Dyslexia, more than a reading disability:
Are reading problems associated with a deficit in featural processing?

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Lokaverkefni til BS-gráðu í sálfræði  
Leiðbeinandi: Heiða María Sigurðardóttir

Sálfræðideild  
Heilbrigðisvisindasvið Háskóla Íslands  
Júní 2017
Ritgerð þessi er lokaverkefni til BS gráðu í sálfræði og er öheimilt að afrita
ritgerðina á nokkurn hátt nema með leyfi rétthaf.

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Prentun: Háskólaprent
Reykjavik, Ísland 2017
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Preface

This thesis was written under the guidance of Dr. Heiða María Sigurðardóttir. We want to thank her for all the help and excellent guidance. It has been a great opportunity to be a part of this research and a very demanding and informative process. We want to thank our collaborators on this research, Anna Sigríður Valgeirsdóttir and Hilma Rósa Ómarsdóttir, for great teamwork. We could not have done it without you girls! We also want to thank Cand. Psych. students Kristján Helgi Hjartarson and Guðbjörn Lárus Guðmundsson for a good collaboration. A special thanks to the people who helped us with the writing of the thesis, grandpa Snorri, Kístín Heba Gisladóttir, Sigurður Pétur Snorrason, and last but not least Æðalsteinn Hugi Gíslason, the statistical genius.
Abstract

**Objective:** In this thesis, we want to determine if people with reading disabilities show deficiencies in facial perception compared to typical readers, in particular featural processing of faces. Dyslexic readers show hypoactivity in brain regions involved in recognition of words and featural processing, and previous research has suggested that dyslexic readers are impaired at perceiving faces compared to typical readers. **Method:** A total of 60 participants participated in the study. All were undergraduate students or had graduated with a bachelor degree within the past two years. History of reading problems was measured using the ARHQ-questionnaire. Featural and holistic processing of faces was assessed with a face perception task. **Results:** Featural processing of faces predicts reading abilities to some extent, indicating that a history of reading problems was associated with poorer featural processing of faces, when response time, prior diagnosis of ADHD/ADD and holistic and featural processing were accounted for. **Conclusion:** Reading problems could partially be caused by deficits in featural processing. The hypoactivity in the visual word form area and adjacent tissues shown in dyslexia could therefore represent a general impairment in featural processing.
It is estimated that learning to read is an extremely difficult task for about 5-10% of children of all cultures because they are affected by developmental dyslexia (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Developmental dyslexia is a specific learning disability with a neurobiological source affecting many aspects of learning and other abilities (Lyon, Shaywitz, & Shaywitz, 2003). It is characterized by difficulties with accurate or fluent word recognition and spelling (Lyon et al., 2003; Shaywitz & Shaywitz, 2005). These symptoms are not directly caused by factors such as impaired intelligence, neurological deficit or poor schooling (Schulte-Körne & Bruder, 2010). Other consequences of dyslexia can include problems in reading comprehension and reduced reading experience that can affect vocabulary and knowledge. Dyslexia is one of the most prevalent disorder of both children and adults in the literate world (Lyon et al., 2003; Shaywitz, Holford, Holahan, Fletcher, Stuebing, Francis & Shaywitz, 1995). In Iceland, a reported 10% of the population experiences reading difficulties despite sufficient schooling (Grétar Marinosson, Fjolnir Asbjornsson, Jonas Halldorsson, & Þóra Kristinsdottir, 1997). However, dyslexia is underdiagnosed in the literate world and there are no recent epidemiology studies on reading difficulties showing the frequency of dyslexia in the Icelandic population (Guðný G. Eydal, Auður B. Kristinsdóttir, Elín Vilhjálmardóttir, Hólmfríður Árnadóttir, Ingibjörg Rafnar, Skúli Sigurðsson & Sigurgrímur Skúlason, 2007). A sex difference exists in diagnosis of developmental dyslexia with a significant male predominance, where males seem to come to clinical attention more than females, although recent data indicates that dyslexia affects boys and girls equally (Flynn & Rahbar, 1994). Dyslexia is an inherited disorder (Fisher & DeFries, 2002; Smith, Kimberling, Pennington, & Lubs, 1983) and family history is one of the main risk factors for dyslexia; having a dyslexic parent increases the probability of dyslexia from 23% to as much as 65% (Shaywitz, 1998).

The dominant view on developmental dyslexia is that it results from a specific language impairment, involving impaired auditory and phonological processing of written or spoken language, referred to as phonological awareness (Bradley & Bryant, 1978). The phonological-deficit hypothesis states that dyslexic readers have difficulty developing the ability to decode written words and letters into smaller units of spoken sounds and understanding the sound structure of words. This cognitive deficit could lead to a complication with word identification and reading found in dyslexic readers (Shaywitz, 1998; Vellutino et al., 2004). However, the underlying cause of this deficit in phonological
processing and the mechanism by which it functions are still not fully known and require further research (Norton, Beach, & Gabrieli, 2015). Reading relies on visual, attentional and linguistic processes (Vellutino et al., 2004). Therefore it is probable that dyslexia is caused by multiple deficits instead of one single deficit (Norton et al., 2015).

Historically, researchers have shown interest in the visual aspects of dyslexia. Samuel Orton reported a deficit in the visual processes of dyslexic readers (Orton, 1925). His optical reversibility theory of dyslexia, among a variety of other theories, implicated that impairment in visual processes such as visual sequencing, visual memory, and visualization were the causes of dyslexia (Hermann, 1959; Orton, 1925). In recent years, visual perception studies have reported that dyslexic individuals show impairments in several visual tasks (Fischer & Weber, 1990; Goswami, 2015; Monzalvo, Fluss, Billard, Dehaene, & Dehaene-Lambertz, 2012; Slaghuis, Twell, & Kingston, 1996), including poor recognition of faces and other complex objects compared to typical readers (Sigurdardottir, Ívarsson, Kristinsdottir, & Kristjánsson, 2015). These results suggest that developmental dyslexia is more complex than originally thought, supporting a possible visual deficit in dyslexia. Dyslexia could be a manifestation of a more general deficit in brain areas involved in both recognizing words and other complex objects.

Reading is a unique human skill that is crucial for living in modern society. Reading requires knowledge of the letters, their shape, what they stand for, and the ability to link this information together to make words and sentences. These processes take place in the ventral visual stream which is involved in the visual recognition of objects and memory (Palmeri & Gauthier, 2004). Indications that deficits in visual perception could underlie dyslexia comes from research on patients with brain damage that resulted in pure alexia (Behrmann, Plaut, & Nelson, 1998). Pure alexia is caused by damage to the left ventral visual stream, resulting in the inability to read (Quint & Gilmore, 1992). Initially, patients with pure alexia were thought to be solely impaired at recognizing written words, with other perceptual abilities mostly spared (Geschwind, 1965). Recent studies however have demonstrated that the reading deficit in pure alexia is not the only problem, as these patients also have other perceptual deficits that includes deficits in the visual perception of non-word visual objects (Behrmann & Plaut, 2012).

