Bilingualism and Attention in Typically Developing Children and Children with Developmental Language Disorder

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Running Head: Bilingualism and Attention

Key words: attention, Attention Network Test, bilingualism, developmental language disorder

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Abstract

Purpose: The aim of the current study was to investigate whether dual language experience modulates the efficiency of the three attentional networks (alerting, orienting, and executive control) in typically developing (TD) children and in children with developmental language disorder (DLD).

Method: We examined the attentional networks in monolingual and bilingual school-aged children (ages 8-12) with and without DLD. TD children (35 monolinguals, 23 bilinguals) and children with DLD (17 monolinguals, 9 bilinguals) completed the Attention Network Test (Fan et al., 2002; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005).

Results: Children with DLD exhibited poorer executive control than TD children, but executive control was not modified by bilingual experience. The bilingual group with DLD and both TD groups exhibited an orienting effect, but the monolingual group with DLD did not. No group differences were found for alerting.

Conclusions: Children with DLD have weak executive control skills. These skills are minimally influenced by dual language experience, at least in this age range. A potential bilingual advantage in orienting may be present in the DLD group.

Key words: attention, Attention Network Test, bilingualism, language impairment

Developmental language disorder (hereafter DLD; or specific language impairment) is a neurodevelopmental disorder whose primary clinical presentation is language difficulties without known causes such as hearing impairment, intellectual disability, and frank neurological disorder (Bishop, Snowling, Thompson, Greenhalgh, & the CATALISE-2 Consortium, 2017). Heritability estimates indicate genetic contributions to DLD (e.g., Tomblin & Buckwalter, 1998). Different environmental factors may also contribute to the manifestation of this disorder (Bishop, 2006); thus, it is important to not only study the affected learning mechanisms that are intrinsic to children with DLD but also examine experiential or extrinsic factors that could impact those learning mechanisms. Here we examined attention, an important intrinsic component for learning (Ebert & Kohnert, 2011), to evaluate the relative contributions of language experience (monolingual vs. bilingual) to attention in children with and without DLD.

Attention

One well-established theoretical perspective on attention describes it "as the activity of a set of brain networks that influence the priority of computations of other brain networks for access to consciousness and observable behavior" (Fan et al., 2009, p. 210). Given that DLD is a neurodevelopmental disorder (American Psychiatric Association, 2013; Evans & Brown, 2015), we selected a neurobiologically motivated attentional network model as the theoretical basis for our study (Fan, McCandliss, Sommer, Raz, and Posner, 2002; Posner & Rothbart, 2007). In the attentional model, attention is comprised of alerting, orienting, and executive control. Alerting is the ability to achieve and maintain a vigilant state to receive incoming stimuli, linked to the thalamic and frontal and parietal cortices. Orienting is the allocation of focus to a particular aspect of sensory stimuli, involved with the posterior brain regions and frontal eye fields. Executive control is the ability to select a target response while inhibiting conflicting responses,

associated with the anterior cingulate, lateral prefrontal cortex, and basal ganglia (see Fan et al., 2002; Posner & Rothbart, 2007).

The proposal of the three separable attentional networks led to the creation of the Attentional Network Test (ANT; Fan et al., 2002; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005) that tests each of the three subcomponents. Notably, no significant correlations among the three attentional networks were reported for children (Rueda et al., 2004) or adults (Fan et al., 2002). The ANT has been used to assess the efficiency of attention in typical (Fan et al., 2002; Mezzacappa, 2004; Rueda et al., 2004) and clinical (Keehn, Lincoln, Müller, & Townsend, 2010; Mullane, Corkum, Klein, McLaughlin, & Lawrence, 2011; Mutreja, Craig & O'Boyle, 2016) populations. Furthermore, the ANT is a visual task, which is important to ensure that task performance is not directly dictated by language abilities. Consequently, we thought this test would be ideal for our experiment.

