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Cognitive and emotional empathy in typical and impaired readers and its relationship to reading competence

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ABSTRACT

Studies indicate a strong relationship between empathy and language skills, but the relationship between reading and empathy remains elusive, although a shared neural substrate (the temporoparietal junction; TPJ) has been implicated in both reading and empathy. Motivated by these observations, the purpose of the current study was to examine empathic skills in a large spectrum of reading abilities, including typical readers and individuals with dyslexia, and their relationship to reading competence. We administered the Intrapersonal Reactivity Index (IRI) test, which differentiates between two subscales of empathy (cognitive and emotional empathy), to a group of participants with dyslexia and typical readers. Results indicate that the general reading score (average *z* scores of all reading tests) was significantly positively correlated with empathic scores. In addition, tests of specific reading abilities—decoding, reading fluency, and reading-related measures of phonological awareness—were significantly positively correlated with empathic scores. Finally, participants with dyslexia who showed low reading abilities had significantly lower scores in total empathy and cognitive empathy, as measured by the IRI test, than did typical participants with high reading abilities. Taken together, these results indicate a strong association between reading-related skills and empathic abilities and may point to involvement of the TPJ in both empathy and reading.

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Language-related skills are fundamental abilities of human cognition, which are learned early in life and are culturally dependent. Language-related skills can be perceived as important predictors of academic achievements and social/behavioral competence, while social skills can be conceived as important contributors to the successful acquisition of language-related skills (Tomblin, Zhang, Buckwalter, & Catts, 2000). Indeed, the evidence points to a robust association between language/speech impairments and behavioral/social performance, such as social adjustment and aggressive behavior (Beitchman, Hood, & Inglis, 1990; Beitchman, Hood, Rochon, & Peterson, 1989; Beitchman et al., 1996; Botting & Conti-Ramsden, 2000; Edwards, 1994; McCabe & Meller, 2004; Tomblin et al., 2000). Furthermore, studies have shown that learning problems affect behavioral development (Pianta & Caldwell, 1990) as well as social growth and social behavior (McCabe & Meller, 2004).

One major aspect of social behavior is our ability to empathize with other individuals. Empathy is an important social ability composed of two separate subsystems: cognitive and emotional empathy. Emotional empathy relates to the ability to experience affective reactions to the observed experience of another and involves emotional connotation, emotion recognition, and shared pain [which are associated with neural activation of the inferior frontal gyrus (IFG), inferior parietal lobe (IPL), anterior cingulate cortex (Faccioli, Peru, Rubini, & Tassinari, 2008), and anterior insula (AI)]. Cognitive empathy, on the other hand, is the capacity of engaging in a cognitive process of adopting

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another point of view, including theory of mind (ToM), the ability to understand and predict the behavior of another by attributing mental states and knowledge. Brain regions associated with ToM are the temporo-parietal junction (TPJ) and the medial prefrontal cortex (mPFC). (For a review see Shamay-Tsoory, 2011).

A large body of evidence indicates a possible relationship between empathy and language skills. Several studies have revealed that children's performance on ToM tests (such as false belief) was related to their language skills. Specifically, Astington and Jenkins (1999) showed that children's language-related skills (such as syntax) predict their later ToM performance. In another study, Ruffman, Slade, Rowlandson, Rumsey, and Garnham (2003) showed that ToM performance is associated with general language ability (rather than with syntax per se). A meta-analysis of more than one hundred studies concluded that language development and ToM performance are significantly related to each other in normal development (Milligan, Astington, & Dack, 2007). Another indication of the relationship between language and empathy is the finding of impaired performance on ToM tests among clinical populations suffering from language problems, such as children with autism (Tager-Flusberg & Joseph, 2005), deaf children (Peterson, 2016; Peterson & Siegal, 1999), and children with specific language impairment (Miller, 2001). Critically Kidd and Castano (2013) have recently reported that reading literary fiction enhances ToM, indicating a causal role between reading and cognitive aspects of empathy. Taken together, these studies suggest a robust relationship between language and empathy skills. Surprisingly, however, no study so far has investigated empathy in individuals with reading disabilities such as individuals with dyslexia.

Developmental dyslexia

Dyslexia is one of the most common language disorders, and it is characterized by difficulties in reading, writing, and spelling skills, including phonological awareness and slow lexical retrieval (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Despite decades of research, the underlying cognitive causes of dyslexia continue to be hotly debated (for reviews see, Démonet, Taylor, & Chaix, 2004; Habib & Giraud, 2012). The commonly held view is that dyslexia arises from deficient or impoverished phonological representations (Snowling, 2000). However, dyslexia is also related to additional deficits such as sensory impairments (Farmer & Klein, 1995), attention deficits (Facoetti et al., 2006; Goldfarb & Shaul, 2013), and procedural learning difficulties (Nicolson & Fawcett, 2011).