Literacy first developed only 5000 years ago and there seems to be no single mechanism intended for reading and word recognition in the human brain (Dehaene, 2009).
Instead, according to most researchers, the mechanism dedicated to word recognition is located within brain structures in the left ventral visual stream dedicated to object and face recognition (Dehaene & Cohen, 2007, 2011). Neurobiological studies of the brain have reported a difference in certain brain regions between dyslexic and typical readers. These regions are lateralized in the left hemisphere, the language dominant hemisphere (Price, 2012). Researchers have revealed a region located in the left hemisphere, in the mid-fusiform gyrus, that shows more activation by visually presented words and letter strings than other visual objects. This area was therefore named the visual word form area (VWFA) (Cohen, Dehaene, Naccache, Lehéricy, Dehaene-Lambertz, Hénaff & Michel, 2000; Cohen & Dehaene, 2004). Dyslexic readers, children and adults, show hypoactivity in this area of the brain (Richlan, Kronbichler, & Wimmer, 2011). Thus, this could mean that there is a dysfunction in the VWFA in dyslexic readers. Therefore, it is important to investigate further the role of vision in dyslexia. In this present study, we set out to determine whether a specific problem with featural processing might be a contributing factor in reading problems.

**Face perception: featural and holistic processing**

We live in a world which is highly variable and where the objects around us differ from one moment to another (e.g. size, orientation). Recognizing faces and objects in our environment is a highly complicated visual task, but we do so effortlessly and under many different circumstances (e.g. in poor lighting, at a distance). We can even recognize faces with different expressions and different looks. For example, we can still recognize our grandfather after he shaves his beard off, or a friend if she would change from glasses to contact lenses. From infancy, faces are important in our interactions with other people. There have been several studies demonstrating that infants and neonates start to discriminate between visual stimuli at this early age and show visual preference for faces (Goren, Sarty, & Wu, 1975; Maurer & Young, 1983), suggesting that this behavior comes from our evolutionary history (Goren et al., 1975).

We identify people by looking at their faces which provides us with countless information; it gives us information about age, gender, emotional state and sometimes even health. This is unique for faces, that is, no other object provides us with such information (Gazzaniga, Ivry, & Mangun, 2014). Studies have reported that faces are perceived differently than other non-face objects, making faces a special class of stimuli (Farah, Wilson, Drain, &
Research on patients with brain damage, causing prosopagnosia or object agnosia, indicates that perceiving faces is different from perceiving other objects (Farah, Levinson, & Klein, 1995; Moscovitch, Winocur, & Behrmann, 1997). Prosopagnosia is an impairment in face perception with little or no impairment in perception of other classes of objects (Bruyer, Laterre, Seron, Feyereisen, Strypstein, Pierrard & Rectem, 1983). In contrast, object agnosia is an impairment in object perception which can leave face perception intact (Moscovitch et al., 1997). This indicates that face perception and object perception are, to some degree, supported by separate mechanisms.

We use different processes when perceiving the world around us. Since the days of Galton, psychologists have known that a face is not perceived by its individual features alone, but by the combination of its parts in a perceivable whole (Galton, 1879). In perception, both holistic and featural systems work together to make recognition fast and reliable (Gazzaniga et al., 2014). These two systems contribute to the perception of faces, objects and scenes in different ways (Peterson & Rhodes, 2003). Discussions of “whole” and “part” processing are common in the literature of perception (i.e., visual, auditory, tactile) (Latimer & Stevens, 1997). In the face perception literature, holistic characteristics refers to the spatial relations of the features and overall global form, determining the perception of the whole face (Mondloch, Le Grand, & Maurer, 2002; Wong, Bukach, Yuen, Yang, Leung, & Greenspon, 2011), for example, comparing the location of the nose to the location of the mouth. Although holistic processing is a central concept in the face perception literature, it has multiple meanings, and there is no consensus on the concept’s definition (Richler, Palmeri & Gauthier, 2012). The definition we use for the concept is that holistic processing reflects the spatial relations between features. Featural characteristics on the other hand concern the basic parts of the face, such as the shape of the eyes, or size of the nose (Farah et al., 1998; Tanaka & Farah, 1993). In the literature, different names are used to describe these concepts, e.g. holistic/global/configural processing and featural/analytic/part-based processing. In this current thesis, the terms holistic and featural processing will be used (Peterson & Rhodes, 2003).

Faces are complex stimuli, they are all made of the same features; two eyes, a mouth, and a nose, which all are organized in a similar manner, varying mainly in holistic characteristics (Maurer, Le Grand & Mondloch, 2002). Studies in the perception literature emphasize that facial perception relies mostly on holistic processing, while object and word
perception relies mainly on featural processing (Tanaka & Farah, 1993; Farah et al., 1998). This has been supported by studies of inverted faces and part-whole tasks (Diamond & Carey, 1986; Farah et al., 1998; Tanaka & Farah, 1993; Valentine, 1988; Yin, 1969). It is a well-known fact that people are not good at recognizing faces when they are upside down (Rhodes, Brake, & Atkinson, 1993). The famous Thatcher illusion (Thompson, 1980) has been used to demonstrate this effect, where it is difficult to notice if single features of the face (e.g. the eyes) are inverted on an entirely inverted face, but when the same face is upright it is obvious that the single features are inverted and the face looks absurd. Yin (1969) concluded that the inversion of faces disrupts holistic processing. This could illustrate that when looking at an inverted face, we look at each feature of the face rather than the face as a whole. This is known as the inversion effect (Diamond & Carey, 1986; Farah et al., 1998; Yin, 1969).

Based on previous research (Bradshaw & Wallace, 1971; Matthews, 1978; Smith & Nielsen, 1970, Sergent, 1984), Tanaka and Farah (1993) used a part-whole task to test the hypothesis that faces are recognized as wholes rather than in terms of their single parts. They taught their subjects to memorize normal faces and other non-face objects, such as inverted faces, scrambled faces, or houses. After the learning phase, they presented subjects with features of these stimuli, both in isolation and in the appropriate context. The result demonstrated that the subjects’ ability to recognize features from normal faces was highly impaired when presented in isolation. On the other hand, when subjects were presented with pictures of whole faces, their ability to recognize the features was unaffected. The ability to recognize the non-face objects (e.g. a house) was intact, both when the features were presented in isolation, and when the features were presented in the context of the whole stimuli. These results could indicate that recognition of faces relies mostly on holistic processing, while recognition of inverted faces and non-face objects relies mainly on featural processing. This can be interpreted from the study since these manipulations affected facial recognition much more than object recognition. Having the facial features in the context of the whole face helped the participants to recognize them but when the context of the face was missing they had trouble recognizing the features.