Attention and Language Abilities in Monolinguals

The maturation of the attention systems may underlie language development (see de Diego-Balaguer, Martinez-Alvarez, & Pons, 2016, for a review). Evidence for a language-attention relationship has focused on executive control, which emerges near the end of the first year of life and continues developing later than the other two attentional systems, alerting and orienting (e.g., de Diego-Balaguer et al., 2016). De Diego-Balaguer et al. (2016) suggest that the gradually developing executive control is associated with later emerging language skills, such as subject-verb agreement (e.g., *he* walk*s* or *he* run*s*). Executive control may enable children to focus on the remote upcoming morpheme (i.e., -*s*) when they hear a subject (i.e., *he*), regardless of which verb follows (e.g., walk or run). Similarly, executive control may be employed as speakers and listeners need to regulate thoughts and actions to align with internal communication

goals (Ye & Zhou, 2009). For instance, speakers should select the target word over competing alternatives while suppressing irrelevant words (Thompson-Schill et al., 1998). Listeners also employ executive control to choose an appropriate interpretation to disambiguate a sentence that contains a temporary syntactic uncertainty (Novick, Trueswell, & Thompson-Schill, 2005). Difficulty in understanding temporarily ambiguous sentences and comprehension ability are found to be associated with immature executive control (Woodard, Pozzan, & Trueswell, 2016).

Beyond executive control, the relationships between language and both orienting and alerting remain understudied. However, there is some indication that all attentional subcomponents play a role in language development. Unlike executive control, alerting and orienting are present at the start of the first year of life and become stabilized during infancy and early childhood (Rueda et al., 2004); both continue maturing until late childhood (e.g., de Diego-Balaguer et al., 2016). Their early presence and development is postulated to allow children to attend to salient speech features such as prosodic cues (e.g., pitch, rhythm, or pauses) that then contribute to early emerging language skills such as word segmentation and word learning.

Consistent with the notion that attention limitations constrain language learning and processing, meta-analyses indicate that monolingual children with DLD exhibit attention deficits. Pauls and Archibald (2016) found that children with DLD exhibit inhibition deficits on flanker and Simon tasks. Ebert and Kohnert (2011) reported that children with DLD performed poorer than their typically developing (TD) peers on continuous performance tasks measuring sustained attention, keeping focused and vigilant over time (Mirsky et al., 1991). Sustained attention requires continuous alertness to maintain a relevant response while inhibiting irrelevant responses over time (Stins et al., 2005), plausibly necessitating a combination of alerting and executive control. Converging evidence suggests that children with DLD may exhibit difficulty

in executive control and perhaps alerting, whereas orienting may be unaffected (Schul, Stiles, Wulfeck, & Townsend, 2004). To our knowledge, no study has directly tested the performance of children with DLD using the ANT to examine the attentional subcomponents and their association with language abilities.

Bilingual Influence on Attention

Several studies have investigated how bilingualism influences attention abilities (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Martin-Rhee & Bialystok, 2008). In particular, studies have focused on executive control as bilinguals must constantly suppress the nontarget language during target language processing, due to simultaneous activation of two languages (see Poarch & Van Hell, 2012a). Such language control is associated with neural regions involved with general executive control (e.g., Abutalebi & Green, 2007; 2008; Pliatsikas & Luk, 2016). Several studies have reported that bilingual children outperform monolingual children on nonverbal executive control or inhibition tasks including Simon-type (Poarch & Van Hell, 2012b; Tse & Altarriba, 2014) and flanker-type (e.g., Poarch & Van Hell, 2012b; Yang, Yang, & Lust, 2011; Yoshida, Tran, Benitez, & Kuwabara, 2011) tasks. Other studies, however, have reported a lack of bilingual influence on Simon-type (Gathercole et al., 2014; Morton & Harper, 2007) and flanker-type (Antón et al., 2014; Kapa & Colombo, 2013; Nicolay & Poncelet, 2013) tasks.

Similar to executive control, alerting and orienting may also be regularly exercised and subsequently enhanced in bilinguals. Alerting may be enhanced to attain and maintain vigilance in monitoring and switching between two languages (Tao et al., 2011) and orienting may be enhanced to swiftly allocate attention to contextual cues in order to select the appropriate language. However, these notions have little empirical support. While Poarch and Van Hell

(2012a) found a bilingual advantage in orienting in TD children, several researchers have not (Antón et al., 2014; Kapa & Colombo, 2013; Yang et al., 2011). Likewise, studies have reported no bilingual advantage in alerting in TD children (Antón et al., 2014; Kapa & Colombo, 2013; Poarch & Van Hell, 2012b; Yang et al., 2011).

Interaction Between Language Impairment Status and Language Experience

What happens when children with DLD grow up in a bilingual environment? It is reasonable to hypothesize that attentional limitations in DLD are alleviated by the practice that bilingual children get navigating their two languages, perhaps to an even greater degree than in TD children. In line with this reasoning, Sorge, Toplank, and Bialystok (2017) found that children with poorer attentional skills benefited from bilingual experience to a greater extent than children with better developed attentional skills.

