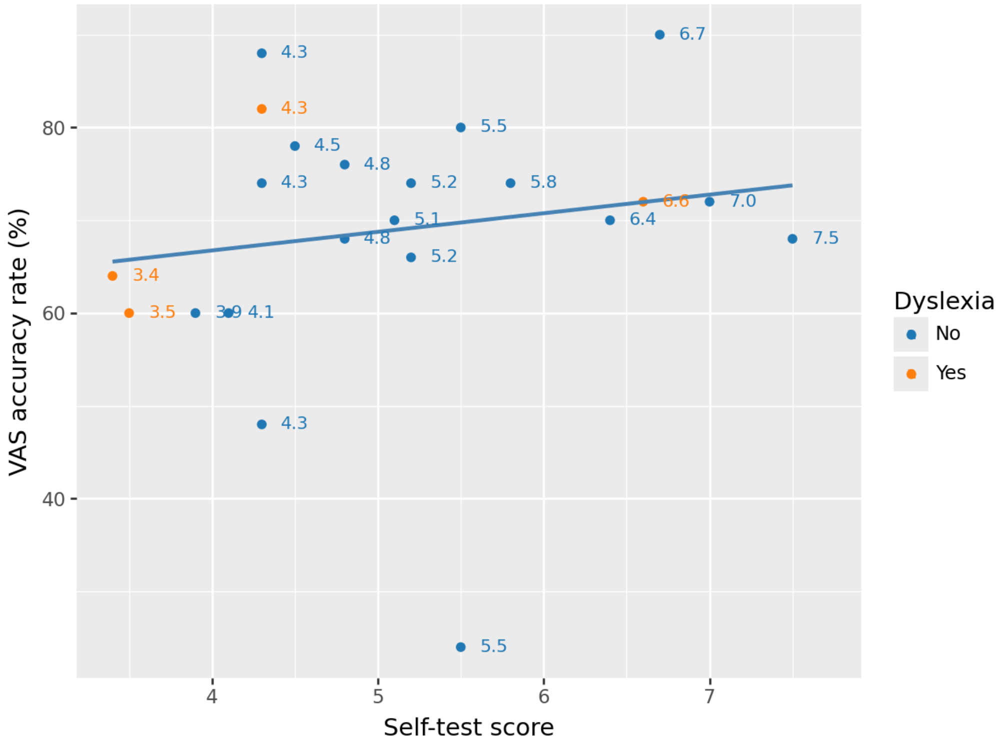

Figure 17: Scatter plot of self-test scores and VAS correct responses

To test the findings from studies that have shown that a deficiency in one reading subskill may exist independently of the other subskill, the correlation between phonological awareness and VAS was also calculated. The result was a correlation of 0.06, which for the participants of this experiment shows that a VAS deficit has very little association with a phonological awareness deficit and vice versa.

5.9. Grouping and ranking results of reading comprehension

As mentioned in 2.6.3, only few adult Danes have been formally tested for dyslexia. It is thus possible that some participants who did not indicate in the questionnaire that they have dyslexia would in fact receive the diagnosis if they sat the formal test. To compare all participants solely on their results in this experiment, participant results were divided into three groups of those scoring low, medium and high on the self-test regardless of participants' dyslexia status. Note that the ranking of low, medium and high relates to the relative score within the participant group, not to the levels of red, yellow and green displayed in Figure 8. Groups 1 and 2 each contain eight participants as more participants had the same score and are thus included in the same group. The number of participants per group, the minimum and maximum self-test scores as well as mean and standard deviations for all three groups are displayed in Table 5.

Table 5: Mean and standard deviations per group

		Find the Word		VAS		Self-test		
Group	**N**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Range**
1. Low	8	0.38	0.12	0.67	0.13	4.01	0.38	3.5-4.4
2. Medium	8	0.65	0.09	0.67	0.18	5.08	0.35	4.5-5.5
3. High	6	0.53	0.24	0.74	0.08	6.67	0.57	5.6-7.5

Group 1, the lowest scoring group on the reading comprehension task, scored the lowest on average on the phonological awareness task. On the VAS task, however, this group's average score was identical to that of the medium-scoring group, group 2. On the other hand, group 2 obtained on average the highest correctness rate on the phonological awareness task. The numbers also show that participants in group 3 on average obtained the highest average accuracy rate on the VAS task and that the obtained rates were relatively close to the mean given the standard deviation of 0.08 only. In summary, group 1 scored the lowest on phonological awareness and reading comprehension, group 2 scored the highest on phonological awareness, and group 3 had the highest accuracy rate on the VAS task and the highest reading comprehension score. When looking more closely at the accuracy scores per consonant position, it is clear from Figure 18 that group 3 had not only the highest overall average accuracy but also the highest accuracy per consonant position of the three groups for all positions except for the fourth one. While groups 1 and 2 had the same overall average accuracy score on the VAS task, Figure 18 shows that the accuracy rate for group 2 was lower on position 3 than that of group 1.

