The Relationship Between Theory of Mind, Dyslexia, and Social Communication Skills

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Þakkir

Ég vil þakka leiðbeinanda mínum og fyrirmynd, Huldu Þórisdóttur, fyrir allan stuðninginn, hjálpsemina og leiðsögnina í vetur. Þakkir til RANNÍS fyrir styrkinn sem veittur var fyrir gerð verkefnisins, og höfunda ARHQ-Ice fyrir afnot af listanum. Þá þakka ég öllum sem gáfu sér tíma til að svara könnuninni. Að lokum fá Óttar, Egill, Inga María og foreldrar mínir bestu þakkir fyrir ómældan stuðning og þolinmæði í vetur.

Abstract

The Reading the mind in the eyes (RME) test has gained popularity as a measure of theory of mind. In this study we examine how it relates to social communication skills as well as previously undocumented relationship with dyslexia. The objective of Study 1 was to translate the RME test to Icelandic and explore it's item structure and correlation to reading habits. In Study 2 we further examined the relation between dyslexia and social communication skills, aiming to establish whether or not dyslexics have impaired social skills compared to non-dyslexics. We hypothesized that they do, based on a recent study revealing impaired recognition of faces in dyslexics. In Study 1, 74 undergraduate students completed an Icelandic version of the RME test, as well as answering questions about reading habits. Results showed a positive correlation between self-reports of relative amount of reading compared to peers, and score on the RME test. Further, a negative correlation between relative amount of listening to non-fictional audiobooks and score on the RME test was established. In Study 2, we therefore assessed 639 participants' self-reported dyslexia, performance on the RME test, and social communication skills. Our results show that people with dyslexia score lower than non-dyslexics on the RME test, and have impaired social communication skills compared to non-dyslexics. We hypothesize that this stems from dyslexia and social communication skills having common neurological grounds. Further work is needed to clarify the generalizability of our results.

Keywords: Dyslexia, reading, social communication skills, theory of mind, empathy

Efnisyfirlit

Introduction

The ability to draw inferences about other people‘s thoughts, beliefs and intentions is essential in social communication and critical to our survival. Take, for example, this scene:

> Imagine you see someone look at their watch, and then jump out of their chair. In all likelihood you would interpret their behavior in terms of them just *noticing* the time, *thinking* that the time was earlier than it really is, and *realizing* that if they don’t run off now they will be late for their appointment. (Baron-Cohen, Wheelwright, Jolliffe, 1997. p. 312).

This cognitive capacity is called theory of mind, and it makes it possible for people to understand that others may have different views from their own (Singer & Klimecki, 2014). Empathy is a related construct, but composed of both cognitive and emotional factors. It is most often defined as the ability to understand what other people are thinking and feeling, and to respond appropriately to the emotional signals of others (Preston & de Waal, 2002; Segal, Wagaman, & Gerdes, 2012). Empathy is considered a motivating factor for pro-social behavior, and lack of it is affiliated with antisocial behavior (Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007). The terms empathy and theory of mind have sometimes been used synonymously, but that is misleading. Theory of mind appears to be roughly equivalent to cognitive empathy, but unrelated to affective empathy (Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007). A more general agreement is therefore to use the terms theory of mind and cognitive empathy interchangeably (Baron-Cohen & Wheelwright, 2004; Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007). Studies on people with Asperger syndrome have revealed that a deficit in theory of mind is a central characteristic of the syndrome, but affective empathy skills are unimpaired (Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007). In fact, many people have autism symptoms of some degree without causing them impairments in functioning. The autism spectrum can be viewed as a continuum of social communication disability, with Asperger syndrome as the bridge between autism and normality (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001b).

The bidimensional nature of empathy makes measuring it difficult, and different definitions of the construct makes comparisons of studies troublesome. Many instruments have been designed but each of them has its shortcomings. Self-evaluation measures are the most common type. Among them is the Interpersonal Reactivity Index (IRI) (Davis, 1983).

The IRI is a 28-item self-test, scored on a five point Likert scale. It has four subscales; perspective taking, empathic concern, personal distress, and fantasy. Separate scores are calculated for each of the subscales (Davis, 1983). Remarkably, no significant correlation has been found between the scores on various empathy scales and the measurement of empathic accuracy, which is measured by comparing a target person's actual thoughts and the perceiver's corresponding inferred thoughts (Levenson & Ruef, 1992). Furthermore, people have been shown to be poor at judging their own empathic accuracy, and social desirability or motivation plays a substantial role there (Laurent and Hodges, 2009). For example, females tend to score higher than males on the IRI, but when people are told that the task evaluates social abilities, as opposed to empathy, there are no significant gender differences on score (Nanda, 2014). In recent years, more researchers are therefore choosing to use direct behavioral measures for empathy instead of self-report scales (Feldman, Huddy, Wronski, & Lown, 2014). With a behavioral measure, one can get around the social desirability which is unavoidable when people are asked to rate themselves on how able and willing they are to feel with others (Feldman, Huddy, Wronski, & Lown, 2014).