To our knowledge, only three studies examined the interaction between language abilities and language experience in children with DLD and the results of those studies are inconsistent. Boerma and colleagues (2017) found that both bilingual and monolingual children with DLD (ages 5-8 years) had weaker auditory and visual sustained attention skills relative to their TD peers. This suggests that children with DLD exhibit attentional weaknesses not significantly alleviated by bilingual exposure. Similarly, Ebert, Rak, Slawny, and Fogg (2019) reported no group differences between monolingual and bilingual children with and without DLD on executive control. The authors used both an ANT flanker task and a sustained attention task. Within the bilingual group, they also found that current exposure to home language was not associated with either executive control or sustained attention. In contrast, Engel de Abreu, Cruz-Santos, and Puglisi (2014) found that, while TD bilingual children outperformed TD monolingual peers on a flanker task, bilingual children with DLD exhibited comparable

performance to the monolingual TD children; monolingual children with DLD were not tested. This result may indicate that bilingualism benefits executive control in bilingual children with DLD. Given the inconsistent results and the lack of research in the three attentional subcomponents, we investigated whether language experience (monolingual vs bilingual) and language impairment status (TD vs. DLD) have additive or interactive effects on each attentional subcomponent.

Current Study

We examined the attentional subcomponents over four groups: TD monolingual and bilingual children and monolingual and bilingual children with DLD. We hypothesized that children with DLD might have an intrinsic deficit in attention, particularly executive control and perhaps alerting and orienting, so we compared the TD and DLD groups on the ANT. We expected children with DLD to exhibit inefficient performance in each attentional component, particularly executive control, relative to TD children. We also expected bilingual children to outperform monolingual children in attention, particularly in executive control and perhaps orienting. Furthermore, we investigated whether monolingual or bilingual experience and TD or DLD language impairment status have additive or interactive effects on each component. We hypothesized that the degree of attention enhancement would differ between TD bilingual children and bilingual children with DLD. If this is the case, the differences between monolingual children with DLD and bilingual children with DLD across the three attentional networks, especially executive control, should be larger than the differences between the monolingual and bilingual TD groups. Conversely, if bilingual experience does not modulate attention, one would expect no interaction between the bilingual status (MO vs. BI) and language impairment status (TD vs. DLD).

Method

Participants

Children were recruited using flyers across various community locations and invitation letters that were distributed in schools. Children with DLD were specifically targeted via invitation letters distributed through the Toronto District School Board Speech-Language Program. Both children with DLD and TD were recruited in Toronto, Ontario, Canada. Only TD children were recruited in the community around State College, Pennsylvania.

A total of 84 children between the ages of 8 and 12 participated in this study: Thirty-five were monolingual TD (MO-TD); 23, bilingual TD (BI-TD); 17 monolingual with DLD (MO-DLD); and nine, bilingual with DLD (BI-DLD). These children also participated in a study investigating procedural learning (Park, Miller, et al., 2018). Out of 10, nine bilingual children with DLD were included in this study given that one child had a very low overall accuracy level in the ANT (12.5%), following conventions established in previous studies (e.g., Westlye, Grydeland, Walhovd, & Fjell, 2011; Xiao et al., 2016).

Group matching

The four groups were matched on age, $p = .721$. The monolingual and bilingual groups did not differ by socioeconomic status (SES) and IQ in both the TD and DLD groups. Given that a cognitive advantage has been observed because of higher SES in bilinguals (e.g., Morton & Harper, 2007), we ensured no SES differences existed between the monolinguals and bilinguals, for both the TD and DLD samples. However, SES and IQ differed between the TD and DLD groups. For SES, the BI-DLD group had lower SES than the BI-TD group ($p < .001$). For IQ, the DLD group had lower IQ scores than the TD group in both monolinguals (MO-DLD vs. MO-TD,

$p < .001$) and bilinguals (BI-DLD vs. BI-TD, $p < .001$). See Table 1 for children's demographic information and performance on standardized tests.

[Table 1]

Determining eligibility

All children were required to meet the following inclusion criteria: (a) nonverbal IQ above 75 as measured by the Wechsler Abbreviated Scale of Intelligence-II (Wechsler, 2011) and (b) within-normal hearing on a hearing screening. Children were excluded from participating if their parents indicated the presence of any of the following conditions: (a) intellectual disability, (b) emotional or behavioral disturbances including autism, (c) frank signs of neurological disorder, or (d) seizure disorders or use of medication to control seizures.