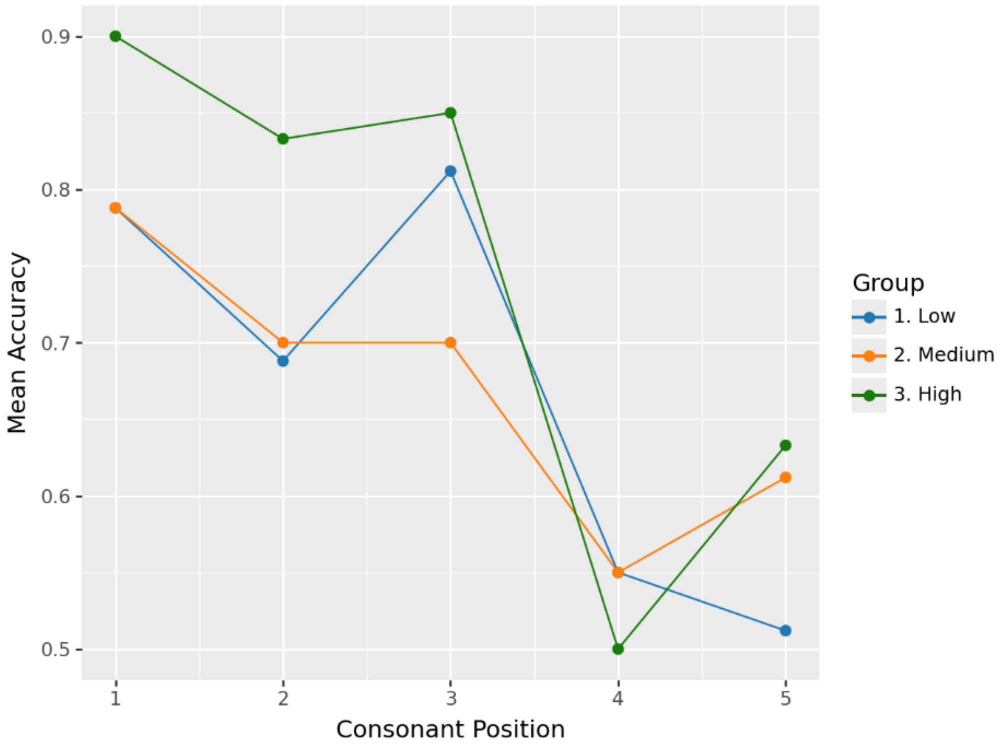

Figure 18: Mean accuracy per consonant position per self-test score group

A higher accuracy score for all three groups on the first three consonant positions is observed in Figure 18. As expected, the target consonant in the first position had the highest accuracy score out of all five positions due to the first-letter advantage. The expected W-shape (explained in section 2.5) is clear for group 3 with peaks for positions 1, 3 and 5. Group 2 shows the same tendencies except for positions 2 and 3 having the exact same accuracy rate. Group 1 is aligned with the W-shape except for the fifth position, which had the lowest accuracy score of all positions for that group.

6. Discussion

The experiment described in this thesis investigated the reading subskills of phonological awareness and VAS and their relation to reading comprehension in L1 Danish adults as well as the differences between dyslexic and non-dyslexic readers. The experiment consisted of three tasks accessible through a web browser and was completed by 22 participants. The tasks were designed to investigate whether the two reading subskills of phonological awareness and VAS influence reading comprehension, and if so, if they contribute equally to reading comprehension (RQ1). Furthermore, the goal was to examine if there are any detectable patterns regarding phonological awareness and VAS that distinguish different levels of reading comprehension regardless of dyslexia (RQ2) and if there is a difference between dyslexic and non-dyslexic readers in terms of the two subskills and their influence on reading comprehension (RQ3). In the following, the results of the three tasks will be discussed with the goal of answering the research questions.

6.1. Phonological awareness, VAS and reading comprehension (RQ1)

Data from the experiment show positive correlations between reading comprehension and phonological awareness and VAS respectively. As explained in section 5.8, the associations are rather weak, and phonological awareness seems to contribute more to better reading comprehension than VAS for the participants of this study. As word decoding is an important component for reading comprehension, it is as expected that a low score on the Find the Word task is associated with a low score on the self-test. The correlation between phonological awareness and VAS was found to be very weak as stated in 5.8. This confirms the expectation from Valdois (2022) that one may be present without the other. In this experiment, nothing suggests that a VAS deficit may be the cause of a poor result on the pseudo-word task of Find the Word as those with a low score on average on that task obtained good average accuracy rates on the VAS task. The expectation based on Bosse et al. (2007) of a VAS deficit negatively impacting pseudo-word reading can thus not be confirmed. When looking at participants individually, the interesting observation can be made that the highest scoring participant on the reading comprehension task with a score of 7.5 obtained only 35% correct answers on the Find the Word task. For that participant, phonological awareness evidently had no particular association to a good score on the self-test. Participants scoring high on reading comprehension generally had a high accuracy rate in the VAS task, too, but exceptions can also be found here when looking at individual participants. One of the participants who obtained a score of 5.5, which is above average, had the lowest VAS accuracy of all participants (24%). In summary, both reading subskills contribute to reading comprehension, and phonological awareness overall contributes slightly more than VAS.

