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Anxiety and Attentional Bias in Children with Specific Learning Disorders

Stephanie L. Haft[1] · Priscilla H. Duong[1,2] · Tiffany C. Ho[3,4] · Robert L. Hendren[1,5] · Fumiko Hoeft[1,5,6,7,8,9]

Abstract

Children with specific learning disorders (SLDs) face a unique set of socio-emotional challenges as a result of their academic difficulties. Although a higher prevalence of anxiety in children with SLD is often reported, there is currently no research on cognitive mechanisms underlying this anxiety. One way to elucidate these mechanisms is to investigate attentional bias to threatening stimuli using a dot-probe paradigm. Our study compared children ages 9–16 with SLD ($n = 48$) to typically-developing (TD) controls ($n = 33$) on their attentional biases to stimuli related to general threats, reading, and stereotypes of SLD. We found a significant threat bias away from reading-related stimuli in the SLD, but not TD group. This attentional bias was not observed with the general threat and stereotype stimuli. Further, children with SLD reported greater anxiety compared to TD children. These results suggest that children with SLD experience greater anxiety, which may partially stem from reading specifically. The finding of avoidance rather than vigilance to reading stimuli indicates the use of more top-down attentional control. This work has important implications for therapeutic approaches to anxiety in children with SLD and highlights the need for attention to socio-emotional difficulties in this population. Future research is needed to further investigate the cognitive aspects of socio-emotional difficulties in children with SLD, as well as how this may impact academic outcomes.

Keywords Attentional bias · Anxiety · Dot probe · Specific learning disorder · Dyslexia · Dyscalculia

✉ Fumiko Hoeft
  Fumiko.Hoeft@uconn.edu

  Stephanie L. Haft
  Stephanie.Haft@ucsf.edu

  Priscilla H. Duong
  Priscilla.Duong@ucsf.edu

  Tiffany C. Ho
  Tiffnie@stanford.edu

  Robert L. Hendren
  Robert.Hendren@ucsf.edu

[1] Department of Psychiatry and Weill Institute for Neurosciences, University of California San Francisco, 401 Parnassus Ave, San Francisco, CA 94143, USA

[2] Palo Alto University, 1791 Arastradero Rd, Palo Alto, CA 94304, USA

[3] Department of Psychology, Stanford University, Stanford, CA 94305, USA

[4] Department of Psychiatry & Behavioral Sciences, Stanford University, Stanford, CA 94304, USA

[5] Dyslexia Center, University of California San Francisco, 675 Nelson Rising Lane, San Francisco, CA 94158, USA

[6] Multi-University Precision Learning Center, 401 Parnassus Ave, San Francisco, CA 94143, USA

[7] Haskins Laboratories, 300 George St #900, New Haven, CT 06511, USA

[8] Department of Neuropsychiatry, Keio University School of Medicine, 35 Shinanomachi, Shinjuku Tokyo 160-8582, Japan

[9] Brain Research Imaging Center & Department of Psychological Sciences, University of Connecticut, Storrs, CT 06269, USA

Introduction

An estimated 5–15% of school-aged children are diagnosed with a Specific Learning Disorder (SLD; American Psychiatric Association 2013). SLD is characterized by underperformance in reading, writing, and/or mathematics that is unexpected given a child's IQ and adequate schooling. SLD is neurobiological in origin (Xia et al. 2017), and a large body of literature has documented cognitive risk factors associated with SLD (Moll et al. 2016). The majority of SLD occurs in the reading domain, yet comorbidity rates between the different SLDs are high. For example, SLD in reading co-occurs with SLD in math at a rate of 30 to 70% (Willcutt et al. 2013). Individuals with SLD often experience poor math and reading outcomes (Dandache et al. 2014; Shalev et al. 2005), and consequently have higher rates of school dropout and lower college attendance than those without SLD (Morrison and Cosden 1997; Murray et al. 2000).

In addition to academic difficulties, children with SLD may experience psychological maladjustment including anxious symptomatology. A recent meta-analysis reported that approximately 70% of students with SLD experience higher levels of anxiety than their non-SLD peers (Nelson and Harwood 2011). In a large dataset of 36,984 individuals, 20% of young people with SLD reported a comorbid anxiety disorder compared to 10% of their peers without SLD (Wilson et al. 2009). In explaining the higher prevalence of anxiety in children with SLD, most theorists propose that anxiety develops as a secondary consequence of repeated school failure (Carroll et al. 2005). Anxiety might also develop as a result of stereotype threat, the fear of confirming a negative stereotype about one's group (Spencer et al. 2016). Although the existence of stereotype threat has yet to be investigated in this population, research shows that students with SLD often feel stigmatized as a result of their diagnosis, which may result in stereotype threat (Shifrer 2013). This stigma may come from the label of SLD – while a formal diagnosis might comfort children in providing an explanation for their difficulties, it can also make them feel ostracized. Indeed, a longitudinal study found that individuals with SLD seemed less concerned with "the day-to-day technical problems of the disability," and more frustrated with "the stigma attached to it by their culture," including feeling "different" from their peers in school (Higgins et al. 2002). Children with SLD in one study, for instance, reported concerns about being perceived as "stupid," "lazy", or "careless" by their peers because of their academic struggles (Riddick 2001). This worry about what others think may lead some children to try to conceal their SLD, leading to considerable stress (Pachankis 2007) that might magnify as their SLD progresses and develops. This stress may be further caused or exacerbated by the increased parental stress and family conflict observed in families of children with SLD (L. Dyson 2010; L. L. Dyson 2003; Karande et al. 2009). Whether from academics or stereotype threat, this anxiety experienced by students with SLD may then interrupt key cognitive processes involved in learning,