Attention-deficit/hyperactivity disorder (ADHD) and attention-deficit disorder (ADD) were not considered as exclusionary criteria because attention deficits often are characteristic of children with DLD due to the link between attention and language development (de Diego-Balaguer et al., 2016). According to the parental language background questionnaire, six children had been diagnosed with ADHD/ADD (five MO-DLD and one BI-DLD). We conducted a post-hoc analysis to determine whether group performance changed by including or excluding the children with DLD and diagnosis of ADHD (see Results).

Confirming TD and DLD status

All children completed a battery of standardized English language tests, and parents filled out a language background questionnaire quantifying children's language history and experience. Receptive and expressive English language abilities were assessed using the Clinical Evaluation of Language Fundamentals-Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003), which is

widely used to confirm DLD status in monolinguals (e.g., Archibald & Joanisse, 2009; Redmond, Ash, & Hogan, 2015).

In the MO-TD group, children were required to have standard scores of 82 (1.25 *SD*s below the mean) or higher on the Receptive Language Index, Expressive Language Index, and Core Language Score on the CELF-4. This cutoff was based on a large-scale epidemiological study in monolingual children (Tomblin, Records, & Zhang, 1996). In the BI-TD group, parental report was used to ensure typical development in children as CELF-4 norms rely on a monolingual norming sample, and, therefore, do not provide an appropriate point of reference for bilingual children (Bedore & Peña, 2008; Kohnert, 2010). Even though the CELF-4 norms were not used as an inclusion criterion, all BI-TD children exhibited language scores above 81 on the Receptive Language index, Expressive Language index, and Core Language Scores on the CELF-4.

The children with DLD (MO-DLD and BI-DLD) were required to be classified as having language learning difficulties in the Toronto District School Board,[1] and children's parents were required to indicate concern regarding the children's language development, including speaking, understanding, reading or writing. Furthermore, all children with DLD received standard scores at or below 81 (1.25 *SD*s below the mean) on one or more of following: (1) the Receptive Language Index, (2) the Expressive Language Index, and (3) Core Language Scores on the CELF-4.

Among the four groups, significant differences in overall language scores were found, $F(3, 80) = 53.11$, $p < .001$. The DLD groups attained significantly lower CELF-4 Core Language Scores than the TD groups in both the monolingual and bilingual groups, MO-TD

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[1] One bilingual child was not referred by the Toronto District School Board. However, we included the child in the DLD group because the child's parent expressed concerns about the child's language abilities and the child was receiving language services at school.

versus MO-DLD ($p < .001$) and BI-TD versus BI-DLD ($p < .001$). However, CELF-4 Core Language scores did not differ by bilingual status in both the TD and DLD groups, MO-TD versus BI-TD ($p = 1.000$) and MO-DLD vs. BI-DLD ($p = .995$).

Confirming monolingual and bilingual status

To confirm monolingual status, all children (TD and DLD) were required to use English at home and at school. Minimal exposure (less than 15% of time) to other languages was confirmed by parental estimate of time spent listening and speaking languages other than English.

To confirm bilingual status, sufficient bilingual exposure in the BI-TD and BI-DLD groups was assessed using the following criteria based on parental report: (a) minimum of 3 years of English exposure; (b) use of home language with at least one member of the household, (c) attendance of school and community events in English,[2] and (d) use of home language at least 20% of the time at home. Requirement (a) was implemented to ensure that the bilingual children had sufficient exposure to English to allow English language assessment and that they had been sufficiently exposed to their two languages. Their dual language exposure was within the range of related studies reporting enhanced performance of bilingual children on executive function tasks (e.g., Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012; Yang et al., 2011). Requirements (b) - (d) were implemented to ensure that children continued to regularly be exposed to two languages. To ensure that children had sufficient exposure to English for the English language assessment, we examined their language dominance. On the basis of the parental report, out of 23 in the BI-TD group, one child was dominant in the home language, one child was equally proficient in both languages, and 21 children were English dominant. All children in the BI-DLD group were English dominant according to parental report.

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[2] One TD participant in Toronto had English as home language and French as school language and one DLD participant had English as home language and Ojibwe as school language.