In contrast with the multiplicity of psychological mechanisms implicated in dyslexia, there is somewhat more consensus concerning the underlying neural patterns associated with the disorder. Many recent studies have uncovered particular neural signatures of dyslexia, including a disruption of posterior reading systems in the left parietotemporal (dorsal stream) and occipitotemporal (ventral stream) areas, with compensatory engagement of anterior systems around the inferior frontal gyrus and a posterior (right occipitotemporal) system (Shaywitz, Mody, & Shaywitz, 2006; Shaywitz et al., 1998). Furthermore, the temporoparietal junction (TPJ) was found to be one of the brain structures that function abnormally in dyslexia. A recent meta-analysis identified changes in gray–white matter differences and in the integrity of white matter tracts using voxel based morphometry in the right superior temporal gyrus near the TPJ among readers with dyslexia as compared with typical readers, in addition to a reduced amount of gray matter in the left superior temporal sulcus (Richlan, Kronbichler, & Wimmer, 2013). Furthermore, a reduction in gray matter volume in bilateral temporoparietal and left occipitotemporal cortex was found among prereaders with high genetic risk for dyslexia (Raschle, Chang, & Gaab, 2011). Functionally, abnormal overactivation in the right TPJ and underactivation in the left hemisphere were found in readers with dyslexia while performing different types of phonological tasks at different levels of difficulty (Raschle et al., 2011). Other studies have also reported abnormal reduction in activation of the left TPJ in readers with dyslexia while performing phonological tasks (Brunswick, McCrory, Price, Frith, & Frith, 1999; Horwitz, Rumsey, & Donohue, 1998; Paulesu et al., 1996; Rumsey et al., 1992; Shaywitz et al., 1998; Simos, Breier, Fletcher, Bergman, & Papanicolaou, 2000). Similarly, functional magnetic resonance imaging (fMRI) studies among Hebrew readers suggest that the reading deficit of readers with dyslexia may be related to a dysfunction in the left TPJ, indicating deficient phonological processing and mapping of orthography to

phonology in small grain-size units (Yael, Tami, & Bitan, 2015).

It has been repeatedly reported that language competence and reading interact. Abundant evidence suggests a reciprocal relationship between reading and phonology (Bentin & Leshem, 1993; Ehri et al., 2001; Melby-Lervåg, Lyster, & Hulme, 2012), and that phonological development interacts with lexical development (Stoel-Gammon, 2011); both are known to be impaired in those with dyslexia (Vellutino et al., 2004). Many children with dyslexia exhibit developmental language delay (Snowling, Bishop, & Stothard, 2000). Based on the robust relationship between language skills and empathy, we speculate that there might be a relationship between individuals with dyslexia language-related measures (such as reading and phonological awareness) and their empathic skills. Furthermore, as noted above, there are several indications for the involvement of the TPJ in the etiology of dyslexia (Raschle, Zuk, & Gaab, 2012; Richlan et al., 2013) as well as in empathy (Saxe & Wexler, 2005). These findings also hint at a possible association between empathic skills and reading competence. Motivated by the reviewed observations, the purpose of the current study was to examine empathic skills in the reading abilities spectrum, including typical readers and readers with dyslexia, and their relationship to reading competence. For this purpose we used the Intrapersonal Reactivity Index (IRI) test (Davis, 1983), which specifically measures four distinct measures: perspective taking (PT), empathic concern (EC), personal distress (PD), and fantasy (FS) skills, which may be divided into two empathy subcomponents (emotional and cognitive empathy). Although these components are different in quality, all these measures relate to reactivity to the observed experiences of others.

We administered this questionnaire to a group with a large range of reading abilities, including individuals with dyslexia and typical readers, and examined the relationship between reading competence and empathic skills. Based on the association between language and empathy and based the involvement of the TPJ in both dyslexia and empathy, we expected to find a positive correlation between reading abilities (as measured by a variety of reading tests) and empathic skills.