Farah (1990) stated that all objects are perceived along a holistic-featural continuum. As reported by her theory, we rely more on holistic processing when perceiving faces, whereas when perceiving written words we rely more on featural processing (Johnston & McClelland, 1980), and the perception of other objects is dependent on both processes (Farah,
1990). These findings are based on disruption of facial, object, and word perception due to brain damage found in neurological patients with pure alexia and prosopagnosia. The results of deficits in these patients point out that there are two kinds of visual processing. One process, holistic processing, is crucial for face perception and effective for object perception. The other process, featural processing, is crucial for word perception, but also effective for object perception (Farah, 1990). Farah and Wallace (1991) reported in accordance to this theory, that prosopagnosia patients had deficits in the right hemisphere and showed more impairment in holistic processing, while alexic patients had deficits in the left hemisphere and showed more impairment in featural processing. However, a recent body of evidence has demonstrated that holistic processing for words depends on the amount of experience with the words. For example, the effect seems to be larger for words within people’s native language compared to second-language, and is greater for real words than pseudowords (Wong et al., 2011).

Although theories of face perception put emphasis on holistic processing, featural processing also plays a role in face perception (Sergent, 1984). Some evidence even suggests that face perception relies solely on featural processing, estimating that 91% of the time we perceive faces by their isolated features, that is, for upright whole faces (Rakover & Teucher, 1997). A more common view in the literature is the dual-code view that states that both holistic and featural processing make crucial contributions to face perception (Cabeza & Kato, 2000). Studies have reported specific neural mechanisms for holistic and featural processing, showing that face perception tasks involving holistic processing, increase activity in the right hemisphere, in the mid-fusiform gyrus. However, face perception tasks involving featural processing strongly activate the mid-fusiform gyrus in the left hemisphere, including the VWFA (Bourne, Vladeanu, & Hole, 2009; Rossion, Dricot, Devolder, Bodart, Crommelinck, De Gelder & Zoontjes, 2000). These finding are consistent with the idea that faces are processed more by their holistic information than by their featural information, as faces strongly activate the right fusiform gyrus, while also emphasizing the importance of featural processing of faces (Collishaw & Hole, 2000). Although early research showed that the right hemisphere is dominant in face perception, there is evidence that both hemispheres are involved in the processing of faces, each hemisphere being specialized in processing different information from faces (Benton, 1980; Collishaw & Hole, 2000; Yin, 1970).
Face recognition: The ventral visual stream

Neural structures in the dorsal and ventral streams, positioned along the temporal and parietal lobes are important for the visual processing of faces and other objects, including words (Cohen & Dehaene, 2004; Kanwisher, Chun, McDermott, & Ledden, 1996). The ventral visual pathway in the brain includes visual areas that support the recognition and memory of objects, whereas the dorsal stream is involved in action and attention (Bauer, 1986; Peissig & Tarr, 2007). It has long been suggested that higher visual regions of the brain could be specialized for recognizing distinct categories of objects, such as words and faces (Grill-Spector, 2003; McCarthy, Puce, Gore, & Allison, 1997). Indication that face perception relies mostly on a specific mechanism comes from lesion studies and recordings of brain activity (Farah, 2004; McCarthy et al., 1997). McCarthy et al. (1997) presented pictures of faces and other objects to participants while measuring neural responses using functional magnetic resonance imaging (fMRI). Their results showed that the ventral surface of the temporal lobe in the fusiform gyrus was specially activated by faces. They also reported greater cortical activity in the right hemisphere compared to the left hemisphere. Findings such as these have been taken to indicate that the right fusiform gyrus, especially the fusiform face area (FFA), is a key brain region in facial recognition (Haxby, Hoffman, & Gobbini, 2000; Kanwisher, McDermott, & Chun, 1997).

A heated debate in the literature has arisen from these studies on the question of whether the FFA is selectively activated for faces or expertise stimuli in general (Gauthier, Skudlarski, Gore, & Anderson, 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Xu, 2005). Expertise stimuli is a class of complex stimuli that requires visual individuation, therefore one needs profound experience in recognizing the stimuli. Gauthier has argued that the right FFA is involved in expertise-specific rather than face-specific visual processing (Gauthier et al., 1999; Gauthier et al., 2000; Sigurdardottir & Gauthier, 2015). However, the classification of objects by experts activates a much wider region of the ventral occipitotemporal cortex, reaching beyond the FFA (Grill-Spector, Knouf, & Kanwisher, 2004; Rhodes, Byatt, Michie, & Puce, 2004). It therefore appears that both theories could to some extent be true. Thus, the FFA is both activated when recognizing expertise stimuli and faces, both of which are complex stimuli and demand profound experience for recognition (Gazzaniga et al., 2014).
**Dyslexia: Impaired recognition of faces**

Sigurdardottir et al. (2015) noted a possible link between dyslexia and an impairment in face and object perception. In their experiment, dyslexic readers showed more difficulties with perceiving faces and other visually complex objects compared to typical readers. They suggested that dyslexia is not only characterized by reading difficulties, but could rather be one manifestation of a more general deficit in brain areas both involved in perceiving words and other complex objects. They also reported that although dyslexic readers had more difficulties with facial perception, they did not have abnormal holistic processing of faces compared to typical readers. This led them to conclude that the differences in facial perception in dyslexia were most likely due to featural processing (Sigurdardottir et al., 2015).

Other recent studies have also implied a possible link between dyslexia and face perception. Monzalvo et al. (2012) reported impairments in the visual system and language system in dyslexic readers. The dyslexic readers in their study did not only have the well-known reduced neural activation for words, but they also had significantly reduced activation for faces.

Learning how to read appears to cause a change in the way we process faces in a systematic way. It has been argued that this process recycles the brain areas which evolved for face and object perception (Dundas, Plaut, & Behrmann, 2013; Dehaene & Cohen, 2007, 2011). With increased literacy, the response to faces and other objects decreases in the left fusiform gyrus and the VWFA (Dehaene et al., 2010) driving the object and face perception to the right hemisphere, namely the right FFA (Dehaene & Cohen, 2007, 2011; Dundas et al., 2013). These findings suggest that the perception of faces and words does not develop independently of each other (Dundas et al., 2013), suggesting a possible connection. Research has demonstrated that holistic and featural processing are dependent on distinct brain mechanisms, with featural processing mostly in the left hemisphere overlapping the VWFA (Bourne et al., 2009). Dyslexic readers show dysfunction in the left fusiform gyrus, an area involved in featural processing (Richlan et al., 2011), which could be an indication that dyslexic readers are impaired at the featural processing of not only words, but also faces and other objects.
The current study

Our primary question is whether disabled readers show specific difficulties with the featural processing of faces. Research suggests that dyslexic readers are poorer in perceiving complex objects and faces compared to typical readers, and that the differences in performance might be related to featural rather than holistic processing (Sigurdardottir et al., 2015). However, this has not been directly demonstrated. The fact that dyslexic readers show hypoactivity in a region related to the visual perception of words and potentially featural processing in general, leads us to the hypothesis that disabled readers have problems with featural processing. Therefore, dyslexic readers could show more difficulties when it comes to featural processing of faces but should be unimpaired in their holistic processing of faces.