In addition, we ensured continued bilingual exposure by considering estimates of home environments and proficiency. On the parental report, all but two of the bilingual parents indicated that one or both of their own native and dominant languages were not English. Also, the parents indicated that on a scale of 0 (*very limited*) to 4 (*native-like proficiency*), their own home language proficiency was high in both the BI-TD group (mother: $M = 4.00$, father: $M = 3.86$) and the BI-DLD group (mother: $M = 4.00$, father: $M = 3.50$). The BI-TD group's parents reported that their children's home language proficiency was relatively high ($M = 3.24$), whereas the BI-DLD group's parents indicated that their children's home language proficiency was relatively low ($M = 1.70$). In the BI-DLD group, we suspect that the children's low home language proficiency is likely a reflection of their language disorder. All children (TD and with DLD) spoke a language different from English at home. In the BI-TD group, nine children spoke Korean; nine, Chinese; two, German; and one each, Bengali, French, and Spanish. In the BI-DLD group, two spoke Korean; two spoke Bengali; and one each spoke Albanian, Chinese, Farsi/Dari, Ojibwe, and Spanish.

ANT

Stimuli

The child version of the ANT (Rueda et al., 2004) was used in this study. Children were asked to look at a row of five cartoon fish on a computer screen and press a button on a response box to indicate the direction in which the target (middle) fish was swimming. The ANT included two factors: "cue type" (no cue, central cue, double cue, spatial cue) and "flanker type" (congruent, incongruent). On congruent trials, four nontarget fish pointed in the same direction as the target (middle) fish. On incongruent trials, four nontarget fish pointed in the opposite direction from the target fish**,** creating interference. In each trial, the target and surrounding stimuli were preceded

by one of four warning cue types: no cue, a central cue, a double cue, or a spatial cue. In the central cue condition, an asterisk was presented at the center of the screen, warning of the upcoming trial but not the location. In the double cue condition, two asterisks appeared both above and below the center location, again giving no indication of the trial location. A spatial cue condition was a single asterisk presented either above or below the upcoming target, which indicated where the array of the five fish would appear. In the no cue condition, no asterisk appeared. Each child completed 16 practice trials and 96 test trials. We deviated from the Rueda et al. (2004) experiment in that we shortened the practice trials from 24 to 16 trials and test trials from 144 to 96 trials in our version and excluded the neutral trials given that the neutral trials were not used to calculate the scores of any of the subcomponents of attention, consistent with the calculation methods in prior research (Fan et al., 2002; Poarch & Van Hell, 2012a).

Procedure

Before the test trials, a series of practice trials with feedback was provided in order to teach children to map the direction (left or right) of target fish head on the screen to a corresponding button. E-Prime software 2.0 (Schneider, Eschman, & Zuccolotto, 2012) and an E-Prime response box were used to present the stimuli and record response time and accuracy for test trials.

Effects of Interest

The components of attention were estimated by comparing the double cue and no cue trials for alerting, the spatial and central cue trials for orienting, and the congruent and incongruent flanker trials for executive control. The alerting effect is present when participants respond to the target more quickly after the double cue than when no cue is present. The orienting effect is observed when participants respond to the target more quickly after the spatial

cue than after the central cue. The executive control effect is present when participants respond more slowly to the target in the incongruent trials as opposed to the congruent trials.

Statistical Analyses

Analyses included the children's accuracy and reaction time (RT) performance. Only RTs for correct responses were analyzed. We analyzed the data in R (Version 3.4.1; R Core Team, 2017) using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). We used Generalized Linear Mixed Models (GLMMs) given that GLMM is a powerful method that combines generalized linear models that allow non normal distributions and mixed models that include both fixed and random effects. Because the beneficial features are combined from the generalized linear models and mixed models, the GLMM controls for nonindependence of dependent variables in repeated measurements. Also, the GLMM does not require normal distribution and homoscedasticity of residuals (Lo & Andrews, 2015; Ng & Cribbie, 2017), which enabled us to use our non normally distributed raw data without data transformations. We obtained p values for GLMM analyses using the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2017). Given the age of the children, we expected high accuracy rates, and thus, selected RTs as our main dependent variable of interest. However, we also conducted analyses for accuracy to ensure there were no speed-accuracy trade-offs. No significant trade-offs were observed in the TD and DLD groups. In the TD group, no significant correlations were observed between accuracy and RT (alerting: $r = .12$, $p = .354$; orienting: $r = -.04$, $p = .787$; executive control: $r = .20$, $p = .128$). Similarly, in the DLD group, no significant correlations were observed between RT and accuracy (alerting: $r = .23$, $p = .284$; orienting: $r = .36$, $p = .083$; executive control: $r = .35$, $p = .089$).