Baron-Cohen, Wheelwright and Jolliffe (1997) developed one such behavioral measure for cognitive empathy. They performed a series of studies on how people read emotions from facial expressions and found that when shown photographs of faces, people generally agree when ascribing mental states to the person in the photos. They compared how accurately people guessed the right mental state when shown pictures of the whole face, the eyes region only, or the mouth region only. The whole face turned out to be most informative for basic emotions such as happy, sad, and mad, but for complex emotions, such as guilt, threat, and distrust, the eyes region turned out just as informative as the whole face. Interestingly, this effect only held for normal adults but not for people with Asperger syndrome. For the Asperger group, the whole face proved more effective in conveying information about complex mental states than the eyes region alone. This suggests that people with Asperger syndrome use a different strategy to recognize mental states. In fact, many of them reported that they could recognize basic mental states from large features like shape of the mouth when given a picture of the whole face, but there are no such obvious features when looking at pictures of the eyes alone (Baron-Cohen, Wheelwright and Jolliffe, 1997). Building on these results, Baron-Cohen, Jolliffe, Mortimore, and Robertson (1997) developed a measure called Reading the Mind in the Eyes (RME) test, in which participants are presented with photographs of the eye-region and instructed to choose the word they think

best describes the person's thoughts or feelings. The test was later revised by Baron-Cohen, Wheelwright, Hill, Raste, and Plumb (2001a) who further confirmed that it has a significant negative correlation with the Autism Spectrum Quotient (AQ), while neither sex nor IQ significantly predicted performance on the test. Recent studies have shown age-related deficits on the RME test which can be explained by a general impairment in the capacity to decode visual cues (Slessor, Phillips, & Bull, 2007). The test been translated to many different languages such as Swedish, French, Hungarian, and Japanese (Hallerbäck, Lugnegård, Hjärthag, & Gillberg, 2009). It has been shown to have a good test-retest reliability. Hallerbäck et al. (2009) tested 58 university students three weeks apart on a Swedish translation of the RME test and found no systematic learning effects with repeated testing. Yildirim et al. (2011) tested 70 participants on a Turkish translation of the test two weeks apart and found no significant difference between test and retest results. Pfaltz et al. (2013) also tested 40 non-clinical participants, three weeks apart, on a German translation of the test, with no indication of learning effects. Cronbach's alpha for the RME test is rarely reported, but tends to be low (Vellante et al., 2013). Harkness et al., 2010, report a value of 0,58 (Vellante et al., 2013), and Dehning, Girma, Gasperi, Meyer, Tesfaye, and Siebeck (2012) report a value of 0,70. It has been suggested that it is a result of the mental states in the test being highly variable and different from each other, and consequently they cannot be grouped into few categories (Vellante et al., 2013) which dramatically affects the Cronbach's alpha. The fact that excluding items does not improve the internal consistency supports this (Khorashad et al., 2015; Prevost et al., 2014).

Studies on reading and empathy have revealed correlations between familiarity with fiction, self-reported empathy, and performance on Reading the mind in the eyes test (Kidd & Castano, 2013; Mar, Oatley, Hirsh, dela Paz, & Peterson, 2006). While it might seem obvious that people who are more empathetic would enjoy reading fiction more than people who are less empathetic, Kidd and Castano (2013) have demonstrated a causal relationship between reading literary fiction and increased empathy. They suggest that reading fiction forces us to do mind-reading and take part in constructing the characters, thus affecting theory of mind processes. They further state that it is specifically literary fiction, and not popular fiction, that works in such a way to engage the reader's theory of mind by making them take on a writerly, as opposed to readerly, role to form representations of the character's mental states. In their studies, Kidd and Castano (2013) performed five experiments to test their hypothesis that reading literary fiction enhances theory of mind. Participants read short texts of different

genres and then answered the Reading the mind in the eyes (RME) test and an Author Recognition Test (ART). The results supported their hypothesis, those who read texts from literary fiction scored higher on the RME test compared with those who read different genres of text like popular fiction or nonfiction, demonstrating short-term effects of reading literary fiction. Higher ART scores also predicted higher RME scores. Taken together, the relation between performance on these three measures suggest that reading literary fiction may lead to stable improvements in theory of mind (Kidd and Castano, 2013).

Dyslexia is among the most common childhood disorders in literate countries. Prevalence estimates range from 5-10% up to 20% (Brosnan et al., 2002). It is defined by problems with accurate and/or fluent recognition of words as well as poor spelling and decoding capabilities. Dyslexia is typically thought to result from a deficit in the phonological component of language, often below expectations considering general intelligence and sufficient classroom instruction. This can cause difficulties in reading comprehension and reduced reading experience, affecting expansion of vocabulary and general knowledge (International Dyslexia Association, n.d).