leading to further underperformance in school. If left untreated, anxious symptoms and psychopathology might contribute to further socio-emotional risk, such as the increased suicide rates that are observed in the SLD population (Wilson et al. 2009).

Despite evidence for a higher rate of anxiety in SLD and its serious implications, the hypothesized mechanisms behind anxiety in this population are understudied. Current research consists largely of self-, parent-, or teacher-reports of anxiety in children with SLD, without investigations into its cognitive underpinnings. One approach for studying anxiety in other populations involves examining attentional bias to negative or threatening stimuli, which is hypothesized to cause and perpetuate anxiety (Bar-Haim et al. 2007). Indeed, studies show that anxious children demonstrate hypervigilance toward threat-related stimuli (see (Dudeney et al. 2015) for meta-analysis) – this bias is commonly evaluated with a dot-probe task. The dot probe compares response times to probes in spatial proximity to threatening or neutral stimuli to quantify a threat-related attentional bias (MacLeod et al. 1986). This task has been used to ascertain attentional bias in a variety of child populations, including those with depression (Joormann et al. 2007; Neshat-Doost et al. 2000; Taghavi et al. 1999), post-traumatic stress disorder (Bertó et al. 2017; Briggs-Gowan et al. 2015; Dalgleish et al. 2001), autism spectrum disorder (Hollocks et al. 2013; May et al. 2015; Moore et al. 2012; Zhao et al. 2016), Williams syndrome (Dodd and Porter 2010; McGrath et al. 2016), asthma (Dudeney et al. 2017; Lowther et al. 2016), and a range of anxiety disorders (Hunt et al. 2007; Salum et al. 2013; Sylvester et al. 2016; Vasey et al. 1995; Waters et al. 2010).

One relevant area of design in dot-probe research is whether the task content is generally threatening or specific to a disorder or population. For example, dot-probe studies with children with asthma have included asthma-related words (e.g. dust, cough, allergic; Dudeney et al. 2017), and studies with depressed children include depression-related words (e.g. crying, bully, lonely; Neshat-Doost et al. 2000). Determining whether attentional bias is due to threats in general or disorder-specific content has implications for cognitive models of anxiety. Attention to threat regardless of its specific content might indicate a more generic attention control dysfunction or amygdala hypersensitivity. Conversely, content specificity in attentional bias may signal more schema-driven processing involving learning and memory (Pergamin-Hight et al. 2015). This distinction has implications for therapeutic approaches for SLD populations. If children with SLD show attentional biases toward general threat stimuli, then treatments for general anxiety such as cognitive behavioral therapy are likely to be applicable to SLD. If, however, the underpinnings of anxiety are content-specific to children with SLD, more tailored interventions may be merited. Furthermore, adopting the approach that anxiety is specific to the SLD experience, it is unclear whether this is due to academic difficulties or struggles with the social stigma of SLD.

Another important consideration is the directionality of the attentional bias, which has been found to vary as a result of task characteristics and clinical psychopathology. According to the vigilance-avoidance pattern, attention may initially be oriented toward threatening information (*vigilance*), and subsequently be directed away from it (*avoidance*; Mogg et al. 2004). The initial vigilance is hypothesized to represent more *bottom-up* processing, where attention is automatically captured by salient stimuli (e.g. a bright flash of lightning). In contrast, avoidance may represent engagement of more *top-down* cognitive mechanisms, meaning attention is voluntarily guided towards or away from certain stimuli in a goal-directed manner (e.g. looking for a friend's yellow hat in a crowd; Aue et al. 2013; Cisler and Koster 2010; Ferri et al. 2013). Avoidance rather than vigilance to threat has been observed with longer stimulus duration times (>500 ms) in the dot-probe task (Koster et al. 2006; Mogg et al. 2004; Waters et al. 2014), presumably capturing the later stage of controlled attentional processing. Other research has shown that bias direction may vary with specific clinical characteristics. Bias away from threat has been found in individuals exposed to severe life-threatening risks (Bar-Haim et al. 2010) or trauma (Pine et al. 2005). Recent work more applicable to the current study has shown that there is dissociation between fear and distress disorders in orienting to threat. Children with distress disorders (e.g. generalized anxiety) tend to be vigilant to threat, whereas children with fear disorders (e.g. specific phobia) tend to avoid threatening information, regardless of stimulus duration (Salum et al. 2013; Waters et al. 2014). Importantly, the direction of attentional bias has predicted response to treatment in children and adults with anxiety (M. Price et al. 2011; Waters et al. 2012). Thus, determining the direction of attentional bias has important implications for elucidating the cognitive mechanisms underlying and clinical implications of anxiety in children with SLD.