6.2. Differences in reading comprehension levels (RQ2)

In general, the numbers in Table 5 show that group 3, which obtained the best reading comprehension results, is characterized by the highest VAS accuracy rate. This result aligns with the finding in Lallier et al. (2014) that VAS skills differentiate the performance of good and poor readers. As mentioned in 2.2, the speed of activation of words and knowledge in the brain is one of the contributing factors to reading comprehension, and the speed of reading has been shown to correlate with VAS as mentioned in 2.5. Combining the two, it may be hypothesized that the faster the elements of a word are recognized visually, the faster the word may be activated in the brain. The higher VAS accuracy rate could thus be linked to a higher reading and word activation pace for the participants of group 3 and thus faster completion of the stimuli of the self-test task resulting in a better score. Group 3 also had a higher accuracy rate on the first three consonant positions which may have contributed to these participants faster and more accurately identifying and recognizing the proposed options in the gaps in the cloze test format. Group 1, on the other hand, scored low on reading comprehension and phonological awareness while its average VAS accuracy rate was no different than that of the medium-scoring group. In summary, patterns found in the groups based on reading comprehension scores indicate that a phonological awareness deficit may be a contributing factor to a low score while a high accuracy score on the VAS tasks is associated with a high reading comprehension score.

6.3. Differences between dyslexics and non-dyslexics (RQ3)

Table 6 combines the results of the three tasks (cf. Tables 2-4) grouped by dyslexics and non-dyslexics.

Table 6: Summary of results of all tasks

	Find the Word			**VAS**			**Self-test**		
Dyslexia	**Mean**	**Std. dev.**	**Range**	**Mean**	**Std. dev.**	**Range**	**Mean**	**Std. dev.**	**Range**
Yes	0.29	0.06	0.20-0.35	0.70	0.10	0.60-0.82	4.45	1.49	3.40-6.60
No	0.57	0.17	0.15-0.80	0.69	0.15	0.24-0.90	5.27	1.05	3.90-7.50

Results from the Find the Word task displayed a correctness score for dyslexics that was on average 50% lower than that of non-dyslexics. This result confirmed the expectation based on Center for Læseforskning (n.d.b) that dyslexics would fare worse in a task involving pseudo-words because of their difficulties in converting graphemes to phonemes. Some of the dyslexic participants reported struggling greatly with this task which is an indication of developmental phonological dyslexia (2.3). With regards to VAS (Table 3), the picture was different as dyslexics on average had a slightly higher accuracy rate across all positions than non-dyslexics (70% vs. 69%). The standard deviation for the dyslexic group was at 0.10 as opposed to 0.15 for the non-dyslexics indicating that the results of the dyslexic participants were centered closer to the mean than for the other group. The data of this experiment do not confirm the findings of studies in Bosse et al. (2007) and Venagli et al. (2025) that dyslexics generally perform worse on VAS tasks than non-dyslexics. One explanation could be that L1 Danish dyslexics, early in the reading acquisition process, experience that GPC is simply too unreliable in a deep orthography like Danish. For this reason, they learn to distribute their attention across larger clusters of graphemes to deduce the pronunciation of a word from its context as opposed to dyslexics in shallower orthographies. The stimuli in the phonological awareness task have an average length of 4.86 characters i.e. inside the five-character scope tested in the VAS task. Given the good VAS accuracy score for the dyslexic group, the low correctness score on the phonological awareness task cannot be attributed to a VAS deficit. The main difference between dyslexic and non-dyslexic participant results clearly lies in the scores on the phonological awareness task while average VAS accuracy rates were almost identical in the two groups.

6.4. Methodological considerations

6.4.1. Find the Word

The decision to base the phonological awareness task on pseudo-words was founded in the extensive research which Center for Læseforskning (n.d.a) presents in favor of deploying this task specifically to identify a phonological awareness deficit. The Find the Word task was simple to implement and ideal in an experiment which called for simple instructions and execution on an online platform. An element, which could have contributed to more insight into the process of GPC and the strategy used when presented with pseudo-words, could have been the recording of participants reading aloud the different pseudo-words while solving the Find the Word task. When participants are asked to do so, it is typically possible to get an impression of the applied strategy of e.g. guessing, repairing incorrectly read words or assembling words phoneme by phoneme as described in Arnbak (2019). On the other hand, an oral element may have prevented potential participants with motor-speech problems from participating (see section 4.2).

As stated in 2.5, a VAS deficit may influence pseudo-word reading. This implies that the results of a pseudo-word task, though commonly used for testing phonological awareness (section 2.4), may in fact correlate with VAS rather than phonological awareness. To omit doubts about the causes of participants' phonological awareness levels, other methods not involving pseudo-words such phoneme segmentation or deletion tasks (Bosse et al., 2007) could be deployed to test for phonological awareness.

6.4.2. VAS

Designing an experiment in Gorilla allows easy access for anyone with an internet connection. Nonetheless, it also removes the element of control over the technical set-up as opposed to a test performed in a laboratory setting. Gorilla data includes information about the size of the monitor used by each participant, making it possible to analyze if this piece of information is relatable to the VAS result. As data showed no extreme outliers in the VAS task, the monitor size information was not further investigated in this study.