The most prominent theory of dyslexia is the phonological theory. Research strongly suggests that deficits in phonological coding are the most common cause of children's reading difficulties (Vellutino, Fletcher, Snowling, & Scanlon, 2004). According to the phonological theory, people with dyslexia have a specific deficit in the representation, storage and/or retrieval of speech sounds, resulting in a poor correspondence between letters and the constituent sounds of speech (Ramus et al., 2003; Stanovich, 1988). Research showing dyslexics' poor performance on tasks requiring phonological awareness support this theory (Ramus et al., 2003). Phonological skills are important determinants of beginning reading ability, while semantic and syntactic skills carry greater weight for more advanced readers (Vellutino et al., 2004). Three other well-known theories of dyslexia are the rapid auditory processing theory, which postulates that the phonological deficit is secondary to a more general auditory deficit; the visual theory, which considers a visual impairment contributing to reading problems (does not exlude a phonological deficit); and the cerebellar theory, claiming a mild cerebellar dysfunction resulting in a number of cognitive difficulties. Finally, the magnocellular theory unifies all the aforementioned theories of dyslexia, postulating a magnocellular dysfunction in all the sensory modalities – visual, auditory and tactile (Ramus et al., 2003).

A comprehensive study by Ramus et al. (2003), however suggest that phonological deficit is in itself a sufficient cause of dyslexia, since it can occur independently of any sensory or motor impairments. However, for a significant proportion of dyslexics, additional auditory, visual or motor deficits follow. It is therefore possible that auditory deficits enhance the phonological deficits, resulting in further impairments of reading. A general sensorimotor dysfunction appears more often in dyslexics than the general population (Ramus, 2003 ; Vellutino et al., 2004). Dyslexia thus seems to be best described as a specific phonological deficit that is sometimes accompanied by a sensorimotor syndrome (Ramus, 2003).

Several developmental disorders tend to be comorbid with dyslexia. The most prominent are attention deficit hyperactivity disorder (ADHD), developmental coordination disorder (DCD), and dysgraphia (Nicolson & Fawcett, 2011). To our knowledge, no reports have been published on deficits in social communication associated with dyslexia, but two recent studies give reason to believe that there could be a link on a neural basis between the two. The first is a study on alexithymia and the second a study on visual processing of dyslexics.

Alexithymia is a condition where people have difficulties identifying and describing their own feelings. It is not a mental disorder, but a personality dimension, varying in severity from one person to another (Zaidel, 2005; Samur et al., 2013). Alexithymia can be measured using questionnaires such as the Toronto Alexithymia Scale, which is a self-report measure that consists of 20 questions regarding difficulties identifying and describing feelings (Bagby, Parker, & Taylor, 1994). Alexithymia symptoms are similar to the difficulties in social-emotional understanding seen in people with high functioning autism, Asperger syndrome, and the broader autism phenotype (BAP). Parents of children with autism spectrum disorder score higher on measures of Alexithymia than parents of children with other developmental disabilities and parents of normal children, and it has been suggested that alexithymia could be viewed as part of the BAP (Szatmari et al., 2008). A recent view on the neural basis of alexithymia is that it is caused by poor interhemispheric transfer of emotional information from the right hemisphere, where it originates, to the left hemisphere for speech production (Zaidel, 2005). In a study on the neurophysiological basis of alexithymia, Parker, Keightley, Smith, and Taylor (1999) used a finger localization task to replicate previous findings by Zeitlin, Lane, O'Leary, & Schrift (1989). Their results suggest there is indeed a general interhemispheric transfer deficit in alexithymia. In a finger localization task, the experimenter lightly touches one or more of the subject‘s fingers while the subject is to indicate which

fingers are touched by touching the same fingers, using the thumb of either the same hand (uncrossed condition) or the opposite hand (crossed condition). Interhemispheric transfer scores are then calculated as the difference of correct answers between the two conditions, with higher score indicating a greater transfer deficit. In Parker et al.'s study (1999) a group of alexithymic, but otherwise healthy, men made more errors in the crossed condition than the men in the control group. The authors point out that similar performance on the finger localization task is seen in individuals with dyslexia and low phonological ability (Parker et al., 1999; Zaidel, 2005). This implies that poor interhemispheric transfer plays a role in both alexithymia and dyslexia.

In a recent study by Sigurdardottir, Ivarsson, Kristinsdottir, and Kristjansson (in press) it was established that people with dyslexia are not only impaired at word-recognition but also the recognition of other complex visual stimuli, such as faces. Their reasoning was based on research on people with pure alexia (reading deficits acquired in adulthood as a result of brain damage). Several studies have hinted that these patients not only have impaired perception of words but also other visual objects, including face matching and discriminating between morphed faces. Pure alexia usually stems from damage to a brain region called the left fusiform gyrus, which includes the visual word form area (VWFA) and fusiform face area (FFA), thought to play a role in visual word recognition and recognition of faces (and other complex visual stimuli), respectively. A meta-analysis by Richlan, Kronbichler, and Wimmer, (2011) showed that dyslexic people, both children and adults, show abnormal functioning, a consistent underactivation, of this same brain region, the left fusiform gyrus. Based on these findings, Sigurdardottir and colleagues tested both dyslexic and normal adults for recognition of faces and other complex objects. While dyslexic people's holistic processing of faces is unimpaired, they seem to be specifically poor at part-based visual processing. Sigurdardottir et al. suggest that dyslexics' difficulty with reading might be the most salient display of a more general high-level visual deficit. They emphasize, however, that this does not automatically argue against theories of different causes of dyslexia, and further research will establish to what extent this high-level visual deficit is associated with for example phonological processing (Sigurdardottir et al., in press).