Method

Participants

Participants were 38 university students: 20 dyslexics and 18 typical readers. All were native Hebrew speakers. Participants declared no history of neurological disorders, psychiatric disorders, or attention deficits. In addition, all participants were right-handed, had normal or corrected-to-normal vision, and were screened for normal hearing. The group was recruited from the University Student Support Service at the University of Haifa, which is a service provided to support students with learning disabilities. Diagnosis of dyslexia was performed by the University of Haifa Learning Disabilities Diagnostic Center using the MATAL test. The MATAL test is a standardized, computer-based test battery for the diagnosis of learning disabilities in adults (dyslexia, dysgraphia, dyscalculia, and attention deficit disorder). The test was developed by the Israeli National Institute for Testing and the Israeli Council for Higher Education (Ben-Simon & Inbar-Weiss, 2012). The MATAL includes 20 tests and 54 performance measures, all of which have been validated and for which national norms were developed (n = 508). It is a highly accepted and used tool for diagnosing dyslexia among Hebrew readers and has been employed in many previous studies (Breznitz et al., 2013; Horowitz-Kraus, 2011; Sela & Karni, 2012; Shiran & Breznitz, 2011). The Israeli National Institute for Testing and Evaluation is responsible for examining its validity and reliability (Ben-Simon, Beyth-Marom, Inbar-Weiss, & Cohen, 2012). To assess dyslexia, the MATAL test calculates performance on several tests, including vocal text reading, nonword reading, phonemic deletion, phoneme counting, rapid automatic naming, verbal fluency, syntactic awareness, and reading comprehension. The psychometric properties of these tests are as follows: vocal text reading accuracy/RT (RT = reaction time; reliability = .72/.89, effect size[1] = −2.35/−2.15); nonword reading (production) accuracy/RT (reliability = .89/.98, effect size = −2.17/−2.72); nonword reading (identification) accuracy/RT (reliability = .85/.96, effect size = −2.39/−2.54); phonemic deletion accuracy/RT (reliability = .87/.97, effect size = −1.37/−2.03); phoneme counting accuracy/RT (reliability = .95/.97, effect size =

[1]The effect size represents the validity coefficient of the subtest.

–.35/–1.32); dictation (reliability = .57 to .28, effect size = –.34 to –3.23); rapid automatic naming of objects, letters, and numbers (reliability = .73 to .86, effect size = –1.17 to –2.03); verbal fluency based on phonological and semantic cues (reliability = .79 to .80, effect size = .–.82 to –.84); syntactic awareness accuracy/RT (reliability = .64/.93), effect size = –2.32/–2.65); and reading comprehension accuracy/RT (readability = .76/.90, effect size = –2.43/–2.93). For a full description of the MATAL tests designed to assess dyslexia including their psychometric properties, see Ben-Simon et al. (2012).

The typical reader group was composed of typical readers who also performed the MATAL test. The study received University of Haifa ethics approval, and written informed consent was obtained from all participants.

Assessment of empathic abilities

To obtain a measure of empathy we administered the IRI test (Davis, 1983). The IRI is a validated self-report questionnaire that measures several dimensions of empathy. It consists of four subscales, each measuring a unique component of empathy (Perspective Taking, PT; Fantasy Scale, FS; Empathic Concern, EC; and Personal Distress, PD).

The PT scale measures the reported tendency to spontaneously adopt the psychological point of view of others ("I sometimes try to understand my friends better by imagining how things look from their perspective"), whereas the FS scale measures the tendency to imaginatively transpose oneself into fictional situations ("When I am reading an interesting story or novel I imagine how I would feel if the events in the story were happening to me"). The PT scale was found to be consistently related to measures of interpersonal functioning, social competence, and high self-esteem, but not to emotional empathy (Davis, 1983). The EC scale taps respondents' feelings of warmth, compassion, and concern for others (e.g., "I often have tender, concerned feelings for people less fortunate than me"). The PD scale assesses self-oriented feelings of anxiety and discomfort resulting from tense interpersonal settings (e.g., "being in a tense emotional situation scares me"). It has been suggested that two of these subscales (Perspective Taking and Fantasy) tap the cognitive component of empathy (Hogan, 1969), whereas the two others (Personal Distress and Empathic Concern) tap emotional components (Harari, Shamay-Tsoory, Ravid, & Levkovitz, 2010). The FS and PT subscales were found to be positively correlated with other validated measures of cognitive empathy, such as the Hogan empathy scale, suggesting that these scales indeed measure cognitive empathy (Davis, 1983).

The readability of the test items is at a reading level of approximately seventh to tenth grade. Internal consistency alpha coefficients of the IRI test range from .68 (acceptable for research) to .79 (good). Our own data indicate an alpha coefficient of .76 in the present sample. Alpha coefficients for the different subscales as well as for composite scores of cognitive (C) and emotional (E) empathy (derived from the present sample) are as follows: IRIPT = .68; IRIFS = .80; IRIC = .73; IRIEC = .66; IRIPS = .714; IRIE = .68. Furthermore, the IRI has been shown to correlate with other measures of empathy, providing support for the construct validity of the measure. In addition, all four subscales have satisfactory internal and test–retest reliabilities (internal reliabilities range from .62 to .71; Davis, 1983).