Some participants reported finding the VAS task frustrating because the consonants were presented for such a short time and indicated that they were missing the option of pressing the option of "I don't know". Such an option would, of course, have defeated the purpose of the task but a more detailed explanation of the goal of the exercise afterwards might convert frustration into understanding of the relevance and importance of the task.

Age has been found to correlate with VAS in some studies, potentially related to increased reading experience (Bosse & Valdois, 2009). Reading experience was not surveyed in this experiment and obtaining reading experience information would have required rephrasing the section in the participant questionnaire on reading. Based on the experience gained while conducting the experiment, it became evident that the value of the responses to the question about reading proficiency in Danish and other languages was low. The target group of the experiment was specifically L1 Danish speakers and, not surprisingly, all but one participant indicated reading at the level of an L1 speaker in Danish. The question should preferably have been related to their perceived reading level for Danish specifically to enable a comparison between this level and their score on the self-test and an evaluation of the claim in Mploy (2016) that especially readers with low proficiency tend to overestimate their reading skills. The indication of L1 and L2 reading proficiency should have been modified to target years of experience and the amount of reading (e.g. number of hours per week) instead to gain insights into the reading experience rather than the perceived proficiency level.

6.4.3. Self-test

As stated in 2.2, using the cloze test format for reading comprehension is not the most common choice. For this experiment, the test at selvtest.nu was included as a time-efficient element that according to Jensen et al. (2015) measures up to traditional reading comprehension tests. A deciding factor was also that it is publicly available. In the scope of this online experiment, the test served its purpose of giving participants a score as an indication of their level of reading comprehension. Nevertheless, Jensen et al. (2015) clearly state the limits of the test and emphasize that it is not a substitute for the traditional thorough and more time-consuming reading evaluation which is generally used in the Danish educational system. In an experiment wanting to investigate reading skills in more depth, the test at selvtest.nu would thus not suffice. From a technical perspective, making use of an externally developed and maintained test reduced the development work required for this thesis. Nevertheless, it also resulted in a lack of control over technical issues encountered by some participants.

As explained in 2.2, background knowledge is of importance when making global inferences. Differences in participants' level of language and general knowledge may have influenced their results on the self-test. Designing a task to evaluate background knowledge was not in scope for this experiment. However, if the purpose is to analyze all the potential contributors to reading comprehension, background knowledge also has to be measured in a task to allow for comparison with levels of phonological awareness and VAS.

General comments from participants confirmed that placing this task last in the experiment was a good decision. Some expressed frustration at not obtaining as high a score as expected. Others reported failing to complete all sentences within the ten-minute limit because they focused so intently on finding the correct answers that the evaluation of each sentence took much longer than expected. The probability of an unexpected low result influencing the remaining part of the experiment could thus have been considerable had the order of the tasks been different. On the other hand, some participants expressed relief at the logical nature of the cloze test format after struggling with the phonological awareness task and thus ended the experiment on a, to them, unexpectedly positive note.

6.4.4. General design considerations

In addition to the considerations about modifications of the tasks for future experiments, some general design changes could be considered to improve the flow and ease of execution of the experiment for the participants. First, it might be considered providing audio versions of written instructions and feedback in all tasks to cater for participants with reading deficiencies like it is done at selvtest.nu where all instructions are provided by means of audio. The drawback of relying exclusively on audio became apparent, however, when participants reported problems with the sound at selvtest.nu. An improved version of the tasks set up in Gorilla could thus include audio as well as written instructions. A second idea for improvement would be to ensure that participants return automatically to the experiment after visiting the external website of selvtest.nu. Gorilla allows for implementing a return token set-up. Nevertheless, due to limited technical knowledge of and lack of direct access to selvtest.nu, such a solution was not feasible in the scope of this experiment. Relying on participants returning to the Gorilla experiment after having visited another website introduced the risk of early exit from the experiment should a participant forget to complete the last part of the experiment or accidentally close the tab containing the Gorilla experiment. As stated in 5.1, only in two out of the 31 non-completed attempts was it the case that a participant reached the self-test component in the Gorilla flow without completing the whole experiment. It is thus not considered highly critical to a future execution of the experiment to ensure integration between Gorilla and the external website. Both proposed ideas would require considerably more time to implement.

6.4.5. Considerations regarding recruitment

Recruiting participants for a 30-minute experiment proved difficult. 21 individuals out of 53 did not proceed beyond the first step in the experiment flow, which informed them about the expected duration. To attract more participants in a future experiment, compensation for completion could be considered. Such an approach would require storage of participants' e-mail addresses to ensure compensation while also preventing the same participant from participating multiple times and would pose a data security risk, and the advantages and disadvantages would thus have to be balanced.