The present paper reports data from two studies. In Study 1 we translate the RME test to Icelandic, explore responses to each item and check if score on the test is correlated with reading habits. We try to replicate the findings from Kidd and Castano (2013) who reported

higher RME scores for people who are more familiar with fiction than those less familiar with it. We also wanted to see if this effect also held for listening to audiobooks (as opposed to reading books). Audiobooks are a rapidly growing section of the book industry, being a cheap, green option, appealing to the modern person's multitasking lifestyle (Irwin, 2009).

In Study 2 we test a large group of participants on the RME test as well as measuring dyslexia symptoms and social communication skills. In light of the results from Study 1, where listening to audiobooks was negatively correlated with score on the RME test, the similarities between alexithymic's and dyslexic's performance on the finger localization task (Zaidel, 2005), and Sigurdardottir et al.'s (in press) conclusions, it seems possible that there may be common neurological grounds for both dyslexia and impaired social skills, resulting in dyslexics scoring lower on measures of social emotional skills than non-dyslexics. We therefore hypothesize that higher dyslexia scores are correlated with lower scores on the RME test and poorer social skills.

STUDY 1

Method

Participants

Sixty-two undergraduate students from the department of political science and twelve undergraduate students from the department of literature at the University of Iceland participated in the study. They used their own computers during class and received a partial course credit for their participation. Forty-five of them were female and twenty-nine male. Their age ranged from 18-55 years old, mean age 26 years.

Materials

The revised version of the „Reading the mind in the eyes" test (Baron-Cohen et al., 2001a) was translated to Icelandic. All the words from the test were divided between eight experts (professors and graduate students in literature, linguistics, and psychology), leaving two people to translate each word. Words that got different translations were discussed at a team meeting and given one translation. In the test, participants are shown 36 pictures of the eye region of faces and asked to select which one of four words they think best describes the person's thoughts or feelings. When developing the test, Baron-Cohen et al. (2001a), set the criteria that for an item to count valid, at least 50% of participants should choose the correct

answer and no more than 25% should choose each of the foil words. We used the same criteria for the translated version of the test. Participants first completed the RME test, followed by questions about reading habits.

To assess reading habits participants were asked four questions regarding how much reading and listening to audiobooks they do. Items were answered on a four point Likert scale, from "considerably less than other people my age" to "considerably more than other people my age", for both fiction and nonfiction (for example textbooks, biographies and reference books).

Finally, participants' age and sex was assessed.

Procedure

Data was collected by using the website QuestionPro.com and analyzed by SPSS software using linear regression.

Results

To examine the item structure in the translated version, the percentage of participants who chose each option was examined for each test item.

Table 1 lists the percentage of participants who chose each word for all 36 items. For eight items, more than 25% of participants selected one of the foil words (items 7, 10, 17, 23, 25, 29, 34 and 36), and on four of those eight items, there were as well fewer than 50% of participants who selected the target word (items 7, 17, 25 and 29).

Table 1

Distribution of responses in percentages (n=76)

Item	Answer 1	Answer 2	Answer 3	Answer 4
1	**70,3**	5,4	17,6	6,8
2	6,8	12,2	**63,5**	17,6
3	5,4	2,7	**90,5**	1,4

4	2,7	8,1	6,8	**82,4**
5	0	8,1	**81,1**	10,8
6	**67,6**	2,7	9,5	20,3
7*	**48,6**	32,4	18,9	0
8	8,1	5,4	2,7	**83,8**
9	2,7	1,4	5,4	**90,5**
10*	36,5	4,1	1,4	**58,1**
11	2,7	1,4	2,7	**93,2**
12	**79,7**	4,1	1,4	14,9
13	10,8	1,4	1,4	**86,5**
14	1,4	4,1	0	**94,6**
15	**91,9**	4,1	0	4,1
16	5,4	**73,0**	1,4	20,3
17*	**41,9**	33,8	18,9	5,4
18	**95,9**	1,4	1,4	1,4
19	9,5	23,0	10,8	**56,8**
20	4,1	**90,5**	5,4	0
21	12,2	**82,4**	5,4	0
22	**87,8**	1,4	4,1	6,8
23*	0	10,8	**51,4**	37,8
24	**78,4**	6,8	9,5	5,4
25*	1,4	44,6	4,1	**48,6**
26	10,8	5,4	**71,6**	12,2
27	0	**79,7**	16,2	4,1

28	**78,4**	0	18,9	2,7
29*	18,9	4,1	29,7	**47,3**
30	5,4	**87,8**	4,1	2,7
31	2,7	**79,7**	2,7	14,9
32	**93,2**	2,7	4,1	0
33	2,7	20,3	2,7	**74,3**
34*	2,7	6,8	**63,5**	27,0
35	16,2	**63,5**	10,8	9,5
36*	2,7	4,1	**60,8**	32,4

*Marked items did not meet criteria and were excluded from analysis

Since the validity of eight items is questionable they were excluded from further analysis, based on Baron-Cohen et al.'s (2001a) criteria. Score of correct answers out of 28 items was therefore calculated. The scores were normally distributed with mean 21,89 and *SD* 2,49. Range 12-26. Scores below 14,40 were treated as outliers since they were more than 3**SD*s from the mean, leaving three participants omitted. That resulted in the mean being 22,14, *SD* 2,03 and range 17-26. There was not a significant sex difference for score, $t(72) = 1{,}65$, $p = 0{,}103$.