Individual scores were obtained for each item (on a scale of 1 to 5) and were calculated for each subscale of the IRI test. In addition, in order to assess cognitive empathy (IRIC) we used the mean score of the PT and FS subscales, whereas emotional empathy (IRIE) was assessed using the mean score on the EC and PD subscales. The use of these cognitive and emotional subscales in combination was previously found reliable in many studies (Harari et al., 2010; Shamay-Tsoory, Aharon-Peretz, & Perry, 2009; Shamay-Tsoory, Shur, Harari, & Levkovitz, 2007; Shamay-Tsoory, Tomer, Goldsher, Berger, & Aharon-Peretz, 2004). Full-scale scores (IRITotal) were also calculated, by calculating the mean score of all subscales.

Performance tests

Intellectual ability

Intellectual ability was assessed by two subtests from the Wechsler Intelligence test for adults (WAIS; Wechsler, 1997). The Similarities subtest is a verbal test, which requires the subject to determine how various pairs of words (e.g., dog/lion, fly/tree) are alike. The Block Design subtest first requires the breaking down of each design

presented into logical units and then a reasoned manipulation of blocks to reconstruct the original design from separate parts.

Reading skills

Decoding, reading fluency, and reading comprehension tests were included.

Decoding. Decoding skills were examined by the One Minute Test of Words (Shatil, 1995) and the One Minute Test of Nonwords (Shatil, 1997), which assessed the number of words and nonwords accurately read aloud in the space of one minute. The One Minute Test of Words contains 168 nonvowelized words of an equivalent level of difficulty listed in columns. The One Minute Test of Nonwords contains 86 successively difficult vowelized nonwords listed in seven columns. Both accuracy (number of correct words read per minute) and speed (number of items read per minute) were measured.

Reading fluency. Reading fluency was assessed using the Reading Tests Oral–Silent obtained from the reading comprehension subset of the Psychometric Entrance Test (1995). In the oral reading test, participants were required to read aloud a text that contained 216 words, as fast and as accurately as possible. Words read correctly per minute were calculated. In the silent reading test participants read the text silently. Words read per minute were calculated.

Reading-related skills: Phonological awareness. Three tests were included: Phoneme Deletion, Segmentation, and Parsing. The Phoneme Deletion test (Breznitz & Misra, 2003) contains 25 nonwords. In this test the experimenter reads a word and specific phoneme, and the participant is required to repeat the word without that phoneme. The Segmentation test (Shatil, 1997) contains 16 nonwords. In this test the experimenter reads each nonword, and the participant is required to segment the word into its basic phonological sounds as fast as possible. The Parsing test (Breznitz, 1997) contains 46 rows of words. Each row contains four words printed with no spaces between them. Participants must identify the words in each row by drawing a line to indicate where the spaces should be. For all tests, both accuracy (number of correct letters/objects read per minute) and time (the time that participants required to complete the task) were measured.

Procedure

Participants first came to the lab to perform the psychometric tests. They were tested in a quiet room. After a minimum of three months, the experimenter contacted the participants and asked them to perform the online empathy questionnaire. Participants were compensated for their time (NIS 60, approximately $15).

Results

The two groups of participants did not differ in chronological age (participants with dyslexia: M = 26.11, SD = 2.92; typical readers: M = 26.8, SD = 3.41), $t(36) = -0.66$, p = 51, or in IQ estimates, as measured by the Block Design subtest (Wechsler, 1997; participants with dyslexia: M = 12.77, SD = 2.43; typical readers: M = 12.8, SD = 3.12), $t(36) = -0.02$, p = .98 (Cohen's d = 0.01) and by verbal ability scores measured by the Similarities subtest (Wechsler, 1997; participants with dyslexia: M = 12.11, SD = 1.45, typical readers: M = 12.45, SD = 1.02), $t(36) = -0.71$, p = .47 (Cohen's d = 0.27). However, compared to the typical readers, the dyslexia group exhibited a clear profile of reading disability conforming to the symptomatology of dyslexia. They differed significantly from the typical readers on word reading, decoding skills, and phonological awareness (phoneme deletion, segmentation, and parsing, all ps<.05).

IRI test

The data indicate the following intercorrelations: PT and PD subscales were negatively associated ($r = -.35$, $p < .05$). Also, the correlation between FS and EC was significant ($r = .40$, $p < .01$). No other intercorrelations were significant (correlation between PT and FS, $r = .02$, $p = .43$; correlation between EC and PD, $r = .05$, $p = .75$).