To our knowledge no previous research has tested specifically the differences in featural processing of faces between impaired and typical readers. Trying to answer this question, we compared the performance of the participants on a facial perception task, measuring holistic and featural processing of faces, and assessed to which extent holistic and featural face processing was related to reading problems.
Method

Participants
A total of 60 subjects participated in the study (48 women and 12 men), out of which 11 reported being diagnosed with dyslexia (8 women and 3 men), two reported a diagnosis of ADHD/ADD and two participants reported having a diagnosis of dyscalculia. All participants were screened for dyslexia via the ARHQ list (see Test materials); 23 participants screened positive (were over the suggested cut-off score of 0.43) (Bjornsdotir, Halldorsson, Steinberg, Hansdottir, Kristjansson, Stefansson & Stefansson, 2014). All participants were either currently studying for a bachelor degree or had graduated with a bachelor degree within the past two years. They all reported normal hearing and normal or corrected-to-normal vision and had Icelandic as their native language. All participants were volunteers and gave their informed consent.

The mean age of the participants was 25.03 years with the standard deviation of 4.76 (age range: 19 to 51 years). Participants were not rewarded for their participation. They were however offered to sign up in a lottery where one out of ten were randomly selected to receive a gift card at the local shopping mall (value of 10,000 ISK).

Test materials
Several measures and tests were administered. The test materials analyzed here are measures of reading abilities and face perception, as further detailed below. Additionally, two separate questionnaires of ADHD/ADD symptoms, as defined by the DSM-IV were administered (Magnússon et al., 2006). Two other tasks measuring visual attention and word length effect were also administered. The results from these questionnaires and tasks will not be analyzed here; information on the results for these questionnaires and tasks are accessible in the Bachelor Thesis written by Anna Sigríður Valgeirsdóttir and Hilma Rós Ómarsdóttir, our collaborators in the current study.

Reading abilities. Three tests were administered to measure reading abilities: The Icelandic version of the Adult Reading History Questionnaire (ARHQ-Ice) to measure history of reading problems, the IS-FORM reading test, and the IS-PSEUDO reading test to measure current reading abilities.
**Adult Reading History Questionnaire (ARHQ).** The questionnaire was designed to measure history of reading problems (Lefly & Pennington, 2000). In this study, the Icelandic version of the ARHQ (ARHQ-Ice) was used to measure difficulties with reading (Bjornsdottir et al., 2014). ARHQ-Ice is a 23-item self-report questionnaire but only 22 items were analyzed in the current study (Bjornsdottir et al., 2014), the items were responded with a 5 point Likert scale ranging from 0-4, resulting in a score between 0-88. To make a score ranging from 0-1 the total score is divided by the maximum possible score, or 88. Higher scores are associated with greater reading difficulties that could indicate dyslexia. A score above 0.43 has been considered a cut off point when screening for dyslexia. The Icelandic adaptation of the ARHQ is a valid and reliable screening instrument for dyslexia (Cronbach’s alpha for internal consistency of .92), which is the same as for the original version of the list (Cronbach’s alpha greater than .90) (Bjornsdottir et al., 2014; Lefly & Pennington, 2000).

**IS-FORM.** The IS-FORM reading test measures current reading ability. The test consists of two lists with word forms of varying difficulty. The first list contains 128 common Icelandic word forms and the second list contains 128 uncommon Icelandic word forms (see appendix A and B). The words appear out of context to minimize guessing (Sigurdardottir et al. 2015).

**IS-PSEUDO.** This list assesses reading ability of pseudowords. The list consists of 128 pseudoword forms that still look like possible and pronounceable word forms in Icelandic (see appendix C) (Sigurdardottir, Danielsdottir, Gudmundsdottir & Kristjansson, 2017).

**Behavioral assessment.** Two separate questionnaires regarding ADHD/ADD symptoms as defined by the DSM-IV were administered to assess ADHD/ADD (Magnússon et al., 2006). Both questionnaires were self-reports of symptoms of behavior. The first one regarded behavior in the past six months and the second one regarded childhood symptoms from ages 5 to 12 years. Participants answered on a 4-point Likert scale, resulting in a total score from 0 to 54 on each list, where higher scores imply more ADHD/ADD-related symptoms. These questionnaires have been proven to be reliable and valid screening tools for ADHD/ADD (Magnússon et al., 2006).

**Facial perception task.** The stimulus set, developed by Van Belle and colleagues (Van Belle, De Smet, De Graef, Van Gool, & Verfaillie, 2009), can be used to measure holistic as well as feature-based processing of faces. Originally there were 30 Caucasian male faces in 15 pairs, all with an identical skin structure and color. From each pair of faces, A and
B, two new faces were created. One had the holistic form (the form of the skull, muscles and fat structure) of face A and the internal features (e.g. the eyes, nose and mouth) of face B. The other face had the holistic form from face B and the internal features of face A (Figure 1). This resulted in a total of 60 face stimuli. So, for every face in the stimulus set there is one face that differs from it only by its holistic form, and another face that differs from it exclusively by its features. All extra facial cues, such as hair, clothing or makeup, were eliminated.

Figure 1. Schematic overview of the creation of the faces

Each trial consisted of three faces lined up side by side at the vertical center of the screen. The sample face was displayed at screen center, or at 0°. The match and foil faces were situated at either 5° or -5° on the screen. The participant’s task was to determine which of the two faces, the right or left one, was more similar to the sample face in the center. The sample face size was 7° in height and 7° in width, while the match and foil faces subtended 5° in height and 5° in width. The faces were displayed on a grey background. The sample face was masked and appeared in an oval window in the center of the mask. The mask was used to keep people from focusing on non-face factors such as ear shape. The stimuli were presented until the participant responded by pressing on one of two keys on the keyboard. The
participants pushed the left arrow key to indicate that the face on the left was more similar to the face in the middle, and the right arrow key if the face on the right was deemed more similar to the face in the middle. After the response, the faces disappeared and a new set of faces appeared one second later.