For accuracy analyses, the GLMM with a binomial distribution and a logit link function

was conducted to fit binary responses (0 for an incorrect response, 1 for a correct response) on each trial. For RT analyses, the median response times from trials with correct responses per child were modelled using the GLMM employing the inverse Gaussian distribution with the identity link to fit the positively skewed raw RT data (Lo & Andrews, 2015). In each model, bilingual status (monolinguals vs. bilinguals), language impairment status (TD vs. DLD), and type (no vs. double cues, central vs. spatial cues, or congruent vs. incongruent trials) as well as the two-way interactions (Bilingual Status x Type, Language Impairment Status x Type, Bilingual Status x Language Impairment Status), and the three-way interactions (Bilingual Status x Language Impairment Status x Type) were entered as fixed effects. A maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013) was employed including the random intercepts for subjects as well as by-subjects random slopes for the effect of type. Across all models, contrast coding was used for dichotomous predictor variables, with the monolingual group coded as -0.5 and the bilingual group coded as 0.5 for ease of interpretation. The TD group was coded as -0.5, and the DLD group was coded as 0.5. The easier type (e.g., congruent, double cue, and spatial cue trials) was coded as -0.5 and the more difficult type (e.g., incongruent, no cue, and central cue trials) was coded as 0.5. With this coding, the model coefficients represented simple main effects of the target variable at the average level of other dichotomous variables. Accuracy results are not described in detail since our primary variable of interest was RT.

Given that TD children and children with DLD often differ in IQ (e.g., Norbury et al., 2016; Park, Mainela-Arnold, & Miller, 2015), it is hardly feasible to closely match the groups on those measures; also, matching two groups on those measures may misrepresent the groups (Dennis et al., 2009; Earle, Gallinat, Grela, Lehto, & Spaulding, 2015). Furthermore, performance IQ measures require a certain amount of attention, and therefore, controlling for IQ

would, in fact, mask the phenomenon that was of particular interest in this study. However, given that bilingual children with DLD had lower SES than the TD groups ($p < .001$), SES was entered as a control variable in the analysis.

Given the small sample size of the DLD group, a Bayesian repeated measures of variance (ANOVA; using JASP [Version 0.9.2.0] for PC with its default settings; JASP Team, 2018) was used to confirm the effects concerning DLD status. Bayesian hypothesis testing compares a model against an alternative model and quantifies the probability or evidence for/against the alternative model using the Bayes factor (Jarosz & Wiley, 2014; Wagenmakers et al., 2018). Relevant to our findings, the Bayes factor is interpreted as "anecdotal" for a value less than 3, "substantial" for a value between 3 and 10, and "decisive" for a value higher than 150 (see Jarosz & Wiley, 2014, p. 8).

Results

Our first research question asked whether alerting, orienting, or executive control differed by language impairment status (TD vs. DLD) and language experience (monolinguals vs. bilinguals). Furthermore, we asked whether language experience differently impacts each attentional network in children with typical and disordered language development. Thus, the particular interests were two-way interactions (Type, Cue or Flanker, x Language Impairment Status, Type x Bilingual Status), and the three-way interaction (Type x Language Impairment Status x Bilingual Status). See Table 2 for children's accuracy and RT on the subcomponents of attention. The results of accuracy and RT analyses are presented in Table 3. The accuracy results are not described in detail since our primary variable of interest was RT (see Table 3). The accuracy results were consistent with the RT results for alerting, that is, no significant two-way and three-way interactions, and orienting, a significant three-way interaction. For executive control, a significant two-way interaction between language impairment status and flanker type

was found only in RT but not in accuracy.

[Table 2]

[Table 3]

Alerting RT

A significant main effect of cue (double vs. no), $t = 4.23$, $p < .001$, indicated that children performed more quickly in the double cue than in the no cue trials. Also, a significant main effect of language impairment status, $t = 2.57$, $p = .010$, indicated that the DLD group responded significantly more slowly than the TD group across cues. No other coefficients in the model were significant. Given the lack of interactions involving language impairment status, bilingual status and cue, the results indicate that alerting did not differ by language status (TD vs. DLD) and bilingual status (monolingual vs. bilingual).