Relationship between empathy and reading measures

To determine whether individuals' reading ability is related to their empathic skills, we performed correlations between subjects' scores on the psychometric tests and empathy scores as measured by the IRI questionnaire. In addition, we calculated

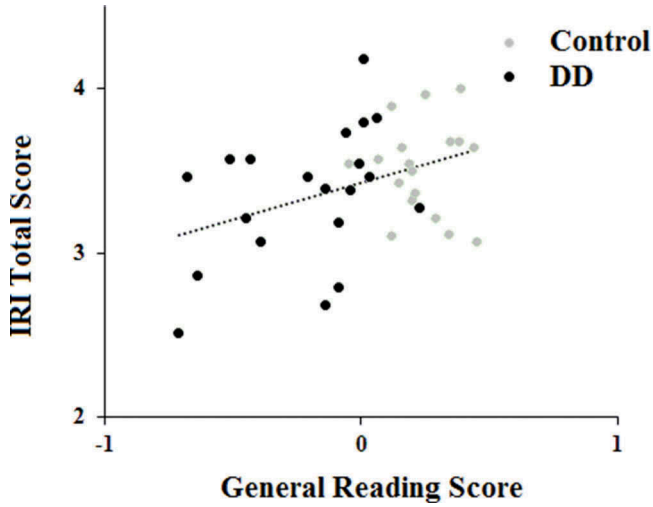

Figure 1. Correlation between empathic scores (IRI total score) and general reading score. IRI = Interpersonal Reactivity Index; DD = participants with developmental dyslexia.

a single index reading measure that was based on average *z* scores of each of the reading tests mentioned (decoding, fluency, and reading-related tests). This measurement was named the "general reading score."

As expected, the general reading score was significantly positively correlated with empathic scores, $r = .38$, $p = .009$ (see Figure 1).

In addition, the tests of specific reading abilities—decoding, reading fluency, and reading comprehension—as well as reading-related measures of phonological awareness, were significantly positively correlated with empathic scores (see Table 1). Note that parsing, segmentation, and phoneme deletion *timed* reading measures all reflect the time that was required for a participant to complete the task, and thus it is no wonder that negative correlations were found between empathy scores and these measures. In contrast, phoneme deletion and segmentation *accuracy* reading measures represent the number of correct letters read per minute, where high scores represent better reading efficiency and thus were correlated with reading scores. Other measures such as word and letter decoding, as well as reading fluency measures, both timed (speed of reading–words read per minute) and accuracy (accuracy in reading), reflect better reading efficiency and thus were positively correlated with empathy.

Table 1. Correlation between performance tests and empathy subscales.

Performance test	IRIPT	IRIFS	IRIEC	IRIPD	IRIC	IRIE	IRItotal
Word and letter decoding							
Oral words recognition accuracy	.07	.34*	.30*	−.01	.32*	.19	.34*
Oral words recognition speed	.05	.33*	.29*	−.01	.30*	.18	.32*
Oral nonwords recognition accuracy	−.05	.37*	.27*	.05	.28*	.20	.30*
Oral nonwords recognition speed	.02	.36*	.25	−.10	.31*	.13	.28*
Reading fluency measures							
Oral text reading (words per min)	.32*	.30*	.34*	−.04	.42**	.20	.40**
Silent text reading (words per min)	.24	.23	.36*	−.06	.32*	.18	.34**
Phonological awareness							
Phoneme deletion (time)	−.06	−.43**	−.29*	−.14	−.40**	−.29*	−.45**
Phoneme deletion (accuracy)	.14	.31	.25	.08	.35*	.22	.38**
Segmentation (time)	−.13	−.05	−.14	.11	−.11	−.01	−.08
Segmentation (accuracy)	.13	.24	.28*	.04	.28*	.25	.33*
Parsing (time)	−.05	−.25	−.30*	−.04	−.24	−.25	−.31*
Parsing (accuracy)	−.01	.20	.19	.03	.16	.14	.20
Intellectual ability							
Block design	.47**	.03	−.13	−.01	.27*	−.11	.14
Similarities	−.03	.01	−.32*	.12	−.01	−.15	−.07

Note. IRI= Interpersonal Reactivity Index; IRIPT= IRI Perspective Taking score; IRIFS= IRI Fantasy score; IRIEC= IRI Emphatic Concern score; IRIPD= IRI Personal Distress score; IRIC= IRI Cognitive Empathy score; IRIE= IRI Emotional Empathy score; IRItotal = IRI Total Empathy score.
*$p < .05$. **$p < .01$.

Relationship to IQ estimates

In order to examine whether intelligence could serve as an explanatory variable of the results, we examined the relationship between IRI subscales and IQ estimates (Block Design and Similarities subtests) as well as between reading scores and IQ estimates. EC subscale (subtest of emotional empathy scale) was negatively correlated with the Similarities subtest (r = –.326, p = .04), whereas PT subscale (subtest of cognitive empathy scale) was positively correlated with the Block Design subtest (r = .47, p < .01). The other subscales were not correlated with any of the IQ estimates (correlations ranged from –.005 to .128). In addition, we did not observe a relationship between IQ estimates and reading measures (correlations ranged from .001 to –.214). The only (albeit small) relationship was found between the Block Design subtest and the phoneme deletion accuracy measure (r = .28, p = .08).