The task included six blocks of trials with 60 trials per block, 360 trials in total. There were 180 trials that measured holistic processing and 180 trials that measured feature form processing that appeared in the same randomized order for each subject. In the holistic processing trials, the match face had the same holistic form as the face in the center, but the foil face had neither the same holistic form or features. Similar for the featural processing trials, the match face had the same features as the face in the center, but the foil face had neither the same features or the same holistic form. Holistic and feature-based trials were intermixed within blocks. All three faces had the same orientation in each trial. The faces were facing forward in 120 trials, facing 30° right in 120 trials and facing 30° left in 120 trials. There were 180 trials where the right arrow key was the correct response and 180 trials where the left arrow key was the correct response. The face stimulus set has previously been used to study holistic and featural face perception (Van Belle et al., 2009).

**Design**

The experimental conditions were the same for all participants. The reading and face perception abilities were assessed. History of reading problems was measured by ARHQ-score, where higher ARHQ-score indicated more reading problems. Participants scoring over the cut-off score (0.43) on the ARHQ-list were deemed disabled readers and others were deemed typical readers. The IS-FORM and IS-PSEUDO reading lists were used for measures on current reading abilities. In the regression analysis, the independent variables were proportion of correct responses in feature matching trials and proportion of correct responses in holistic matching trials. Response times were also measured. The dependent variable was the scaled ARHQ-score.

**Procedure**

The study was approved by the Icelandic Science Review Board (Vísnindasiðanefnd) and reported to the Icelandic Data Protection Authority (Persónuvernd). All sessions with participants started by gaining their informed consent. The study took place in a soundproof,
well lit room with only one participant partaking in the study at a time. The participant began by filling out a questionnaire in paper form regarding former diagnosis for dyslexia, ADHD/ADD, dyscalculia, autism, speech impairment apart from dyslexia or hearing impairment and whether they were taking any medication for ADHD/ADD symptoms (see appendix D). Next the participant was placed in front of a computer screen (Dell OptiPlex 760, 17-inch screen, resolution: 1024x768, 85 Hz). PsychoPy (Pierce, 2009) was used to administer the Adult Reading History Questionnaire, the ADHD/ADD questionnaires, the face perception task and the tasks on visual attention and word length effect. First the participant answered the questionnaires. The examiner read aloud the instructions for each questionnaire at a time and offered to read aloud the questions if the participant preferred, otherwise the examiner stepped out of the room to give the participant privacy.

The examiner then administered the facial perception task. In the facial perception task the participant used the left and right arrow-keys and the space key on the keyboard. The participant was placed in a chinrest to control for the viewing distance from the screen, which was approximately 57 cm. They listened to a recording of the instructions for the task and went through two practice trials with cartoon faces before starting the experiment. The participant was encouraged to stand up from the computer screen at least once during each break between blocks.

After completing the facial perception task the participant went on to complete two other tasks that measured visual attention and word length effect. These two tasks were a visual search task and a word length task. These two measures will not be included in this current thesis.

Lastly the examiner administered the two reading tests, IS-FORM and IS-PSEUDO. The participant was instructed to read each word list aloud as fast as possible, while making as few errors as possible. The reading was recorded in Audacity (Team, 2015).

**Statistical analysis**

The statistical analysis of the experiment was conducted using Statistical Package of Social Sciences (SPSS, version 23) and R (R Core Team, 2017). Trials with response times ± 3 SDs from an individual’s mean were excluded for each participant which lead to the removal of 7.4 trials on average for each participant. After the removal of these trials the proportion of correct responses was calculated.
An alpha level of 0.05 was used to determine the significance of the statistical tests, all two-sided. Correlation was estimated using Pearson’s r and effect size was estimated using Cohen’s d. An independent-sample t-test was conducted to assess the difference between typical readers and disabled readers on the ADHD/ADD questionnaires. A linear regression analysis was conducted to assess the relationship between ARHQ-scores and the accuracy of holistic and feature-based facial perception. No participants were excluded from the sample in the analysis, all 60 participants successfully completed their participation. However, a second linear regression analysis was conducted without two participants with a prior diagnosis of ADHD/ADD.
Results

Reading measures
ARHQ was used to screen for dyslexia. The questionnaire is a reliable and valid screening instrument for dyslexia (Bjornsdottir et al., 2014). IS-FORM and IS-PSEUDO were used to measure current reading; the number of words read per minute and proportion of correctly read words were assessed for common words, uncommon words, and pseudowords. The reading speed and reading accuracy for all word lists measures (IS-FORM and IS-PSEUDO) showed significant moderate to high positive correlation (lowest correlation: $r = 0.49$, and highest correlation $r = 0.91$), indicating that they are all to some extent measuring the same construct. The ARHQ-score showed significant moderate negative correlation with all word list measures (reading speed and accuracy for common word forms, uncommon word forms, and pseudowords; lowest correlation: $r = -0.36$, and highest correlation: $r = -0.61$).

Figure 2 shows a clear negative correlation between ARHQ-scores and reading speed (mean from all word lists). Figure 3 shows the relationship between ARHQ-score and reading accuracy (mean correct responses from all word lists); while there is a negative relationship between the two variables there are also signs of a ceiling effect. These results indicate that ARHQ-scores are associated with slower and less accurate reading, confirming the ARHQs validity as a screening tool for dyslexia. In the following analysis, ARHQ-scores will be used as our primary measure of reading difficulties. The cut-off score (0.43) of ARHQ will be used to differentiate between typical readers and disabled readers (Bjornsdottir et al., 2014).

The two groups differed greatly in their current reading abilities (Table 1). Disabled readers on average performed considerably poorer than typical readers on all word list measures, both in terms of reading speed and accuracy, although the reading accuracy of disabled readers varied greatly. The difference was significant both for reading speed, $t(58) = -4.56$, $p < 0.001$, $d = 1.2$, and for reading accuracy, $t(25.334) = -3.62$, $p = 0.001$, $d = 1.04$. 


Figure 2. The relationship between ARHQ-score and readings speed

Figure 3. The relationship between ARHQ-score and reading accuracy
We also screened for symptoms of ADHD/ADD using two separate questionnaires regarding ADHD/ADD symptoms in childhood and current symptoms. The results show that participants defined disabled readers scored higher, on average, on the ADHD/ADD screening tests for both childhood symptoms and current symptoms. This difference was significant for both childhood symptoms, \( t(30.69) = 4.47, p < 0.001, d = 1.3 \), and current symptoms, \( t(58) = 5.02, p < 0.001, d = 1.6 \).

**Measures of face perception**

Collapsing across trial type (holistic or featural), typical readers scored higher, on average, on the facial perception task than disabled readers (*Table 1*). However, the difference between the groups was not significant, \( t(58) = -1.61, p = 0.11, d = 0.44 \). Difference in performance between the two groups in feature processing was larger than the difference between the groups in holistic processing, where typical readers showed more accurate responding. The difference between the group means was significant for feature matching trials, \( t(58) = -2.05, p = 0.045, d = 0.9 \), while the difference between performance on holistic matching trials was not significant, \( t(58) = -0.75, p = 0.46, d = 0.2 \).