The current study was designed to address a gap in the literature by examining a potential marker and mechanism of anxiety in children with SLD compared to typically-developing (TD) controls matched on age, gender, and vocabulary (often used as a proxy for verbal IQ). Self-report measures were used to compare the groups on anxiety. A linguistic dot-probe paradigm was employed to evaluate attentional bias with words associated with general threats, reading, and stereotypes of SLD. Reading stimuli was chosen for several reasons: the majority of SLDs occur in the domain of reading, reading is involved in nearly every academic subject, and attentional bias has yet to be investigated with reading (though it has with math and school/academics more broadly). The words used in the reading condition and in the stereotype condition of the dot probe were developed using focus groups, the process of which is detailed in the methods. The overall aim was to compare children with SLD and TD children on self-report measures of anxiety, distinguish between general and content-specific attentional bias to threat, and determine direction of attentional bias. This study is the first to examine attentional bias to threat in children with SLD, and has implications for understanding and treating anxiety and related socio-emotional issues in this population.

Consistent with literature documenting increased anxious symptomatology in children with SLD, we hypothesized that children with SLD would score higher than their TD counterparts on anxiety. Regarding attentional bias, we could not make strong predictions as there are no previous studies examining this construct in an SLD population. However, a recent meta-analysis showed that content specific to a disorder evokes more attentional bias than general threat stimuli (Pergamin-Hight et al. 2015). Combining this finding with the theory that anxiety is a secondary consequence of SLD, we predicted that an attentional bias with reading stimuli (e.g. *book, read*) and stereotype stimuli (e.g. *disabled, slow*; both content specific to SLD) but not general threat stimuli (e.g. *bomb, kill*) would be shown. In regard to directionality of the biases, vigilance would represent engagement of more bottom-up mechanisms and clinical similarity of anxiety in children with SLD to distress disorders. Avoidance would indicate more top-down processing and resemblance to fear disorders. We did not have strong predictions as to directionality given the scarcity of research on mechanisms of anxiety in children with SLD – thus, this aspect of our study was exploratory. Finally, we hypothesized that attentional bias with the general threat stimuli only would be correlated with self-reported anxiety, since our anxiety measure was not specific to distress from reading or stereotype consciousness.

Method

Participants

Participants were children between the ages of 9–16. Children with SLD ($n = 50$) were recruited from private schools for students with SLD in the San Francisco Bay Area. Two participants from this group were excluded in processing steps due to lack of usable data, (total $n = 48$; see Data Preparation section below). Although independent diagnoses of SLD were not obtained for all students, schools indicated that all children in the SLD group had received a formal diagnosis from the school psychologist – these diagnoses were collected and used in reporting below. Diagnoses were further confirmed by examining neuropsychological reports from the school psychologist when they were made available to the first author ($n = 3$). Additionally, independent neuropsychological testing of a subsample of students ($n = 9$) was conducted with our staff psychologist which provided confirmation of reported diagnoses (total $n = 12$ independent confirmation of diagnoses). Of our analysis sample (n = 48), 42 students (87.5%) had an SLD with impairment in reading (reading disorder; RD), and the remaining 6 students (12.5%) had an SLD with impairment in math only (mathematics disorder; MD). Of the students with RD, 24 had a

diagnosis of RD only, 11 had comorbid RD and writing disorder (WD), and 7 had comorbid RD, WD, and MD. There were 26 students (54.2%) of the analysis sample who had a comorbid diagnosis of ADHD. The occurrences of comorbid diagnoses in our SLD sample is reflective of the heterogeneity observed within SLD populations as a whole (see Hendren et al. 2018).

The control group of TD children ($n = 33$) was recruited from one private school in the San Francisco Bay Area, as well as from the community through online advertisements. Exclusion criteria for the TD group included current or past diagnosis of any anxiety or neurodevelopmental disorder. We excluded children with these diagnoses as the purpose of the study was to investigate group differences in attentional bias in those with versus without an SLD diagnosis. We therefore wanted group differences to be attributable to the SLD diagnosis and label, rather than to group differences in anxiety diagnoses. Groups were matched on age, gender, and vocabulary level – participant characteristics are summarized in Table 1.

Study protocol was approved through the University of California San Francisco Institutional Review Board (Study #16–20,551), and written consent for each participant was obtained from a parent or legal guardian. Verbal assent from each participant was also obtained. Testing sessions consisted of the following tasks that were randomized in order for each participant: (1) vocabulary assessment, (2) word-reading task, (3) self-report questionnaires (anxiety, sense of mastery, emotional reactivity), and (4) dot-probe paradigm. All questionnaires had audio options for items to be read out loud to the participant. The entire protocol lasted about 1 h for each child.