One might argue that the reading–empathy correlations are simply driven by general intelligence. In order to rule out this possibility we conducted partial correlations controlling for estimated IQ (Block Design and Similarities scores). All measures remained significantly correlated with empathy (ps < 0.5), except for the segmentation time measure (p = .31). This analysis rules out the possibility that IRI simply reflects a third-variable correlation between reading and IQ.

Comparison between groups

In order to determine whether the dyslexia and typical readers groups differed in their empathy measures as a group, a t test was conducted with group (dyslexia vs. typical readers) and total empathy variables. Participants with dyslexia presented lower scores on the total empathy measure (M= 3.34, SD = 0.41) than typical readers (M= 3.51, SD = 0.28). The group difference was not significant, $t(36)$ = –1.43, p = .15; however, it showed a medium size effect (Cohen's d = 0.48).

We further divided the two groups using a more rigorous criterion of reading competence.[2] Specifically, participants were divided into low- and high-competence readers based on the general reading index score. Half the participants from the dyslexia group (10 participants) with the lowest reading abilities were compared to the 10 participants from the typical readers group with the highest reading abilities. Again, these two groups did not differ in chronological age (participants with dyslexia: M = 26.5 years, SD = 3.00; typical readers: M = 26.5 years, SD = 3.56), $t(18)$ = –0.00, p = 1.00, or in IQ estimates, as measured by the Block Design subtest (Wechsler, 1997; participants with dyslexia: M = 11.6, SD = 3.56; typical readers: M = 13.1, SD = 2.42), $t(18)$ = –1.1, p = .28 (Cohen's d = 0.48) and by verbal ability scores measured by the Similarities subtest (Wechsler, 1997; participants with dyslexia: M = 12.3, SD = 1.33, typical readers: M = 12.3, SD = 1.63), $t(18)$ = –0.00, p = 1 (Cohen's d = 0). However, significant group differences were observed for all reading and phonological awareness measures (ps < .5). For empathy measures, results revealed that both groups significantly differed from each other, $t(18)$ = –2.14, p = .04 (Cohen's d = 0.98), such that participants with dyslexia with low reading abilities had significantly lower scores on total empathy (M = 3.17, SD = 0.38), as measured by the IRI questionnaire, than did typical readers with high reading abilities (M = 3.52, SD = 0.33). Furthermore, both groups did not differ in emotional empathy, $t(18)$ = –0.45, p = .65 (Cohen's d = 0.19), whereas significant group differences were observed for cognitive empathy, $t(18)$ = –2.82, p = .011 (Cohen's d = 1.26), with the dyslexia group with low reading abilities exhibiting lower cognitive empathy scores (M = 3.19, SD = 0.50) than the typical readers with high reading abilities (M = 3.76, SD = 0.39). It should be noted that reading difficulties were correlated with the IRI score, implying that the empathy score might be a possible predictor of reading difficulties. In addition, intervention programs for reading disabilities may also take into account possible difficulties involving empathy.

Discussion

The present study examined empathic abilities in individuals with a large range of reading

[2]The examination of the correlations between reading-related measures and the IRI test is based on the full sample size, whereas the examination of group differences is based on a more rigorous sample.

abilities, including normal readers and readers with dyslexia, and their relationship to language-related skills. We found an association between reading competence and empathy scores. Specifically, reading skills such as decoding, reading fluency, and reading-related tests were all correlated with the IRITotal score. The more accurate and fast a participant's reading, the higher his or her score on the IRI questionnaire. Phonological awareness, which is an important predictor of reading acquisition (Wagner & Torgesen, 1987), was also correlated with empathic scores. Specifically, the time required for a participant to manipulate speech sounds was negatively correlated with empathic scores, whereas accuracy in manipulating speech sounds was positively correlated with empathic scores. Taken together, these results indicate a strong relationship between empathy and language-related skills such as reading and phonological awareness.