*Table 1. Descriptive statistics between those screened positive and negative for dyslexia by the ARHQ-questionnaire on face perception task and reading abilities*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dyslexic Mean</th>
<th>Dyslexic SD</th>
<th>Not dyslexic Mean</th>
<th>Not dyslexic SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct response in all trials (%)</td>
<td>0.75</td>
<td>0.05</td>
<td>0.77</td>
<td>0.04</td>
</tr>
<tr>
<td>Feature matching: Correct response (%)*</td>
<td>66.55</td>
<td>6.10</td>
<td>69.29</td>
<td>4.27</td>
</tr>
<tr>
<td>Global matching: Correct response (%)</td>
<td>83.62</td>
<td>5.99</td>
<td>84.64</td>
<td>4.48</td>
</tr>
<tr>
<td>Feature matching: Mean response time (s)</td>
<td>4.42</td>
<td>1.85</td>
<td>4.83</td>
<td>1.91</td>
</tr>
<tr>
<td>Global matching: Mean response time (s)</td>
<td>3.29</td>
<td>1.13</td>
<td>3.56</td>
<td>1.24</td>
</tr>
<tr>
<td>Correct words (%): Mean for all word lists**</td>
<td>90.31</td>
<td>7.62</td>
<td>96.27</td>
<td>2.65</td>
</tr>
<tr>
<td>Words read per minute: Mean for all word lists**</td>
<td>60.98</td>
<td>15.09</td>
<td>80.48</td>
<td>16.68</td>
</tr>
</tbody>
</table>

Note: *p<0.05; **p<0.01.
Association of reading and face measures

The correlation between ARHQ-scores and feature processing was not significant, although in the assumed direction, showing negative correlation, \( r = -0.16 \). The higher the ARHQ-score the poorer performance on feature matching trials, although this relationship is very weak. The correlation between ARHQ-scores and holistic processing was not significant, showing no correlation, \( r = 0.08 \), as assumed. However, this does not take into account the fact that a large proportion of variance in performance is shared by the two face perception tasks. The correlation between featural and holistic matching trials was moderate, \( r = 0.53 \). To look for the possible independent contribution of holistic and featural processing to reading disabilities, three linear regression analyses were conducted (Table 2). One included all participants of the sample, while in the second one, all participants with a prior diagnosis of ADHD/ADD were removed, for reasons discussed below. The third regression included all participants where response times were additionally accounted for.

Table 2. Summary of regression analyses for face recognition and dyslexia

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictor variable</th>
<th>B</th>
<th>SE(B)</th>
<th>β</th>
<th>t</th>
<th>Sig. (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response accuracy</td>
<td>feature match</td>
<td>-0.97</td>
<td>0.53</td>
<td>-0.28</td>
<td>-1.85</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>global match</td>
<td>0.78</td>
<td>0.54</td>
<td>0.23</td>
<td>1.49</td>
<td>0.14</td>
</tr>
<tr>
<td>Response accuracy</td>
<td>feature match</td>
<td>-1.38</td>
<td>0.50</td>
<td>-0.40</td>
<td>-2.73</td>
<td>0.009</td>
</tr>
<tr>
<td>(ADHD removed)</td>
<td>global match</td>
<td>0.90</td>
<td>0.49</td>
<td>0.27</td>
<td>1.80</td>
<td>0.08</td>
</tr>
<tr>
<td>Response accuracy and</td>
<td>feature match</td>
<td>-1.36</td>
<td>0.62</td>
<td>-0.39</td>
<td>-2.18</td>
<td>0.03</td>
</tr>
<tr>
<td>response time</td>
<td>global match</td>
<td>0.59</td>
<td>0.71</td>
<td>0.17</td>
<td>0.83</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>feature match (RT)</td>
<td>0.02</td>
<td>0.06</td>
<td>0.18</td>
<td>0.30</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>global match (RT)</td>
<td>0.01</td>
<td>0.08</td>
<td>0.05</td>
<td>0.09</td>
<td>0.90</td>
</tr>
</tbody>
</table>

A linear regression analysis was conducted with proportion of correct responses for feature matching and holistic matching trials as the independent variables, and ARHQ-score as the dependent variable, to assess the influence of feature and holistic processing in
dyslexia. When including all the participants of the sample the model explained 6.2% of the variance in performance and was not significant, $F(2, 57) = 1.89$, $p = 0.16$, showing that feature and holistic processing were not significant predictors of having a history of reading problems.

In the sample two participants had a prior diagnosis of ADHD/ADD. The ARHQ-list and ADHD-lists have a moderate correlation (Current ADHD/ADD symptoms, $r = 0.5$; Childhood ADHD/ADD symptoms, $r = 0.47$), showing that ARHQ might be measuring ADHD/ADD to some extent. A potential problem arises when including participants with a former diagnosis of ADHD/ADD, as their ADHD/ADD symptoms can inflate their score on the ARHQ, our primary dependent variable. Furthermore, the face perception task demands full attention for a long period of time and diagnosis of ADHD/ADD could therefore affect performance independent of any association with reading problems. For these reasons the two participants were removed from the sample. It is however worth noting that the two participants had a prior diagnosis of dyslexia and were screened true dyslexic by the ARHQ-list. This is in line with a high comorbidity between the diagnosis of dyslexia and ADHD/ADD (Willcutt & Pennington, 2000). A linear regression analysis was conducted with proportion of correct responses for featural and holistic matching trials as the independent variables, and the ARHQ-score as the dependent variable. When removing the two participants with a diagnosis for ADHD/ADD from the sample, the model as a whole explained 12.2% of the variance in performance and was significant, $F(2, 55) = 3.82$, $p = 0.03$, indicating that feature and holistic processing could be predictors of reading ability. The slope for feature matching, 95% CI [-2.39; -0.37], shows that when proportion of correct responses increases by one percentage point, the ARHQ-score on average decreases by 1.4 percentage points, when performance for holistic face processing is accounted for. This means that less accurate featural processing of faces is associated with greater reading disabilities. The slope for holistic processing, 95% CI [-0.098; 1.897], was not significant, demonstrating that there is no linear effect between ARHQ-score and holistic processing.

There was a correlation between correct answers and reaction time for both featural processing and holistic processing. The correlation between correct responses and response time in feature matching trials was significant and showed a moderate positive correlation ($r = .63$). The correlation between correct responses and response time in holistic matching trials was also significant and showed a positive weak correlation ($r = .39$). This could indicate a
speed-accuracy trade-off, where more time spent on each trial increases the likelihood of correct response, especially for feature matching trials. This is evidence that the measurement of correct responses for feature matching is not pure, showing that carefulness influences performance on the task.