To assess the RME test's relation to reading habits, participants were asked to rate their amount of reading and listening to audiobooks compared to other people their age. Table 2 lists descriptive statistics for participant's self-reported amount of reading and listening.

Table 2

Self-reported amount of reading and listening to books, compared to other people same age (%)

	Considerably less	Somewhat less	Somewhat more	Considerably more
Read fiction	9,5	36,5	39,7	14,3
Listen to fiction	46,0	36,5	15,9	1,6
Read non-fiction	9,5	28,6	47,6	14,3
Listen to non-fiction	44,4	41,3	9,5	4,8

To examine if the same participants report both reading and listening to books to a greater extent than other people their age, correlation coefficients for different reading habits were obtained. Table 3 lists this. There were significant correlations for reading fiction and non-fiction, as well as for listening to fiction and non-fiction, but no significant correlations for the different modes of literature-consumption.

Table 3

Correlation coefficients for reading habits

	Read fiction	Listen to fiction	Read non-fiction	Listen to non-fiction
Read fiction	1	0,10	0,55**	0,06
Listen to fiction	0,10	1	0,20	0,84**
Read non-fiction	0,55**	0,20	1	0,20
Listen to non-fiction	0,06	0,84**	0,20	1

**$p < 0,01$

Linear regressions were performed in which RME was regressed on reading habits to study the relationship between the two. First we examined the relationship between reading and RME scores. Table 4 shows reading fiction was a significant positive predictor of RME score. The effect did not remain significant when controlling for age, sex, and education. Reading non-fiction did not predict RME score.

Table 4

Linear regression analysis for Reading fiction on RME score

Model		*B*	*SE B*	*β*
1	Read fiction	0,64*	0,31	0,27
2	Read fiction	0,47	0,31	0,20
	Age	- 0,08	0,08	- 0,14
	Sex	0,88	0,58	0,21
	Edu. level	0,77	1,48	0,07

*$p < 0,05$

Model 1 $R^2 = 0,07$; Model 2 $R^2 = 0,18$

Second, when examining the relationship between listening and RME, we found that listening to fiction had a marginally significant negative effect on RME score, $p = 0,053$, but the effect disappeared when controlling for age, sex, and education. Listening to non-fiction, on the other hand, had a significant negative effect on RME score, that is, scores on the RME test were higher for those who reported listening more to non-fiction audiobooks than other people their age (see Table 5). The effect remained significant when controlling for age, sex, and education.

Table 5

Linear regression analysis for Listening to non-fiction on RME score

Model		*B*	*SE B*	*β*
1	Listen to non-fiction	- 0,90**	0,33	- 0,35
2	Listen to non-fiction	- 0,80*	0,34	- 0,31
	Age	- 0,10	0,08	- 0,18
	Sex	0,66	0,58	0,16
	Edu. level	0,98	1,43	0,09

*$p < 0,05$; **$p < 0,01$

Model 1 $R^2 = 0,12$; Model 2 $R^2 = 0,22$

Discussion

In this study the RME test was translated to Icelandic, item response was explored and the test's correlation with reading habits examined. Eight items did not turn out useful in the translation, so a 28-item version of the test was used to assess relationship with reading habits. As expected, reading fiction was positively correlated with RME score, this is in line with previous research by Kidd and Castano (2013). To the contrary, listening to both fiction and non-fiction was negatively correlated with RME score.

The mean percentage of correct scores on the RME test was 79,0% which is a little higher than the 72,7% Baron-Cohen et. al (2001a) found in their study. This difference most likely stems from us using 28 items instead of 36, as we had to leave out eight items that did not meet criteria but would have lowered the mean score had they been included. A Swedish translation of the test which used 28 items instead of 36, reported 80% average correct scores (Hallerbäck et al., 2009). We found no sex difference for score on the RME test which is consistent with the results of Baron-Cohen and colleagues.

Correlation analysis revealed significant correlation within modes of consuming books, that is, on the one hand there was a significant correlation between reading fiction and non-fiction, and on the other hand a significant correlation between listening to fiction and non-fiction. No significant correlations emerged for different modes of enjoying literature. This implies that greater listening to audiobooks does not represent enhanced overall literature-consumption.

Our results show that people who report reading more fiction than other people same age score higher on the RME test compared to people who report reading less fiction, however the effect did not hold when controlling for age, sex, and education. Reading non-fiction did not have a significant correlation with score on the RME test. This is consistent with previous research by Kidd and Castano (2013).