A closer examination of the two subscales of empathy (IRIC and IRIE scores) suggests that cognitive empathy, and specifically the FS component, was more positively correlated with reading scores than emotional empathy. Previous studies have shown that these two facets of empathy are dissociated and may depend on distinct neural substrates (Shamay-Tsoory et al., 2009). Specifically, it was suggested that cognitive empathy is subserved by the right TPJ as well as by the medial prefrontal cortex (mPFC), whereas the emotional component of empathy may rely upon the inferior frontal gyrus (IFG). Although it is acceptable to combine individual scores into the two facets of empathy, significant correlations between individual scores (that are combined for each scale) were not always demonstrated. In the present study, PT and FS scales that are combined for the cognitive empathy component (IRI-Cognitive) showed no correlation, and the EC and PD scales did not correlate as expected for the component of emotional empathy (IRI-Emotional). This contradicts predictions from the theory and research (Davis, 1983) but is consistent with other findings (Fernández, Dufey, & Kramp, 2011; Sonnby-Borgström, 2009). Further research is needed in order to examine whether the relationship between empathy and other phenomena should be investigated while combining the two facets of empathy (as in the present study) or by using individualized scores from the IRI test.

As reviewed above, neuroanatomical and functional findings suggest that the TPJ is abnormal in dyslexia. The fact that we found the strongest association between cognitive empathy and reading skills confirms this prediction. In addition, participants with dyslexia with low reading abilities and typical readers with high reading abilities also exhibited different levels of empathy as measured by the IRI questionnaire, with participants with dyslexia with low reading abilities displaying significantly lower levels of empathy. This observation is compatible with studies reporting social problems as well as difficulties in interpreting facial emotions among individuals with dyslexia (Ryan, 1994; Whiting & Robinson, 2001). It is also compatible with studies demonstrating low ToM skills among participants with specific language impairments (Miller, 2001).

The present study is the first to report an association between reading, phonological awareness, and empathic skills, and as such broadens previous research that found an association between empathy skills and other types of language-related performance. For example, studies on normal readers reveal that the neural mechanisms of empathic processing are also activated during language processing. Specifically, it has been shown that brain regions responsible for mentalizing, including the TPJ and the mPFC, are activated when understanding the nonliteral meaning of sentences such as ironic remarks (Bohrn, Altmann, & Jacobs, 2012; Shibata, Toyomura, Itoh, & Abe, 2010; Spotorno, Koun, Prado, Van Der Henst, & Noveck, 2012) or an indirect request (van Ackeren, Casasanto, Bekkering, Hagoort, & Rueschemeyer, 2012). Accordingly, using functional magnetic resonance imaging, Aziz-Zadeh, Sheng, and Gheytanchi (2010) showed that activity in regions that support production and perception of prosody was found to correlate with measures of emotional empathy. Also, Nieuwland, Ditman, and Kuperberg (2010) showed that individuals who empathize to a greater degree revealed larger N400 event-related potential effects (an electrophysiological index of semantic processing) of socially relevant information in a linguistic context. Similarly, van den Brink et al. (2012) showed that participants with high empathic skills showed stronger N400 effects in responding to sentences with meaning–speaker identity incongruence. Recently, Li, Jiang, Yu, and Zhou (2014) revealed that individuals' cognitive empathic ability as

measured by the IRI test modulated brain activity underlying the processing of pragmatic constraints during sentence comprehension. The current study broadens those previous investigations by showing a significant relationship between reading performance and empathic skills.

There are several possible explanations for the association between language-related skills such as reading and phonology and empathic skills. One possibility is that reading competence and empathy skills are interrelated. Difficulties in reading acquisition can potentially lead to poor school adjustment, also affecting social skills such as empathy. Also, poor social and communication skills may affect school performance, including reading acquisition and reading comprehension. Second, the TPJ has been implicated in empathy and also functions abnormally in dyslexia. Thus, impairment of the TPJ is expected to affect both empathy and reading skills, as in the case of dyslexia. It is possible, then, that the neural substrates of empathy are also activated during reading.

Limitations and future directions

The present study has several limitations that should be taken into consideration. First since the IRI questionnaire requires sentence reading, there might be a concern that reading problems among individuals with dyslexia may affect their ability to read and comprehend the items of the IRI. We judge this possibility as less likely. First, although our empathy measures required reading ability, the level of reading required to complete the IRI test is modest. The test includes simple sentences such as "I sometimes try to understand my friends better by imagining how things look from their perspective," and the participants are requested to rate them on a scale. Sentences are presented to participants with no time limit, and completion of the questionnaire is self-paced. This test was examined in populations with more severe linguistic impairments than those observed in dyslexia, such as people with severe frontal brain lesions (Shamay-Tsoory, Tomer, Berger, & Aharon-Peretz, 2003; Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005) as well as people with schizophrenia (Shamay-Tsoory, Shur, Barcai-Goodman, et al., 2007). Furthermore, this study examined high-functioning university students with dyslexia, so it is unlikely that the participants were unable to understand the questionnaire that included very basic questions. On the other hand, replication of the current study is needed in a more varied sample, as well as in clinical samples, in order to test the generalizability of the results. Finally, it should be noted that the pattern of results cannot be explained by participants with dyslexia reading impairments, since inability to understand the meaning of the presented sentences should not produce a bias toward a reduced empathy score. Items in the IRI questionnaire are phrased in such a way that a general bias of responses (a tendency to give larger or smaller responses) should not produce a systematic bias in the empathy score.