A regression analysis was conducted with response time and proportion of correct responses for feature and holistic matching trials as the independent variables and the ARHQ-score as dependent variable to control for the speed-accuracy trade-off effect. The model explained 9.1% of the variance in reading abilities, and was not significant, $F(4, 55) = 1.37, p = 0.26$. The slope for feature matching was significant when response accuracy on holistic trials and response time in featural and holistic trials was accounted for. The slope of featural processing, 95% CI [-2.61; -1.11], shows that for each additional percentage point on feature matching trial for correct responses, the ARHQ-score decreases on average by 1.4 percentage points, when holistic face processing and response times for feature and holistic processing were accounted for. These results should be interpreted carefully since the model was not significant. However, because we have a priori hypothesis of this association, and we want to account for the effects of response time and holistic processing, we consider it justifiable to interpret that featural processing of faces predicts reading abilities.

To check the reliability of components of the facial perception task, we separately calculated Cronbach's alpha for feature matching and holistic matching trials. Cronbach's alpha reliability coefficient normally ranges from 0 to 1, where the closer the coefficient is to 1 the greater internal consistency of the items in the analysis. The trials for feature matching have a reasonably strong alpha coefficient of .664, indicating that the measurement is touching on the underlying construct of featural processing but it might have limited applicability. The Cronbach's alpha for the holistic matching trials was higher, .778, suggesting that the holistic trials are adequate in measuring the construct holistic processing.

Discussion

The current study indicates that disabled readers could be impaired in featural processing of faces compared to typical readers, while showing no differences in holistic processing of faces. Our hypothesis, that dyslexic readers show more impairment in featural processing of faces is therefore partially supported. Disabled readers displayed significantly worse performance in featural processing of faces compared to typical readers, while the differences
between the groups in holistic processing of faces was not significant. These results are consistent with previous findings; that dyslexic readers and typical readers show no differences in holistic processing of faces, rather the difference in facial perception between the groups could be regarding featural processing. (Sigurdardottir et al., 2015). Although it is important to note that to our knowledge, no previous research has tested directly the difference in featural processing of faces between typical readers and disabled readers.

A regression analysis including all participants, assessing the influence of featural and holistic processing in reading problems as assessed on a continuum by ARHQ, was not significant. However, the relationship was in the assumed direction, showing that the more reading problems an individual experiences, the poorer the performance in featural processing of faces. These results also indicate no relationship between holistic processing and reading abilities.

Dyslexia and ADHD/ADD show high comorbidity (Willcutt & Pennington, 2000) and therefore, ADHD/ADD could be inflating the participants ARHQ-score. To account for the effect of ADHD/ADD on the results we therefore removed all participants with prior diagnosis of ADHD/ADD from the sample. When accounting for diagnosis of ADHD/ADD and holistic processing, the influence of featural processing of faces on reading abilities was significant. This shows that reading problems could be associated with poorer featural perception of faces.

In the face perception task the response times and accuracy were correlated. This indicates a speed-accuracy trade-off, a complex relationship between the willingness to respond accurately and trying to respond fast (Kreutzer, Caplan & DeLuca, 2011). This can be detected by the individuals’ performance, as those with higher response accuracy on average took longer to respond. This correlation was found both for featural and holistic processing and was particularly strong for featural processing. This could indicate that the feature matching trials are more difficult than the holistic trials and therefore, slowing down the participant response time. This is also evidence that the measurement for featural processing of faces is not pure, as it is not certain whether a particular participant emphasized speed or accuracy. It could be that some participants emphasized speed while other emphasized accuracy. It is not unusual that participants with longer response time also have higher response accuracy, however it must be taken to consideration when interpreting the results (Bullinaria, 2000). In trying to control for the response-accuracy trade-off effect, a regression
analysis was conducted where response times and holistic processing was accounted for. The relationship between featural processing of faces and history of reading problems was significant in this analysis, which could be further evidence that the difficulties disabled readers experience is with featural processing.

The findings on the relations of facial perception and reading problems do demonstrate that featural processing of faces predicts reading problems to some extent. Two out of three regressions indicated that more reading problems were associated with a poorer performance in featural recognition of faces. Our findings are consistent with the growing body of evidence showing that dyslexia might be caused by a general high-level visual deficit (Richlan et al., 2011; Sigurdardottir et al., 2015). Studies have reported that dyslexic readers show hypoactivation of a region in the left fusiform gyrus, namely the VWFA, a region important in the processing of written words (Cohen et al., 2000; Cohen & Dehaene, 2004). The same region has also been linked with featural processing (Rossion et al., 2000) which is thought to be crucial when it comes to perceiving written language (Johnston & McClelland, 1980) and a wide range of perceptual processes, such as perceiving objects and faces (Cabeza & Kato, 2000; Tanaka & Farah, 1993). This indicates that the impairment dyslexic readers experience might be a general deficit in featural processing, suggesting that dyslexic readers experience a visual deficit high up in the ventral stream.

Research indicates that dyslexia is underdiagnosed in the literate world (Grétar Marinsson et al., 1997; Guðný G. Eydal et al., 2007). Findings such as these brings us one step closer to understanding the causes of dyslexia, and further knowledge of the subject could prove beneficial in improving the diagnosis and treatment of this disorder. Even though our results indicate that the more reading disability one experiences the poorer featural processing of faces one has, we do not know if these impairments are contributing to dyslexia or if they are a consequence of dyslexia. To learn more about the relationship between these two processes, further longitudinal studies are needed.

The current study was limited in two ways. First, the sample included only current or former university students. University students with reading disabilities are not representative for all individuals with reading disabilities in general. Individuals with more profound reading disabilities may not pursue going to university. University students with reading disabilities might therefore have less profound difficulties in reading in the first place and have more experience with written words, making them more distinct from dyslexic readers in general.
The second limitation was the face stimuli set used to measure featural and holistic processing of faces. The stimuli were computer-generated images of faces which were arguably less detailed than real faces, which could again diminish the featural processing of these faces as compared to real faces. The reliability for our measure of holistic face processing was acceptable, proving that the task is good at measuring holistic processing. However, the reliability for featural processing was questionable, establishing that the task was not efficient for measuring featural processing, although this task is measuring featural processing to some limited extent. Having said that, it is important to note the limits of these reliability measures. There are a lot of trials for each measurement (180 for featural matching and 180 for holistic matching) in the task, which spontaneously inflates the alpha coefficient in the analysis, even though the task is not necessarily measuring the same underlying construct. Although this stimulus set has been proven reliable in measures of featural and holistic processing of faces in previous studies (Van Belle et al., 2009), it might not hold for our face perception task. In previous studies using the same stimuli set, the experiment only included 80 trials; 40 trials for featural processing and 40 trials for holistic processing. It could therefore be that the face perception task was too long in our experiment, and fatigue played a potential role.