Interestingly, people who report listening to non-fictional audiobooks more than other people same age score lower on the RME test than people who report listening less to non-fictional audiobooks. We cannot conclude why these people are choosing to listen to audiobooks but it seems probable that difficulties with reading play a role, since there was a

very low correlation between reading (m = 2,67) and listening to non-fiction (m = 1,75), r = 0,20.

In sum, 28 out of 36 items on the translated version of the RME test proved useful. The score was normally distributed with a mean score little higher than in the original version, probably due to leaving out 8 of the most challenging items, sex did not affect total score. People who report reading more fiction than other people their age score higher on the test but people who report listening more to audiobooks score lower, the results seem to indicate linkake between reading difficulties and poor recognition of emotion from static facial expression.

STUDY 2

In light of recent work by Sigurdardottir et al. (in press) and Zaidel's (2005) results revealing the similarities between alexithymic's and dyslexic's performance on the finger localization task, we speculate that there is, at least partly, a common neurological ground for dyslexia and recognizing emotion from facial expression, as measured by the RME test. If it turns out that amount of dyslexia symptoms is negatively correlated with RME score it does not necessarily mean that dyslexics are inadequate at recognizing other people's mental states in real life situations. It could imply only their deficiencies in part-based visual processing. If dyslexics can make up for their visual processing deficit by using other cues to read emotions (for example focus more on the settings, what is said etc.) it might lead the RME test not to be a valid measurement for dyslexics. If, on the other hand, dyslexics really are deficient at reading emotion in real life settings, they should score higher than non-dyslexics on a measure of social communication deficiencies. To test this, we designed a new study where we tested a large group of participants on the RME test as well as measuring dyslexia symptoms using a valid dyslexia measurement, and social communication skills using questions from the Baron-Cohen et al's (2001b) Autism Spectrum Quotient. Our hypothesis is that social communication deficits and dyslexia have some common neurological basis, resulting in a correlation between the two.

Method

Participants

Six hundred thirty-nine people participated in the study, of which 573 were female, 63 male and 3 who identified their gender as "other". Participants were recruited using the social

media website Facebook. Although not a representative sample, research has shown that this type of online recruitment can be superior to the traditional university pools of psychology students, saving both time and money as well as resulting in a more varied sample (Casler, Bickel, & Hackett, 2013). They received no incentives for participating, other than getting to know their final score on the RME test at the end of the questionnaire. Participants‘ age ranged from 18-72 and was mildly positively skewed with mean age 30,2 and *SD* 10,4 (median 27,0).

Materials

Participants first answered the Icelandic translation of Baron-Cohen's et al. (2001a) Reading the Mind in the Eyes test. The test consists of 28 items (excluding items number 7, 10, 17, 23, 25, 39, 34, and 36 from the original test) where participants are shown pictures of the eye-region of faces while they are asked to choose from four options which word best describes what the person in the picture is thinking or feeling.

To measure degree of social communication skills selected items from The Autism Spectrum Quotient (AQ) (Baron-Cohen et al., 2001b) were translated. Two experts translated each item, and any discrepancies were discussed at a meeting and resolved. The AQ is a brief, self-administered instrument which can be used to measure a normal adults' degree of autistic traits and is intended for adults with normal intelligence. Items are answered on a four point scale, from "definitely agree" to "definitely disagree". Higher score indicates more autistic traits. The original instrument has 50 items, assessing social skills, attention switching, attention to detail, communication and imagination (Baron-Cohen, et al., 2001b). We selected 11 items from the social skills, communication, and imagination domains (see Appendix A). Lowest possible score is therefore 11, and highest possible score 44. We chose to use selected items and not the whole list because we wanted to keep the questionnaire as short as possible. Example items are "I find it difficult to work out people's intentions", and "When I talk on the phone, I'm not sure when it's my turn to speak".

To measure dyslexia symptoms we used items from The Adult Reading History Questionnaire (ARHQ) by Lefly and Pennington (2000), which is a self-report measure of dyslexia symptoms. An Icelandic version of the questionnaire has been shown to be both a reliable and valid instrument to screen for dyslexia among adults (Bjornsdottir et al., 2013). Items are answered on a 5-point Likert scale. The original questionnaire measures three

factors; dyslexic symptoms, current reading, and memory. The dyslexic symptoms scale is most robust of the three and contains 12 items (see Appendix B). We therefore only used these 12 items to assess dyslexic symptoms, again to keep the questionnaire as short as possible.

Finally participants' background information was assessed; their age, sex, education level (Highest completed degree: Grade school, high school, bachelor's degree, master's degree or doctoral degree) and knowledge of the Icelandic language (Icelandic is my native language, Icelandic and another language(s) are my native languages, Icelandic is not my native language but I have very a good knowledge of it, Icelandic is not my native language but I have average knowledge of it, Other (state)).