A second limitation of the present study is the time lag between administration of the reading and empathy measures. Although the administration time lag was consistent across all participants, there might be a risk that unrelated factors occurring during this time lag could potentially influence the participants' cognitive and emotional state (e.g., level of alertness, mood changes, etc.) and as a result influence the measurement of empathy. However, the fact that administration of the reading and empathy tests was conducted at different sessions 3 months apart may also imply that the pattern of results is not likely a consequence of a carryover effect between the tests and is not influenced by fatigue during testing. It can strengthen the claim that the relationship between empathy and reading abilities is persistent over time and represents a real association between them. Future studies, however, should avoid such a lag in administration in order to reduce the influence of confounding factors.

Additionally, a substantial limitation of the design is low power due to the small sample. Although significant correlations were found between reading and empathy skills, an additional analysis was conducted in order to examine differences in empathy while dividing the sample into two groups (participants with dyslexia vs. typical readers). Significant differences in empathic scores were observed when examining participants with dyslexia and typical readers with the lowest and highest reading scores. When considering the entire sample, no significant differences in empathy were observed between the two groups. Yet, the design lacked adequate power to detect medium effect size between participants with dyslexia and typical readers. For example, differences in empathy

between the two groups of participants showed a medium effect size (Cohen's d = 0.48); however, the statistical test lacked adequate power to detect significance for this effect. Similarly, potential explanatory variables, such as the relationship of estimated IQ to empathy, showed meaningful effects that were underpowered to interpret null findings. This weakness, as well as the numerous statistical tests conducted without adjustment for familywise error, increases the likelihood that these findings could be observed by chance. Furthermore, the clinical significance of the results, if replicated, remains to be established. Specifically, although groups were statistically different, participants showed a similar, average level of empathy (in the range of 3 on a 5-point scale). It may be the case that the observed group differences arise from limited variability within each group (high-functioning university students were included in the present study, which likely restricted the variability of the scores). Replication in a larger and more varied sample is essential in order to support these preliminary findings.

A final concern relates to the interpretation of the current findings. In the present study we found a significant relationship between empathy and reading/phonological awareness. Although important, the present data do not conclusively determine the nature of this relationship. Indeed, more research will be needed in order to investigate whether there is a causal relationship between reading and empathy and its direction. Longitudinal studies conducted among preschool readers may be needed in order to investigate whether a risk for developing dyslexia may predict future empathic skills (Kidd & Castano, 2013). Similarly, the present data do not suggest a definitive answer as to whether phonological rather than orthographic processing is correlated with empathic skills. Note that the TPJ implicated in empathy is related to the dorsal (phonological) rather than the ventral (orthographic) route of reading (Pugh et al., 2001). The dorsal phonological route is associated with word access through grapheme–phoneme mapping, whereas the ventral orthographic route promotes direct access from word shape to meaning and hence constitutes the direct route of reading. Based on the hypothesized shared neural substrate between reading and empathy (the TPJ), it is possible that phonological processing is related to empathic skills more than to orthographic processing. Although correlations between phonological measures and empathic skills were observed, other complex measures that contain both phonological and orthographic features (such as word reading) were also correlated with empathic skills. In order to examine whether empathic skills are indeed related to phonological processing more than to orthographic processing, one must assess phonological and orthographic processing separately and to examine their relationship to empathy in future studies. One way of testing this hypothesis is by using same–different orthographic tasks, as well as rhyme–nonrhyme phonological decision tasks. In such tasks, words are presented visually on the screen, yet the orthographic task requires responses to letters containing a specific visual structure (requires reading through direct identification of visual features without necessitating the application of phonological rules) whereas the phonological task requires responses to letters that rhyme with a target letter (requiring reading through phoneme–grapheme conversion rules; Barnea & Breznits, 1998).

Although brain imaging studies will be required in order to verify the speculated relationship of the TPJ and its influence on reading and empathy in DD, the present results are significant in demonstrating for the first time a relationship between reading-related skills and empathy in typical readers and in people with dyslexia. Based on the present findings, future research should explore additional social processes such as ToM and its relationship to the spectrum of reading abilities, as well how the TPJ is presumed to affect reading and empathy processing among normal and impaired readers. In addition, more sensitive tools for assessing empathy and its relationship with reading-related skills should be employed in future studies in order to assess the clinical utility of the present findings.

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