7. Conclusion

In this thesis, the contribution of phonological awareness and VAS to reading comprehension was examined for adult L1 Danish readers. Both reading subskills independently were found to have a weak positive correlation with reading comprehension with phonological awareness having the highest correlation. When grouping participants according to their level of reading comprehension, it was observed that the group with the lowest reading comprehension results exhibited poor phonological awareness skills. The group which obtained the best reading comprehension results was found to also perform the best with regards to VAS accuracy. In the comparison of declared dyslexics and non-dyslexics, a great difference was observed between the phonological awareness skills of the two groups with the dyslexic participants obtaining noticeably low correct response rates compared to the other group. This difference was not present in the results from the VAS task in which the dyslexic participants on average performed on par with the non-dyslexics. In conclusion, a phonological awareness deficit seemed to be prevalent in those with the weakest reading comprehension skills as well as among dyslexics. A VAS deficit could not be detected specifically in association with poor reading comprehension results, but high VAS accuracy, on the other hand, seemed to be associated with better reading comprehension. Strengthened phonological awareness thus seems to be a prerequisite for obtaining a basic level of reading comprehension. Once that level has been reached, strengthening VAS skills may help readers improve their reading comprehension skills additionally. Both skills thus contribute to helping L1 Danish readers at different levels make sense of the "complete mess" of Danish orthography.

8. Use of AI

The AI tools Lumo and CoPilot were used for the generation of some of the Python code used for the data analyses and visualization above. AI tools were used for no other purposes.

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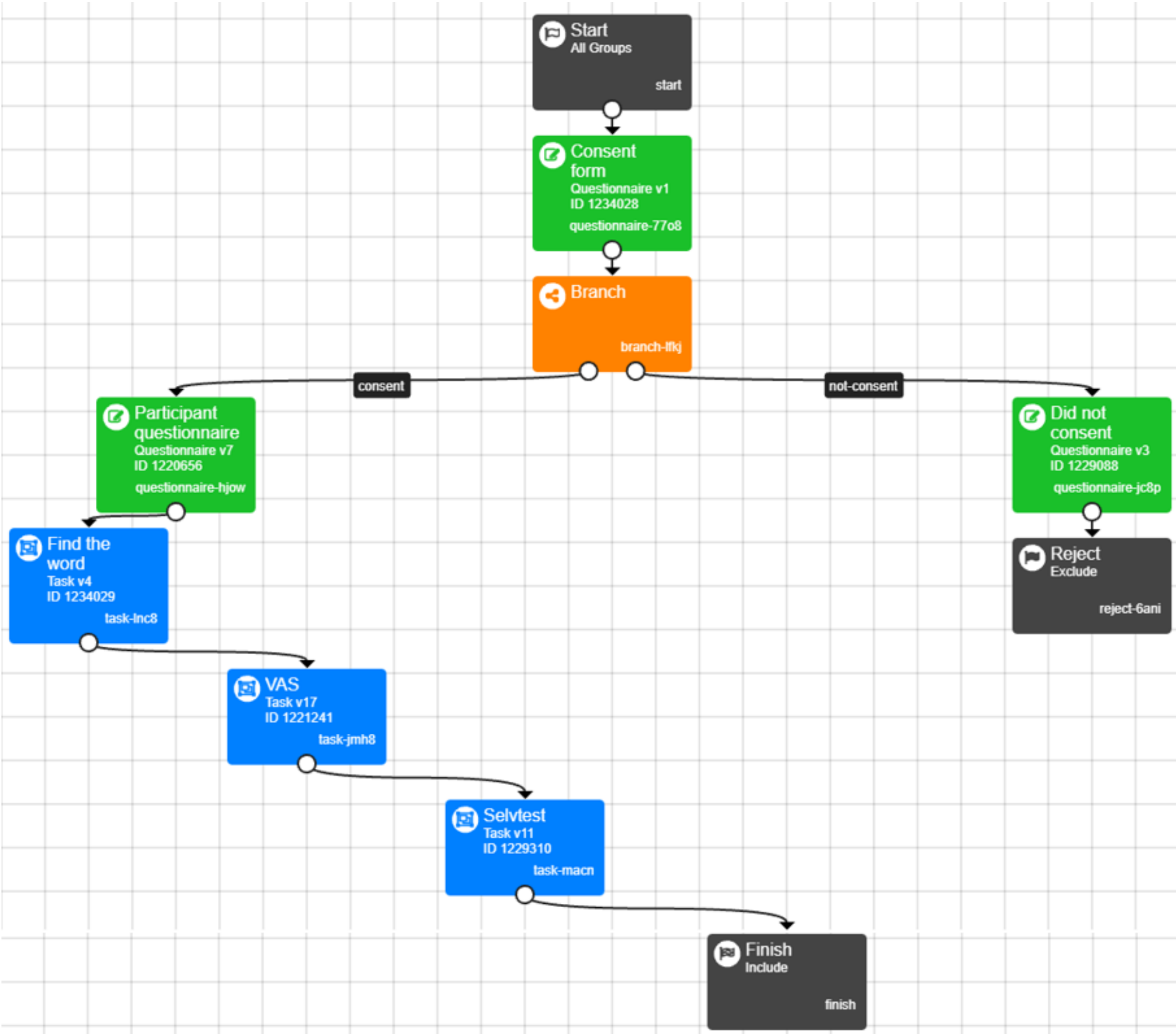
10. Appendices

A. Experiment Flow



B. Consent form

Samtykkeerklæring

I dette forsøg indsamles data til udarbejdelse af et bachelorprojekt på Lunds Universitet.