Measures

Vocabulary The Picture Vocabulary subtest from the Woodcock Johnson-IV Test of Achievement (WJ-IV ACH; Schrank et al. 2014) was administered in order to determine the vocabulary level of each participant. Standard scores from this assessment were used to compare the vocabulary level of the SLD and TD groups to ensure that there were no

significant differences. Test-retest reliability for this measure ranges from 0.78 to 0.87 for the ages in our sample.

Word Reading Word-reading fluency was assessed by administering the Sight Word Efficiency subtest from the Test of Word Reading Efficiency Second Edition (TOWRE-2; Torgesen et al. 2012). Standard scores were obtained and used to control for reading ability in our analyses. Test-retest reliability for this measure ranges from 0.90 to 0.91 for the ages in our sample.

Anxiety Participants completed the anxiety scale from the Behavior Assessment System for Children Second Edition (BASC-2) adolescent self-report. This scale instructs participants to rate how frequently feelings and thoughts of generalized fear and worry occur. Although BASC-2 reports are not used for clinical diagnoses, T-scores obtained can fall into three categories: within normal limits, at risk, or clinically significant. The BASC-2 is widely used to assess behavioral and emotional issues in children, and the anxiety self-report scale has excellent reliability (coefficient alpha = 0.86) and convergent validity with other anxiety scales (Reynolds and Kamphaus 2004).

Attentional Bias Attentional bias was measured using an adapted version of the dot-probe paradigm (MacLeod et al. 1986, see Fig. 1). Each participant was seated approximately 1.5 ft away from a CF-54 Panasonic Toughbook laptop with a 14″ screen (visual angle <5°). Participants were told that they would see a fixation cross, followed by a pair of words one on top of the other, and then an arrow pointing either left or right. Participants were instructed to press an arrow key on a keyboard that corresponded to the direction of an arrow on the screen as quickly as possible. The fixation cross appeared for 500 ms, followed by 1250 ms of word pairs. After the word pairs, an arrow remained on the screen until participant response, and a 500 ms inter-trial interval preceded the next fixation cross. These parameters were chosen to be consistent with stimulus durations in previous literature using dot-probe

Table 1 Comparison of SLD and TD controls on demographics and measures

Measures	Overall			Children with SLD			Controls			t	p
	n	Mean	SD	n	Mean	SD	n	Mean	SD		
Age, years	81	11.7	1.9	48	11.4	1.5	33	12.1	2.4	−1.562	0.121
Vocabulary (S)		101	10.9		99	10.0		104	11.7	−1.846	0.069
Word Reading (S)		95	16.9		89	14.7		105	15.1	−4.806	<0.001
Anxiety (T)°		54	10.1		56	10.7		51	8.6	2.056	0.043

S, Standard Scores; ≤ *70*, Extremely Low; *71–79*, Low; *80–89*, Low Average; *90–110*, Average; *111–120*, High Average; *T*, T Scores; *121–129*, Superior; ≥ *130*, Very Superior; < *60*, Within Normal Limits; *60–69*, At-Risk; ≥ *70*, Clinically Significant

◊ 5 children in the SLD group and 1 child in the Control group had Anxiety scores in the clinically significant range

500 ms

1250 ms
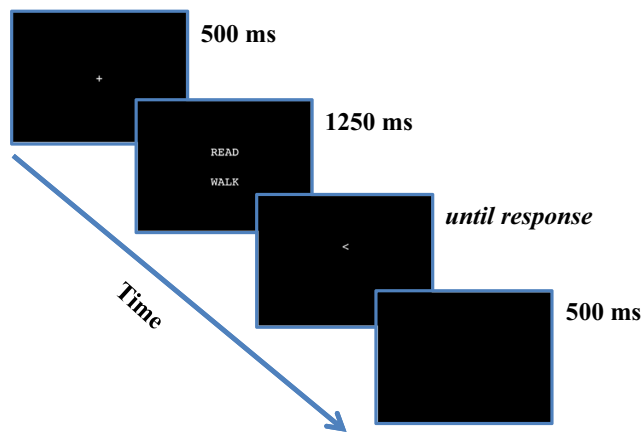
READ

WALK

until response

<

500 ms

Time

Fig. 1 An illustration of the dot probe paradigm

tasks with children (Dudeney et al. 2017; Vasey et al. 1995). Words appeared 1 cm tall with 3 cm of vertical separation in a monospaced font (Courier) previously shown to be appropriate for individuals with SLD (Rello and Baeza-Yates 2013). Arrows replaced either the top or bottom word and were 1 cm tall. All stimuli appeared in white on a black screen using E-Prime 2.0 software. Response times and accuracy for each arrow keyboard response were recorded.