Orienting RT

A significant main effect of cue (Spatial vs. Central cue), $t = 4.07$, $p < .001$, indicated that children performed faster in the spatial cue than in the central cue trials. A significant main effect of language impairment status, $t = 2.87$, $p = .004$, indicated that the DLD group responded significantly slower than the TD group across cues. Importantly, there was a significant two-way interaction (Spatial vs. Central Cue x Bilingual Status), $t = 2.10$, $p = .036$, and three-way interaction (Cue x Bilingual Status x Language Impairment Status), $t = 3.54$, $p < .001$. The difference in the two-way interaction (Cue x Bilingual Status) was examined in the TD and DLD groups separately. Within the two TD groups, the main effect of cue was significant, $t = 3.60$, $p < .001$, but the interaction (Cue x Bilingual Status), $t = -1.43$, $p = .153$, was not significant, indicating that both monolingual and bilingual TD children responded faster to the spatial cues than to the central cues. Conversely, within the two DLD groups, a significant interaction (Cue x

Bilingual Status) was found, $t = 3.22$, $p = .001$. The post hoc analysis yielded no orienting effect for the MO-DLD group, $t = -0.25$, $p = .806$, but yielded a significant orienting effect for the BI-DLD group, who showed faster responses after the spatial cues than the central cues, $t = 3.68$, $p < .001$. No other coefficients in the model were significant.

 [Figure 1]

The Bayesian Repeated measures ANOVA confirmed the significant three-way interaction, indicating that the findings were 1,470.76 times more likely to occur under the model with the three-way interaction than under the model without it.

Executive Control RT

A significant main effect of flanker, $t = 11.74$, $p < .001$, indicated that children performed faster in the congruent trials than in the incongruent trials. Also, a significant main effect of language impairment status, $t = 3.15$, $p = .002$, indicated that the DLD groups responded significantly slower than the TD groups across both flanker trials. Most importantly, a significant two-way interaction (Flanker x Language Impairment Status) was found, $t = 2.56$, $p = .010$. While children in all four groups performed faster in the congruent trials than in the incongruent trials, the difference between the congruent and incongruent trials was greater in the DLD group than in the TD group as indicated by a steeper slope (β) in the DLD ($\beta = 96.27$) than the TD group ($\beta = 62.02$). No other coefficients in the model were significant, indicating that the flanker effect did not significantly differ by bilingual status.

[Figure 2]

The Bayesian Repeated Measures ANOVA confirmed the significant two-way interaction, indicating that the findings were 3.81 times more likely to occur under the model with the interaction than under the model without it.

As ADHD/ADD was not an exclusionary criterion for the DLD group, an additional analysis was conducted to ensure that the above results were not driven by the children with DLD who were also diagnosed with ADHD/ADD. When the six children with DLD and ADHD/ADD were removed, the significant two-way interaction (Flanker x Language Impairment Status) remained the same, $t = 2.47$, $p = .014$. In this analysis, the monolingual and bilingual groups were combined given that there was no significant difference in executive control between the two groups. The Bayesian analysis corroborated the significant two-way interaction, suggesting that the findings were 9.45 times more likely to occur under the model with the interaction than under the model without it.

Discussion

This study examined whether attentional subcomponents differ by bilingual experience and language impairment status and whether there is any interaction between these factors. To this end, we compared the performance of bilingual and monolingual children with and without DLD on a task that measured alerting, orienting, and executive control. We found no evidence for bilingual effects on executive control. However, we observed significant RT differences in executive control between children with DLD and TD children. No bilingual effects on orienting were observed in TD children, but interestingly, there was a potential bilingual benefit in orienting that was restricted to bilingual children with DLD. Specifically, similar to the TD group, the BI-DLD group exhibited a significant orienting effect, but the MO-DLD group did not. In the case of alerting, no group differences were observed for either language impairment status or bilingual status.

Executive Control

This study provides evidence that internal, but not external, language factors account for

individual variability in children's executive control. RTs indicated weaker executive control in children with DLD compared to TD children, regardless of bilingual status. This result agrees with the meta-analyses of studies reporting weaker executive control in monolingual children with DLD relative to TD controls (Ebert & Kohnert, 2011; Pauls & Archibald, 2016). We found no clear bilingual advantage in executive control, consistent with prior findings reported for TD children (Antón et al., 2014; Duñabeitia et al., 2014; Ebert et al., 2019; Mueller Gathercole et al., 2014) and children with DLD (Ebert et al., 2019). Given that both executive control (Fan, Wu, Fossella, & Posner, 2001; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005) and DLD (Tomblin & Buckwalter, 1998) are heritable, future research should examine potential shared genetic and neural mechanisms contributing to individual differences in the two domains.