Der indsamles data om alder, uddannelsesniveau og læsevaner samt resultater fra de tre dele af forsøget.

De indsamlede data indeholder **ikke** oplysninger om dine private forhold, som vil kunne anvendes til at genkende dig som person.

Data, som ikke må bruges til fremtidig forskning (se spørgsmålet nedenfor), slettes ved udgangen af juni 2026.

Du kan når som helst afbryde forsøget.

Hvis du har spørgsmål til brug og opbevaring af data, kan du kontakte Helle Lindsted på he8877li-s@student.lu.se.

Før du fortsætter, bedes du svare på følgende spørgsmål (**bemærk, at du skal svare ja til til de tre første spørgsmål for at kunne deltage i forsøget**):

	Ja	Nej
Har du dansk som (ét af dine) modersmål?	☐	☐
Er du villig til at udføre forsøget online?	☐	☐
Giver du samtykke til, at dine svar bliver gemt i en database til brug i dette projekt?	☐	☐
Giver du samtykke til, at dine svar kan bruges anonymt i fremtidig forskning?	☐	☐

C. Did not consent

Du kan desværre ikke deltage i forsøget, da du ikke svarede ja på alle spørgsmålene.
Tak for din tid og interesse i forsøget.

Afslut

D. Participant questionnaire

Spørgeskema

Du bedes nu svare på et kort spørgeskema, inden du går i gang med selve forsøget.

Vælg fødselsår og -måned

MM ⌄ YYYY ⌄

Vælg køn:

Vælg dit højeste fuldførte uddannelsesniveau:

Vælg **din mors** højeste fuldførte uddannelsesniveau:

Vælg **din fars** højeste fuldførte uddannelsesniveau:

Hvilke(t) sprog kan du læse på? Vælg det relevante niveau ud for hvert sprog.

	Begynder	Lidt øvet	Meget øvet	Som en indfødt	Kan ikke læse på dette sprog
Dansk	○	○	○	○	○
Engelsk	○	○	○	○	○
Tysk	○	○	○	○	○
Fransk	○	○	○	○	○
Spansk	○	○	○	○	○
Italiensk	○	○	○	○	○
Russisk	○	○	○	○	○
Arabisk	○	○	○	○	○
Svensk	○	○	○	○	○
Norsk	○	○	○	○	○

Skriv evt. andre sprog, som du kan læse på og angiv niveauet i parentes:

Er du ordblind?

- Ja, jeg har taget en test, som viser det
- Ja, men jeg har aldrig taget en test, som viser det
- Nej
- Ved ikke

Conditional fields if participant declares dyslexia:

Har du modtaget særlig støtte, fordi du er ordblind?

Ja ⌄

Hvilken slags støtte har du modtaget?