Procedure

Data was collected by using the website QuestionPro.com and analyzed by SPSS software using correlation analysis and linear regression. In order to reduce dropout from dyslexics we offered the choice of a playback of all questions and answer options, as well as a larger text on yellow background, which, according to research by Rello & Baeza-Yates (2012) is the most common preference of text display for dyslexics. Two participants who did not either speak Icelandic as a first language or have a very good knowledge of the language, were excluded from the analysis, since it can affect performance on the RME test.

Results

Chronbach's Alpha for the AQ scale was 0,732 and for the Dyslexia scale 0,907.

AQ scores were normally distributed with mean 20,96 and *SD* 4,28. The range was 11 to 37. Dyslexia scores were slightly positively skewed with mean 11,75 and *SD* 9,24. The range was 0 to 44.

Scores on the RME test were normally distributed with mean 21,82 and *SD* 2,88. The range was 11 to 28. Scores below 13 were treated as outliers as they were more than three standard deviations from the mean, leaving three participants omitted. That resulted in the mean being 21,87, *SD* 2,79 and the range 13-28.

To determine if dyslexics differ from non-dyslexics on measures of theory of mind (RME) and social communication skills (AQ), scores for dyslexia symptoms were converted

to binary variables for logistic regression. To determine a cutoff value we used the same criteria as Bjornsdottir et al. (2013), that is, participants who scored greater than 43% were identified as dyslexics. Using that criteria, 12,8% of participants were classified as dyslexics, 81,1% as non-dyslexics and for 6,2% it was not determined as they did not answer all of the questions. Table 6 lists results from a binary logistic regression, with dyslexia as the dependent variable, and scores on the RME test and AQ measure as independent variables.

Table 6

Binary logistic regression analysis for dyslexia

	B	*SE B*	Exp(*B*)
RME score	- 0,13**	0,04	0,88
AQ score	- 0,05*	0,03	1,06

*$p < 0,05$; **$p < 0,01$

To assess the separate effects of social communication deficits and dyslexia as continuous measures on the RME score we performed a stepwise multiple regression analysis. In the analysis, RME score was entered as the dependent variable, and age, sex, education level, AQ score, and dyslexia score as the independent variables. The results can be seen in Table 7. In the first step, age was a significant predictor of RME score, but neither were sex nor education level. In step 2, AQ score significantly predicted RME score, along with age. In the third step, when dyslexia scores were added, they significantly predicted RME score, with age remaining significant but the effects of AQ score becoming non-significant.

Table 7
Linear regression analysis for RME score

Model		*B*	*SE B*	*β*
1	Age	- 0,08**	0,01	- 0,30
	Sex	- 0,10	0,34	- 0,01
	Edu. level	0,11	0,06	0,08
2	Age	- 0,08**	0,01	- 0,30
	Sex	- 0,14	0,36	- 0,02
	Edu. level	0,1	0,06	0,07
	AQ score	- 0,06*	0,03	- 0,1
3	Age	- 0,08**	0,01	- 0,30
	Sex	- 0,08	0,35	- 0,01
	Edu. level	0,07	0,06	0,05
	AQ score	- 0,04	0,03	- 0,06
	Dys.score	- 0,05**	0,01	- 0,15

*$p < 0,05$; **$p < 0,01$
Model 1 $R^2 = 0,08$; Model 2 $R^2 = 0,09$; Model 3 $R^2 = 0,11$

Discussion

A binary logistic regression revealed that both RME score and AQ score are significant predictors of dyslexia. This suggests that dyslexics are deficient in theory of mind and social communication abilities, compared to non-dyslexics. A stepwise multiple regression for RME score showed age to be a consistent negative predictor of RME score. This is consistent with earlier findings, showing age-related decline in performance on the RME task (Slessor et al., 2007). Our results further signify that dyslexia and AQ score predict the same part of the total variability of RME score. This is consistent with our hypothesis that dyslexia and social communication skills have some common neurological grounds. However, the effect is modest and needs to be examined further.

General discussion

This paper presents data on the relationship between theory of mind, reading habits, dyslexia, and social communication skills. In a couple of studies we discovered that people who report having reading difficulties also have inferior ability to detect theory of mind and impaired social communication skills, compared to those who do not report having any reading difficulties.

In Study 1 the aim was to translate the Reading the Mind in the Eyes (RME) test by Baron-Cohen et al. (2001a), explore responses to each test item and examine the test's relation to reading habits. Participants' perceived amount of reading and listening to both fiction and non-fiction, was assessed, and regressed on RME score. Using Baron-Cohen's et al. (2001a) criteria for selection of items on the RME test, 28 out of a total list of 36 items were included in the final translated version. The mean score was slightly higher than in the original version, which is likely a result from the elimination of eight difficult items, but comparable to the mean score in a Swedish translation of the test (Hallerbäck et al., 2009). There were no sex differences for score on the RME test, which is consistent with former findings (Baron-Cohen et al., 2001a).

In line with earlier findings by Kidd and Castano (2013), reading fiction turned out to predict greater theory of mind ability, as measured by higher scores on the RME test. Remarkably, listening to non-fictional audiobooks turned out to have the opposite effect, that

is, predict less theory of mind ability. There was a low correlation between reading and listening to audiobooks so it seems that greater amount of listening does not indicate increased overall book consuming, but possibly implies that the audiobook-listening group represents people with reading difficulties.