Participants were given 4 practice trials and needed an accurate response on at least three of these (75% accuracy) to move on to the test trials. If participants did not reach this level of accuracy, further sets of practice with 4 trials were administered up to two more times until 75% accuracy was achieved – all participants in our sample met at least 75% accuracy on one of the sets of practice trials. Test trials consisted of 16 neutral-neutral (NN) word pairs, 16 threat-neutral (TN) word pairs, 16 reading-neutral (RN) word pairs, and 16 stereotype-neutral (SN) word pairs. Word pairs were matched on their number of letters and syllables, as well as their frequency of appearance in the English language. Each word selected had a maximum age of acquisition rating of 9 years. Frequency, age of acquisition rating, and emotional valence of words were determined from a database of 13,915 English lemmas (Warriner et al. 2013). Each word pair was presented four times to counterbalance word and arrow location for a total of 256 trials. Participants were given a two-minute break in the middle of the task.

NN word pairs were selected based on their rated valence and appropriate age of acquisition (< 9 years; Warriner et al. 2013). Threat words were selected using valence ratings and terms from previous literature when available (e.g. Hunt et al. 2007; Neshat-Doost et al. 2000; Vasey et al. 1995), then paired with neutral words on the properties described above to create TN pairs.

To generate reading words for RN pairs, the first author used school curriculums and a thesaurus to compile a list of 20 words related to reading. This list of words was then sent to

a pilot group of 12 children between the ages of 10 and 14 (*n* = 8 SLD and *n* = 4 TD; of the SLD group, 2 had RD only, 2 had MD only, and 4 had comorbid RD + ADHD). The pilot group was asked to rate (a) their understanding of the meaning of the word (0 = do not understand, 1 = sort of understand, 2 = understand), and (b) the valence of the term (negative, neutral, or positive). From these ratings, two words with the lowest understanding were excluded. An additional two words were excluded whose average ratings did not fall into the neutral valence range. The resulting list of words was matched on valence (from Warriner et al. 2013), frequency, and number of letters and syllables to form 16 RN word pairs.

To generate words associated with stereotypes of SLD, a focus group (*n* = 76) of individuals were recruited from an organization for persons with SLD. The focus group was asked to list terms that they believed were associated with stereotypes of SLD. A list of the top 20 most frequently listed words was compiled and sent to the pilot group, who rated the words on understanding and valence. The list was narrowed down to 16 words by excluding three words with low understanding and one word rated as having a positive valence. The resulting list of words was matched with neutral words on frequency (from Warriner et al. 2013) and number of letters and syllables to form 16 SN word pairs.

The final list of words used in the present study are detailed in Supplementary Table 1.

Data Preparation

Trials with incorrect responses and inordinately fast (< 200 ms) or slow (> 2000 ms) response times (RTs) were excluded per standard practice (e.g. Bradley et al. 1999; Mogg et al. 2004; Pérez-Edgar et al. 2011). These RTs suggest either unintentional responses or lapses in attention. Additionally, individual outliers of trials were excluded, defined as RTs that were 3 standard deviations away from that participant's mean RT. Participants with removed trials constituting more than 5% of their data were excluded from further analysis – 2 participants from the SLD group were dropped as a result. Following removal of these participants, excluded trials accounted for 4.7% of the final data.

Attentional bias indices were calculated by subtracting the mean RT when the arrow replaced the threat/reading/stereotype word from the mean RT when the arrow replaced the neutral word. The index results in positive values for greater attention towards threat/reading/stereotype stimuli and negative values for attention away from these words.

A Shapiro-Wilk test of normality was performed on all questionnaires, assessments, and dot-probe RT data. Data for each group together and separately (SLD, TD) did not violate the test of normality (all *p's* > 0.05). Split-half reliability analysis using intraclass correlation coefficient (ICC) of average

probe response time per child in the two parts of the task, separated by condition, indicated excellent reliability (ICC = 0.948, $p < 0.001$).

Analyses

Differences between the SLD and TD groups on demographic, questionnaire, and assessment data were investigated using t-tests and χ^2 tests. A two-way mixed analysis of covariance (ANCOVA) was conducted to determine if there was an interaction between group (SLD/control) and word condition (threat/stereotype/reading) on bias indices, controlling for word-reading level and vocabulary. A one-sample t-test was used to compare bias indices to 0 to determine if any significant attentional bias was present separately for each group. To analyze group differences in any significant attentional bias, an independent samples t-test was used, followed by an ANCOVA to control for word-reading level and vocabulary. Relationships between reading, questionnaire and attentional bias data were examined using correlational analyses. Data were processed using R version 3.3.2 (R Core Team 2013) and analyzed using SPSS version 23.

Results

Participant Characteristics and Anxiety

Participants consisted of 48 SLD (11.4 ± 1.5 years; 63% male) and 33 TD children (12.1 ± 2.4 years; 48% male). There were no significant differences between gender ($\chi^2_{(1)} = 1.565$, $p = 0.211$), age ($t_{(79)} = -1.579$, $p = 0.121$), or vocabulary ($t_{(79)} = -1.846$, $p = 0.069$) between the two groups. As expected, however, there was a significant group difference in word-reading ability, with higher word reading scores in the TD group ($t_{(79)} = -4.806$, $p < 0.001$). Children with SLD reported significantly higher anxiety than TD children ($t_{(79)} = 2.056$, $p = 0.043$). Group demographics and comparisons are summarized in Table 1.