E. Stimuli for Find the Word task

Display	first	second	third	fourth	Target	Danish orthography	Pronunciation
Practice trial	kraf	van	rabe	tafd	Van	vand	[ˈvanˀ]
Practice trial	styb	stib	stæb	ståb	Ståb	stop	[ˈsdʌb]
Practice trial	brørsde	børsde	brøse	bøsged	børsde	børste	[ˈbœɐ̯sdə]
Trial	dmæ	dim	dym	dæm	Dæm	dem	[dəm]
Trial	bår	båw	båf	båh	Båw	bog	[ˈbɔˀw]
Trial	kåsd	kåfs	kåsl	kåsm	Kåsd	kost	[ˈkɔsd]
Trial	sbig	gæb	sgib	sni	Sgib	skib	[ˈsgiˀb]
Trial	mæl	mill	fmil	myl	Mill	mild	[ˈmilˀ]
Trial	swad	davn	sdaw	svad	Sdaw	stav	[ˈsdæˀw]
Trial	fælsg	flalsg	flasge	flæls	flasge	flaske	[ˈflasgə]
Trial	fym	myf	fæm	fræ	Fæm	fem	[ˈfɛmˀ]
Trial	gan	pan	lan	nan	Lan	land	[ˈlanˀ]
Trial	låbbe	libbe	lybbe	lubbe	Låbbe	loppe	[ˈlʌbə]
Trial	pnas	sanp	span	naps	Span	spand	[ˈsbanˀ]
Trial	sagl	sygl	sægl	søgl	Sygl	cykel	[ˈsygəl]
Trial	tånnel	tynnel	fynnel	dånnel	tånnel	tunnel	[ˈtɔnˀəl]
Trial	fjærn	nærf	fjød	førl	Fjærn	fjern	[ˈfjæɐ̯ˀn]
Trial	tjag	tågge	tjægge	tytte	tjægge	tjekke	[ˈtjɛgə]
Trial	kral	skra	sgag	glal	Sgag	skak	[ˈsgɑg]
Trial	bagansje	bagase	bagasje	baganje	bagasje	bagage	[baˈgæːɕə]
Trial	bræv	vyrb	rævb	træv	Bræv	brev	[ˈbʁɛwˀ]
Trial	pråb	porb	brop	pårb	Pråb	prop	[ˈpʁʌb]
Trial	laj	lij	lyj	luj	Laj	leg	[ˈlɑjˀ]
Trial	sgrae	sgrie	grye	sgybe	Sgrie	skrige	[ˈsgʁiːə]
Trial	dårbs	bråsd	sdråb	lårbs	Sdråb	strop	[ˈsdʁʌb]
Trial	valb	balv	larb	blav	Valb	hvalp	[ˈvalˀb]
Trial	sæms	sægd	selm	sælf	Sægd	sekt	[ˈsɛgd]
Trial	plab	blap	gabs	sgab	Sgab	skab	[ˈsgæˀb]
Trial	sdæge	dægse	gædse	sdegge	sdegge	stikke	[ˈsdegə]
Trial	sæle	sælte	cælde	sælle	Sælle	celle	[ˈsɛlə]
Trial	bryt	bræg	brål	brar	Bræg	brik	[ˈbʁɛg]
Trial	harte	julde	hurde	jærde	Jærde	hjerte	[ˈjæɐ̯də]
Trial	lyge	lågge	lålle	lysse	Lågge	lukke	[ˈlɔgə]
Trial	bralle	brælle	brylle	brulle	brælle	brille	[ˈbʁɛlə]
Trial	hælle	hille	hulle	hølle	Hælle	helle	[ˈhɛlə]
Trial	gærpe	græppe	prægge	præmme	prægge	prikke	[ˈpʁɛgə]
Trial	drøng	dærng	draing	drung	draing	dreng	[ˈdʁaŋˀ]
Trial	nørje	jørle	jørne	nrøje	Jørne	hjørne	[ˈjœɐ̯nə]
Trial	fisle	fasme	forsle	fæsde	fæsde	feste	[ˈfɛsdə]
Trial	hyrdi	hældi	håndi	hildi	hældi	heldig	[ˈhɛldi]

Display	**first**	**second**	**third**	**fourth**	**Target**	**Danish orthography**	**Pronunciation**
Trial	sdason	dasjon	sdasjon	dason	sdasjon	station	[sdaˈɕoˀn]
Trial	kåb	bår	kyb	byk	kåb	kop	[ˈkʌb]
Trial	kumbåder	kåmpjuder	kympuder	kåmbåder	kåmpjuder	computer	[kʌmˈpjuːdʌ]

F. Stimuli for VAS task

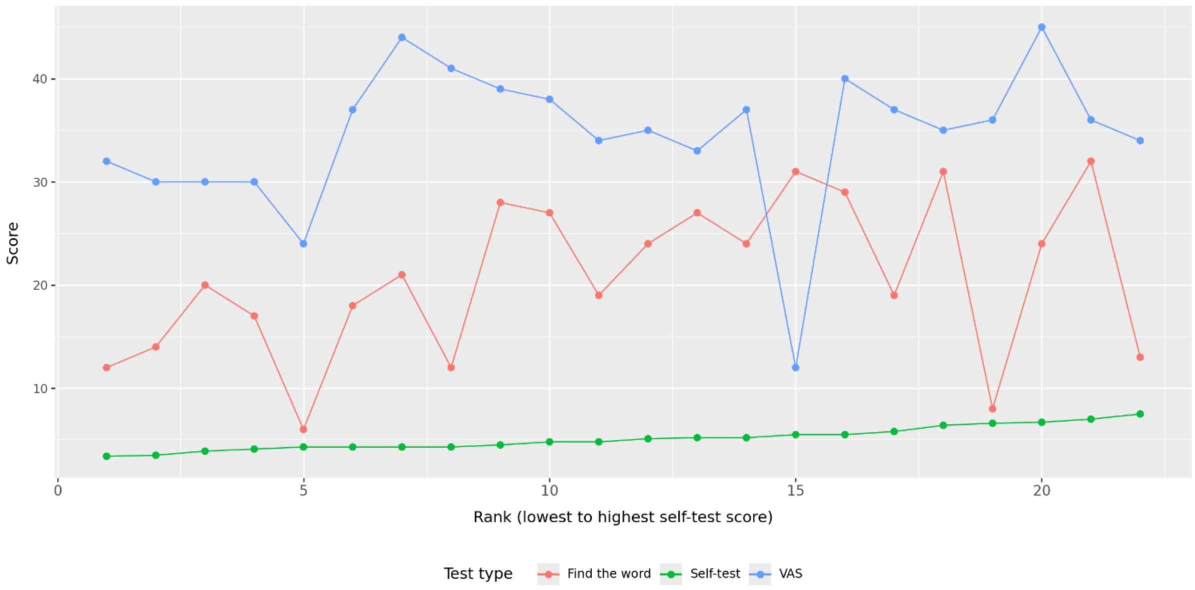
Display	String	Target	Correct	Position
Practice trial	T P Q N M	Q	YES	3
Practice trial	M D N P L	S	NO	none
Practice trial	V P S N D	V	YES	1
Practice trial	R C D V S	M	NO	none
Trial	B C V T H	B	YES	1
Trial	Z B H N T	B	YES	2
Trial	H Z B T V	B	YES	3
Trial	Q F V B N	B	YES	4
Trial	Z Q S H B	B	YES	5
Trial	F Q H T S	B	NO	none
Trial	V Q H S C	B	NO	none
Trial	Q T V N H	B	NO	none
Trial	C N Q V T	C	YES	1
Trial	H C V Q B	C	YES	2
Trial	T N C S B	C	YES	3
Trial	F V Q C N	C	YES	4
Trial	H F V B C	C	YES	5
Trial	V B Q S N	C	NO	none
Trial	N S F Q B	C	NO	none
Trial	B S N Z F	C	NO	none
Trial	F Q H V S	F	YES	1
Trial	H F N C Q	F	YES	2
Trial	Z H F S C	F	YES	3
Trial	H S Q F B	F	YES	4
Trial	Q C T S F	F	YES	5
Trial	T C Q V B	F	NO	none
Trial	H N B T S	F	NO	none
Trial	V Q C S N	F	NO	none
Trial	H Z V B C	H	YES	1
Trial	N H Z V T	H	YES	2
Trial	V S H Z C	H	YES	3
Trial	T C F H Z	H	YES	4
Trial	V Q S Z H	H	YES	5
Trial	Z B V F N	H	NO	none
Trial	B C F S T	H	NO	none
Trial	S B F T C	H	NO	none
Trial	N H V S B	N	YES	1
Trial	C N Z H F	N	YES	2
Trial	Z F N Q S	N	YES	3
Trial	C V B N H	N	YES	4