These limitations should be considered in future research. Further research on this matter could benefit from gathering a wider and more representative sample. This could be done by gathering a sample that is not restricted to university students and thus, would include disabled readers that did not attend university. Using different facial stimuli set with real, more detailed faces could be useful in further research on face perception. With a better and more reliable measure on featural processing, the relation between dyslexia and difficulties with featural processing could be better established.
References


Appendix A.

IS-FORM Common words

glugganum bænum leyti starfaði skyndilega föður ferðinni möguleika undarlegt vinur hlutverk andskotans líkara klukkutíma ánægður ástæðu aðygli borgarinnar heimilinu barnið kvöldið sögu áratugnum loft auðvitað fjölskyldunnar hliðina mánuði andlit drengurinn tennurnar reynslu eldhúsínu aðstæður skemmtilegt kafli klukkan eftir jörðina gamla leggjast hæfileika morguninn nóttina lítið þjóðarinnar kalt síðustu mínútur höndina tónlist vegginn prófessorinn sérstaka tilviljun borðinu hafa umhverfi verkefni höfuðið áhuga garðinum lifandi ákveðnum yngri lífi augunum framtíðinni göður orðum dyrunum nafnið krakkarnir vandamál bílnum maðurinn strax hvarflaði ljóst nauðsynlegt hugmynd læknir rúminu svipinn sagði svar miklu upplýsingar kaffi hermenn peninga veturinn skóla ætlaði kosti sunnudögum spurningar sumarið afsökunar rauninni oftast sterkari viðurkenna lengra líklega þekkingu hæði áhrifum ömögulegt heimsókn hádegi mátti stóran stólum erindi vinnu rödd hafið ástandið mikilvægt stofunni mamma málið ákvörðun samband staðreynd áherslu skugga
Appendix B.

IS-FORM Uncommon words

gyðju amen gígappa fuss samdóma hneisan ónæmur góðfúsan mara
turnspírum standlampa óhvikull maltöl blábrúnina skarann ræskingu
augastað mætt dagslok fossandi spillt deiði eikartré tvívegis
verkstjórn andmælti nellíkur nagdírin seppa pilsfald suddi blýgrænir
þverflautudeild örtungl dauni áburður þvældu framhleypin sallað
slotaði stórbifreið norðurundan beískju skóbúð hagli hverft sætlega
pakkaður heygarðshornið sjúkraflugi heyrnleysingi hótinu smíðatól
hvalvef skyggníshúfa temprað hveragufu sauðbrár skrautskrift
fatabinginn viðsemjendum bræddur kræla stundartöfrar kórbaki
harmakvein hleðslugjót mannslíf reykstrókur rykhimina forsjón
afnám fasteignaverð tálmynd elristrén skinnflyksu skandall póstlagt
nýmjólk stjórnbóða eldspýtustokk verkfræði ættfróð klaufi jarðvinnu
rógg krapiða yxna rauðlitaða rauðþrútnu brek guðadrykk rjúpur
mektarfólk garðyrkju stórfínt freknunef mismunaði heimsending
alþjóða faldinn duftpoka þorskgíldum hefil þýfinu jólafótin öskureið
fátkenndum kandís saðning frágangur remningskoss keikur hlífðar
armstólum innað hnuar matarmekkur kventónskálds strákslání
buðu höfuðkapp vátryggja smáhausverk sírennsli ákefð
manndrápum embættisbíll
Appendix C.

IS-PSEUDO Pseudo words

talt sólerubegt fjóturinnar purlerk bínustu löstpagt krek lauri
dandarnöfar sorbjón paunlinni þvarskautubeld eslibrén kölbynd
þúffilið baxna mumbingsfess pröddur örkuflleið fleppa höfmið guðinni
peiksju prautkist spengurinn lammhinni vendru nímótrur físspald
meldirennt umbarliftn bunnulösum skólrum gósbrútu lanem nútsilt
parbaði þvosku ennrað grífðar kreipan satakinginn farflaði sötbygli
rusgarinnar plúgga hlóðsibrjót harnkesingu lessnemm hilbið áplæsu
pannhvíf rælka neiksúkur þólarötin rútitu skurblúð œunvisað kaðulinn
slóttnima nerkubef bammrand skögumeika kemtargólk mynsórð
úsuga ærskingu neddu naffað skúrnporna díðasmól skramfiðíinni
blebbinn górlínt taðbeind sköllt bissvinn andgitt kaðsring kúspasan
glóssalepa erbósum rítlagi karðbyrkju hílbórinu kuss ánabugnum furt
pryðju górdaki trufið senníkur skyfinu plúminu pokkrýsingar homptís
græbela gáldið pátti krask tibblurnar böðusapp snurfónsálds lefginga
slépari verskbildum ratpæður terðinni ogglýpa borkpræði kabbri
markpunir hílnum ãppreggur ralgi fisliggáði skráttulína lurfinum
lafgám fuldarbé uildhósinu gúspur fleikur áttreslu túrfurinn
máðsynlert
Appendix D.

A questionnaire regarding former diagnosis
Fylgiskjal fyrir þátttakendur í rannsókninni:

“Hlutverk æðri sjónskynjunar, sjónhreyfíferla og sjónrænnar athygli í læsi og torlæsi”

A) Hefur þú greinst með eftirfarandi:

<table>
<thead>
<tr>
<th>Item</th>
<th>Ja</th>
<th>Nei</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesblindu (dyslexia)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athyglisbrest með eða án ofvirkni (ADD/ADHD)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talnabindu (dyscalculia)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Röskun á einhverfurófi?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tal- eða málmein (að lesblindu / dyslexíu undanskilinni)?</td>
<td>Ja</td>
<td>Nei</td>
</tr>
<tr>
<td>Heyrnarskerðingu?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B) Hefur móðir þín, faðir þinn eða systkini þitt greinst með lesblindu (dyslexia)? Hér er átt við lífræðilegan skyldleika.

| Ja | Nei |

C) Ert þú núna á eftirfarandi lyfjum við athyglisbresti með eða án ofvirkni (ADD/ADHD)?

<table>
<thead>
<tr>
<th>Lyf</th>
<th>Ja</th>
<th>Nei</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concerta?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ritalin?</td>
<td>Ja</td>
<td>Nei</td>
</tr>
<tr>
<td>Ritalin Uno?</td>
<td>Ja</td>
<td>Nei</td>
</tr>
<tr>
<td>Strattera?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annað lyf við athyglisbresti með eða án ofvirkni (ADD / ADHD)?</td>
<td>Ja</td>
<td>Nei</td>
</tr>
</tbody>
</table>

D) Hefur þú íslensku að móðurmáli?

| Ja | Nei |

Dagsetning

Auðkenni þátttakanda

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