Attentional Bias

Attentional bias scores are displayed in Table 2. The two-way mixed ANCOVA with vocabulary and word-reading as covariates showed a significant main effect of group in bias indices for SLD compared to control, $F(1, 77) = 4.177$, $p = 0.044$, partial $\eta^2 = 0.051$. There was no statistically significant interaction between word condition (threat/reading/stereotype) and group (SLD/control) on bias indices, $F(2, 154) = 1.205$, $p = 0.302$, partial $\eta^2 = 0.015$. The main effect of word condition did not show a statistically significant difference in bias indices, $F(2, 154) = 0.655$, $p = 0.521$, partial $\eta^2 = 0.008$.

Table 2 Mean attentional bias indices (standard deviation in parentheses)

	SLD	Control	Effect Size (d)
Threat bias	−3.07 (41.46)	−8.49 (33.90)	0.143
Reading bias	−11.78 (36.74)	5.38 (23.55)	0.556*
Stereotype bias	0.10 (36.67)	2.37 (35.94)	0.063

*$p < 0.05$ in a one-sample t-test compared to 0

When compared to zero, the SLD group showed a significant negative bias away from reading stimuli ($t_{(47)} = -2.219$, $p = 0.031$), but no significant effects of threat ($t_{(47)} = -0.513$, $p = 0.610$) or stereotype ($t_{(47)} = 0.019$, $p = 0.985$) stimuli on RT biases. The TD group showed no significant bias with threat ($t_{(32)} = -1.438$, $p = 0.160$), reading ($t_{(32)} = 1.311$, $p = 0.199$), or stereotype ($t_{(32)} = 0.379$, $p = 0.707$) stimuli.

Although subsample size was small, we repeated this analysis dividing the SLD group into those with comorbid ADHD ($n = 26$) and without ($n = 22$). Results did not change. A significant negative bias away from reading stimuli was still shown in children with and without comorbid ADHD (all p's < 0.05), and there were no significant effects of threat or stereotype stimuli on RT biases in both groups (all p's > 0.05). Because of this, analysis of group differences between the SLD and TD group uses the SLD group as a whole (including those with and without comorbid ADHD).

There was a significant difference between groups in attentional bias scores with reading stimuli ($t_{(79)} = -2.558$, $p = 0.012$, $d = 0.56$), with the SLD group having significantly greater attentional bias away from reading words. To control for the potential confounding impact of vocabulary and word reading, we compared groups on reading attentional bias scores with a one-way ANCOVA. Vocabulary, word-reading scores, and age were mean-centered and entered as covariates. There was still a significant group difference on attentional bias with reading stimuli when controlling for word reading, vocabulary, and age (F(1,77) = 4.984, $p = 0.029$). Vocabulary (F(1,77) = 0.775, $p = 0.381$), word reading (F(1,77) = 0.441, $p = 0.509$), and age (F(1,77) = 3.822, $p = 0.054$) were not significant covariates.

Correlation Analyses

Bivariate correlations were performed between attentional biases, anxiety, and reading measures for children with SLD and TD children separately and overall (Table 3). There were no significant correlations between any of the attentional bias indices and anxiety scores for either group (all p's > 0.05). There were also no significant correlations between any of the attentional bias indices and word reading or vocabulary scores (all p's > 0.05).

Table 3 Correlations between bias indices, anxiety, and reading measures overall and for each group

		1	2	3	4	5
1. Threat bias	Overall					
	SLD	–				
	Control					
2. Reading bias	Overall	0.009				
	SLD	0.044	–			
	Control	−0.014				
3. Stereotype bias	Overall	−0.191	−0.159			
	SLD	−0.281	−0.188	–		
	Control	−0.023	−0.150			
4. Word reading	Overall	−0.160	0.035	−0.074		
	SLD	−0.228	−0.139	−0.069	–	
	Control	0.000	−0.029	−0.147		
5. Vocabulary	Overall	0.011	−0.068	−0.094	0.302**	
	SLD	0.248	−0.128	−0.055	0.371**	–
	Control	−0.317	−0.141	−0.164	0.076	
6. Anxiety	Overall	0.004	−0.136	0.112	−0.174	−0.225*
	SLD	0.028	−0.139	0.231	0.002	−0.273
	Control	−0.102	0.074	−.080	−0.223	−0.064

$** = p < 0.01$, $* = p < 0.05$

Discussion

The current study investigated differences in anxiety and attentional biases in children with SLD and TD controls. As hypothesized, the SLD group reported significantly higher anxiety compared to the TD group. Children with SLD showed a significantly greater attentional bias away from reading stimuli than TD children. Finally, attentional bias in each stimuli condition was not correlated with anxiety scores.