In light of results from Study 1, earlier work indicating similarities between alexithymic's and dyslecix's performance on a finger localization task (Zaidel, 2005), as well as recent findings by Sigurdardottir et al. (in press), who reported impaired recognition of faces and objects in dyslexia, we hypothesized that there is a link between dyslexia and social communication skills, resulting from common neurological grounds.

If dyslexia symptoms are negatively correlated with RME score it does not necessarily indicate that dyslexics are inadequate at recognizing other people's mental states in real life situations. It could imply only their deficiencies in part-based visual processing. If dyslexics can make up for their visual processing deficit by using other cues to read emotions (for example focus more on the settings, what is said etc.) it might cause the RME test to be an invalid measurement for dyslexics. If, on the other hand, dyslexics really are deficient at reading emotion in real life settings, they should score higher than non-dyslexics on a measure of social communication deficiencies. To test this, in Study 2 we tested a large group of participants on the RME test as well as measuring dyslexia symptoms using a the dyslexia symptoms scale from the Adult Reading History Questionnaire (Lefly & Pennington, 2000), and social communication skills using questions from the Baron-Cohen et al's (2001b) Autism Spectrum Quotient (AQ). Our hypothesis is that social communication deficits and dyslexia have some common neurological basis, resulting in a correlation between the two.

Our results show that compared to non-dyslexics, people with dyslexia are impaired at reading emotion from facial expression, as measured by the RME test, and show a general impairment in social communication, as measured by items from the AQ. Furthermore, dyslexia and AQ score seem to predict the same part of the total variability of RME score. This is consistent with our hypothesis that dyslexia and social communication skills have some common neurological grounds.

To our knowledge, this is the first study to document diminished social communication skills in people with dyslexia, and the results are not without limitations. Since our participants were recruited online using social media we have a subgroup of people who were

interested in and able to complete a survey that takes around 15 minutes to answer and includes some reading. Even though adjustments in size of text and color of background, as well as playback of questions were offered, this might have lead to severely dyslexic participants dropping out. Subject's age was very unevenly distributed, although it ranged from 18-72, more than 50% of them were aged 18-27 years old and 75% being 35 years old or younger. The dyslexic and typical readers were not matched in terms of age, gender, level of schooling, and we can therefore not say with certainty that they did not differ in any other possible way (besides having or not having dyslexia) that might have influenced the results. Future research would clearly benefit from such matching of participants.

We consider our findings an important step toward understanding what Sigurdardottir et al. (in press) have proposed is a syndrome in which dyslexia is but one of the symptoms. As Sigurdardottir et al. (in press) remark, this does not automatically argue against theories of different causes of dyslexia, and further research will establish to what extent this is associated with for example phonological processing.

Further studies are needed to probe for the replicability of our results by verifying the dyslexia diagnosis as well as matching participants for age, sex and educational background. Also, using dynamic social stimuli to identify if the effect is also seen in more ecologically valid settings could help clarifying the generalizability of our results.

In sum, people with dyslexia seem to have impaired social communication abilities compared to non-dyslexics. Their performance on tests measuring recognition of mental states from facial expression, and on tests measuring social skills, are poorer than seen in non-dyslexic controls. However, the effect is small, and further studies are needed to clarify our findings.

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Appendix A

Selected items from the Autism Spectrum Questionnaire

11. I find social situations easy. (SS)
17. I enjoy social chitchat. (C)
20. When I'm reading a story, I find it difficult to work out the characters' intentions. (I)
26. I frequently find that I don't know how to keep a conversation going. (C)
27. I find it easy to 'read between the lines' when someone is talking to me. (C)
31. I know how to tell if someone listening to me is getting bored. (C)
33. When I talk on the phone, I'm not sure when it's my turn to speak. (C)
36. I find it easy to work out what someone is thinking or feeling just by looking at their face. (SS)
40. When I was young, I used to enjoy playing games involving pretending with other children. (I)
42. I find it difficult to imagine what it would be like to be someone else. (I)
45. I find it difficult to work out people's intentions. (SS)

SS = social skills, C = communication, I = imagination

Appendix B

Selected items from the Adult Reading History Questionnaire

1. Which of the following most nearly describes *your* attitude toward school when you were a child?
2. How much difficulty did *you* have *learning to read* in elementary school?
3. How much extra help did *you* need when learning to read in elementary school?
4. Did you ever reverse the order of letters or numbers when you were a child?
5. Did you have difficulty learning letter and/or color names when you were a child?
6. How would you compare your reading skill to that of others in your elementary classes?
7. All students struggle from time to time in school. In comparison to others in your classes. how much did you struggle to complete your work?
8. Did you experience difficulty in high school or college Icelandic classes?
11. How would you compare your current reading speed to that of others of the same age and education?
13. How much difficulty did you have *learning to spell* in elementary school?
14. How would you compare your current spelling to that of others of the same age and education?
19. Do you currently reverse the order of letters or numbers when you read or write?