Display	**String**	**Target**	**Correct**	**Position**
Trial	F C S T N	N	YES	5
Trial	Z B H S C	N	NO	none
Trial	Q H T F V	N	NO	none
Trial	C B F Z S	N	NO	none
Trial	Q C B V H	Q	YES	1
Trial	H Q C Z B	Q	YES	2
Trial	N Z Q T F	Q	YES	3
Trial	B Z S Q V	Q	YES	4
Trial	S N B T Q	Q	YES	5
Trial	C V Z S F	Q	NO	none
Trial	S C T N H	Q	NO	none
Trial	V T H N Z	Q	NO	none
Trial	S Q H Z F	S	YES	1
Trial	H S F Z Q	S	YES	2
Trial	N F S V Z	S	YES	3
Trial	C F Z S H	S	YES	4
Trial	B T C Q S	S	YES	5
Trial	T N F B V	S	NO	none
Trial	Z H Q T C	S	NO	none
Trial	F Q B Z H	S	NO	none
Trial	T V S N H	T	YES	1
Trial	H T S C B	T	YES	2
Trial	B V T C Q	T	YES	3
Trial	Z C N T F	T	YES	4
Trial	H B N Q T	T	YES	5
Trial	C Z Q V H	T	NO	none
Trial	S H N C V	T	NO	none
Trial	Q F H B N	T	NO	none
Trial	V C N B F	V	YES	1
Trial	Q V Z N B	V	YES	2
Trial	H N V Z T	V	YES	3
Trial	S F C V Z	V	YES	4
Trial	Q T F H V	V	YES	5
Trial	S Q T Z N	V	NO	none
Trial	N T Q B S	V	NO	none
Trial	N C B Q H	V	NO	none
Trial	Z C V F S	Z	YES	1
Trial	F Z T B C	Z	YES	2
Trial	B H Z S N	Z	YES	3
Trial	H S B Z V	Z	YES	4
Trial	Q T S V Z	Z	YES	5
Trial	C Q B N S	Z	NO	none

Display	**String**	**Target**	**Correct**	**Position**
Trial	B C N F Q	Z	NO	none
Trial	F N C Q S	Z	NO	none

G. Participant results

Age Group	Education	Find the Word correct responses (out of 40)	VAS accuracy rate (out of 50)	Self-test score
19-29	Bachelor	12	32	3.4
40-49	Master	14	30	3.5
50-59	Master	20	30	3.9
70-79	Bachelor	17	30	4.1
60-69	Master	18	37	4.3
19-29	Secondary	12	41	4.3
40-49	Master	6	24	4.3
60-69	Bachelor	21	44	4.3
50-59	Master	28	39	4.5
19-29	Secondary	27	38	4.8
40-49	Bachelor	19	34	4.8
50-59	Bachelor	24	35	5.1
60-69	Secondary	27	33	5.2
50-59	Bachelor	24	37	5.2
60-69	Bachelor	31	12	5.5
19-29	Secondary	29	40	5.5
50-59	Bachelor	19	37	5.8
50-59	Master	31	35	6.4
50-59	Bachelor	8	36	6.6
19-29	Secondary	24	45	6.7
50-59	Bachelor	32	36	7.0
40-49	Bachelor	13	34	7.5



Score
40
30
20
10
0
5
10
15
20
Rank (lowest to highest self-test score)
Test type
Find the word
Self-test
VAS