The finding of significantly higher anxiety in children with SLD compared to controls is in line with previous literature on this topic (Nelson and Harwood 2011). Children with SLD face a number of academic and social stressors as a result of their disorder, and consequently may experience emotional distress. Results also revealed that there was a significant group difference on attentional bias with reading-related words, with children with SLD showing avoidance of reading-related stimuli. Our finding was especially interesting given that the reading words were matched on valence to the neutral words, so these trials could be construed as a neutral-neutral pairing. Why would children with SLD show avoidance of neutral words associated with reading – a pattern otherwise observed with threatening stimuli? One explanation might be that because the task itself presented words, the topic of reading was primed. However, if this were the case, we would expect to see an attentional bias in TD children as well. Therefore, a more likely explanation is that there is greater sensitivity surrounding the reading words for the SLD group,

suggesting a perception of threat. Indeed, our SLD group consisted mainly of children with primary impairment in reading –thus, reading is a source of difficulty and emotional struggle for these children. These findings are in line with a recent meta-analysis that showed disorder-congruent stimuli (content specific to a clinical population) evoke greater attentional bias than general threat stimuli for a range of disorders (Pergamin-Hight et al. 2015). In our study, a significant bias away from reading but not general threat content was observed, suggesting reading-related content may be a more salient threat to our SLD sample compared to controls.

The avoidance of reading stimuli observed in the SLD group suggests the engagement of more *top-down* cognitive mechanisms. This potential use of top-down processing might have been revealed as a result of our longer stimulus duration time (1250 ms). This attention avoidance may represent a fear reduction strategy after an initial vigilance to the reading words (Aue et al. 2013) – our current methods do not allow for this initial detection, which represents an area of future research. These results suggest that attentional bias in children with SLD shows avoidance patterns similar to children with fear-related disorders such as specific phobias, rather than vigilance as is observed in children with generalized anxiety. This concurs with finding a content-specific bias with reading, but not general threat words in children with SLD, and has implications for treatment. Current attention bias modification treatments that train anxious individuals to be threat avoidant (Eldar et al. 2012) may not be a suitable treatment for children who already show avoidance to threat, such as our sample.

The lack of attentional bias to threat stimuli in the SLD sample warrants further discussion. Studies on attention to threat have generally shown mixed results in children, with significant biases primarily in children diagnosed with clinical anxiety disorders (Dudeney et al. 2015). Our TD group was screened for anxiety disorders, since we sought to investigate group differences in SLD status, rather than anxiety. Only one participant's self-reported anxiety from the TD group fell into the clinically significant range. Of our SLD group, only five children had clinical levels of anxiety according to the used self-report measure – this sample is too small for separate analyses comparing those with and without clinically significant anxiety symptoms. A future study might specifically recruit a larger sample of children with SLD and comorbid anxiety disorders to see if results with our paradigm would be different.

We also did not find an attentional bias with stereotype stimuli in either SLD or TD children. Because stereotype stimuli were developed specifically for children with SLD, we expected to find an attentional bias with this content in this group. It is possible that, given their context, the words were not perceived as unique to SLD. For example, terms such as "dumb," "lazy," and "stupid" might be perceived as general social threats. If this is true, these stimuli might be more salient

for children with general social anxiety than SLD. Of note, our study protocol did not cue an SLD identity – children were not told that they were selected for the study because of their SLD. Future work might therefore consider explicitly priming an SLD identity before administering the task. While our findings do not confirm a bias toward SLD stereotype stimuli, they do not necessarily preclude the existence of a stereotype threat phenomenon in this population either.

There were no significant correlations between attentional bias indices and self-reported anxiety. The lack of correlation between threat biases and anxiety may be due to differences between self-report measures and cognitive paradigms, where self-report measures may be susceptible to bias – more research is warranted in this area. A lack of correlation with the reading and stereotype bias indices was expected because of the content-specific nature of the threat. The BASC anxiety scale measures behaviors and feelings in general situations – we may see different results with a questionnaire asking about anxiety specific to reading or stereotype threat. Unfortunately, there are currently no tools to assess for anxiety specific to reading or stereotypes of SLD.

Several limitations of our study should be acknowledged. First, while we found a main effect of group, the finding of a significant attentional bias away from reading stimuli in children with SLD was only significant with an uncorrected threshold. Because our study was exploratory in nature as the first to use this paradigm in children with SLD, and because we found significant group differences in this bias, we still chose to discuss the implications of these results with an alpha level of .05. Second, the SLD sample had notably low word-reading ability as a result of their disorder, and a linguistic version of the dot-probe paradigm was used. TD children were not matched on reading ability. However, we controlled for the potential confounding impact of word reading by using an ANCOVA, and results remained the same. We also propose that, were children unable to understand the words, there would be no attentional bias at all in any direction (e.g. they would equally attend to each word). However, results indicate that this is not the case, suggesting children were able to successfully read the words and that this impacted their attention. Finally, questionnaire measures were available in an audio format to assist the comprehension of students with SLD. Future research might consider replicating this study using a picture dot-probe task, though some of our words may be difficult to adapt. Our third limitation is that we did not obtain independent SLD diagnoses for all students – thus, we could not investigate differences based on SLD severity. For our study, we were more interested in the impact of the experience of SLD and its associated label on socioemotional functioning assessed using multiple methods (i.e., self-report and attentional biases), rather than its neuropsychological

properties. Because our SLD sample came from schools that only admit students with an SLD diagnosis, we can assume that these children were categorized accurately. A fourth limitation is that although majority (87.5%) of our SLD group had impairment in reading, the diagnoses were heterogeneous and contained students with impairments in math, writing, and comorbid ADHD. Given this heterogeneity, the use of only reading-related stimuli in our paradigm may not have fully captured academic-related attentional biases in those with writing or math disorders. Future dot probe paradigms collected in this population might consider developing a more broad range of academic-related words. A fifth limitation is that our sample of both SLD and TD children came from one geographic area – thus, while our groups were demographically similar to each other, they may not be representative of larger child populations. We should therefore be careful in generalizing these results, and future research should make an effort to include children from a wide range of socio-economic, cultural, and geographic backgrounds.

Relatedly, because our children with SLD came from private SLD schools, we may expect different results from children with SLD immersed in public school settings. Research has confirmed that children with SLD experience greater bullying and peer victimization than their TD peers (Cummings et al. 2006; Mishna 2003), and lower peer acceptance (Estell et al. 2008). However, it is currently unclear how the prevalence of these instances – and the social disadvantage and socio-emotional consequences that may result – differs between mainstream and SLD-only schools. One might hypothesize that students in SLD-only schools feel less "different" than their peers, leading to greater feelings of social acceptance and lower anxiety. However, research has also found that children with SLD are more frequently identified as perpetrators of bullying than their TD peers (Mishna 2003) – this may mean that SLD-only schools have similar or even increased instances of bullying than mainstream settings. Given that perceived peer support can impact socio-emotional and mental health outcomes for children with SLD (e.g. (Al-Yagon 2016)), the school social climate would presumably impact anxiety and attentional bias levels. Unfortunately, research comparing differences in social and emotional outcomes for children with SLD between different educational settings is extremely limited, and represents a needed area of investigation.

A final limitation is that there are criticisms of RT paradigms in children (Brown et al. 2014), and with the psychometric properties of the dot-probe task specifically (Kappenman et al. 2014; Schmukle 2005). These criticisms point to poor internal and test-retest reliability of the dot probe. Given that previous research has still found the dot probe to be a useful tool for elucidating cognitive

mechanisms in clinical populations (Bar-Haim et al. 2007), and in particular children (Dudeney et al. 2015), we used it in our study. Additionally, we were careful to note some of the best practices recommendations outlined by (Price et al. 2015), such as determining outliers in a data-driven manner. The continued use of the dot probe is further justified by studies that show associations between attentional bias and measures of sustained pupil dilation (Price et al. 2013), event-related fMRI (Price et al. 2014), and ERP components (Thai et al. 2016) in response to threat. Thus, future work might consider an additional use of eye-tracking, neurobiological or electrophysiological measures to supplement investigating these research questions.

Even with these limitations, our study offers a notable contribution to work on the unique challenges facing children with SLD. Notwithstanding the attentional bias results, our findings of differences between children with SLD and TD children in anxiety add to the literature on the nature of psychosocial difficulties in this population. Previous work has confirmed greater prevalence of anxiety and socio-emotional issues in children with SLD, but to the authors' knowledge our study is the first to date to investigate one potential marker of this maladjustment. Our results suggest that children with SLD may have attentional biases specific to reading, which might signal a biased information processing system. Moreover, this attentional bias manifests as avoidance of, rather than vigilance to threat stimuli, suggesting engagement of more controlled top-down processes which may have been captured by our paradigm design. Further longitudinal work on attentional bias and anxiety in SLD can inform whether biased information processing specific to reading is a mechanism behind increased rates of anxiety in SLD.

It remains to be seen whether the avoidance of reading stimuli in students with SLD maintains or exacerbates negative attitudes and behaviors regarding reading. Previous studies have suggested a link between attentional bias and particular behaviors, such as ability to inhibit a prepotent response and social withdrawal (Pacheco-Unguetti et al. 2012; Pérez-Edgar et al. 2010; Thai et al. 2016). Applied to the classroom context, this could mean that children with high levels of attentional bias may be more distracted by stimuli evoking certain threats, which would render them less able to focus on the task at hand, and might lead to avoidance of the threat. Given these studies and our results, educators and clinicians might consider investigating ways to attenuate the threatening nature of reading for children with SLD (e.g. by providing choices to children in what and how they read and fostering an accommodating reading environment). This has implications for both the socio-emotional well-being and academic success of children with SLD and represents an important area of future research for this population.

Compliance with Ethical Standards

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