Orienting

Unlike executive control, the MO-TD, BI-TD and BI-DLD groups exhibited a significant orienting effect (i.e., shorter RTs for the spatial cues than the central cues), whereas the MO-DLD group did not. A possible interpretation for this finding is that monolingual children with DLD failed to encode or use the central, as opposed to the spatial, cue information to direct their attention. Other than one study reporting that children with DLD and TD children performed similarly on an attentional orienting task (Schul et al., 2004), no prior studies have directly examined orienting in children with DLD. Our result is also consistent with developmental studies (Lewis, Robert, & Johnson, 2018; Mezzacappa, 2004) reporting that, as children age, they exhibit a more efficient use of the warning cues (e.g., spatial and double cues). Interestingly, the BI-DLD group did exhibit a significant orienting effect similar to both monolingual and bilingual TD children, indicating that a bilingual advantage in orienting may be restricted to children with DLD.

We note that this notion is inconsistent with the findings of Poarch and van Hell (2012b), who reported a bilingual advantage in orienting in TD children. Bilingual and trilingual children showed an orienting effect with larger RT differences between spatial and central cues relative to children who began learning a second language later. Given that our participants had less home language exposure than the participants in Poarch and Van Hell (2012a), which may explain why we did not observe a bilingual advantage in typically developing children as they did. However, the reason why we observed a bilingual advantage in children with DLD may be inferred from a recent study by Sorge and colleagues (2017). Their study found that children with poorer attention skills benefited from bilingual experience to a greater extent than children with better attention skills. Together, these studies suggest that bilingualism confers a benefit for certain aspects of allocating attention, but that the degree of benefit may differ between TD children and children with DLD.

Alerting

While significant alerting effects were observed, alerting skills were not affected in DLD nor modified by bilingual language experience. Our results are consistent with prior findings that showed no bilingual advantages in alerting (Antón et al., 2014; Kapa & Colombo, 2013; Poarch & Van Hell, 2012a). On the other hand, it has been reported that children with DLD showed difficulty in sustained attention (Ebert & Kohnert, 2011; Ebert et al., 2019; Finneran, Francis, & Leonard, 2009; Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2001), which may require a combination of alerting and executive control. The current study suggests that the reason why children with DLD express difficulty in sustained attention derives from difficulty in executive control rather than from alerting per se. Given that alerting skills were neither affected in DLD nor modified by dual language experience, it is likely that alerting is not a mechanism

that significantly impacts language abilities, at least in school-aged children.

Bilingualism and Attention in Children With and Without Language Impairment

The absence of a bilingual advantage in executive control in our study might relate to language distance or structural differences between the bilinguals' languages (e.g., Coderre & Van Heuven, 2014). However, given a reported bilingual advantage in executive functioning regardless of different language sets and mixed home language backgrounds (Poarch & Bialystok, 2015; Scaltritti, Navarrete, & Peressotti, 2015; Sorge et al., 2017), it is unlikely that we failed to observe bilingual advantages due to the heterogeneous language backgrounds of our bilingual samples.

The lack of a bilingual advantage in executive control may derive from intensity and balance of bilingual exposure, particularly when the intensity in daily use of both languages is unbalanced. Dong and Li (2015) reasoned that more frequent use of two languages may lead to enhanced executive control, given the greater amount of simultaneous activations, thereby providing bilinguals additional opportunities to inhibit their unintended language. Given that it was quite challenging to find homogenous language experiences in bilingual children with DLD, the bilingual children varied in the intensity of daily use of both languages in the current study (See Table 1). Future studies should endeavor to address the effects of dual language exposure.

Another point for consideration is the length of bilingual exposure. As noted in the Method section, we assumed that 3-4 years of bilingual exposure would be sufficient to yield a bilingual advantage (if indeed this exists), because previous studies that observed a bilingual advantage in executive function used similar, or shorter, lengths of bilingual exposure (Engel de Abreu et al., 2012 – 4 years ; Yang et al., 2011 – 11 months). However, a much longer exposure might be needed to observe bilingual advantage (Park, Ellis Weismer, & Kaushanskaya, 2018).

Future studies should explore how bilingualism influences attention in children with DLD and TD children by testing children with longer bilingual exposure than in the present study.

A fourth factor relevant to the present study pertains to cognitive strengths found in Asian populations. Studies have reported superior executive control in Asians, presumably due to a culture that values more self-discipline (see Samuel, Roehr-Brackin, Pak, & Kim, 2018, for a review; but see Tran, Arredondo, & Yoshida, 2015, who found better skills in both alerting and executive control in Asian samples). If, indeed, culture impacted performance, we should have observed a bilingual advantage in alerting and/or executive control, given that our bilingual sample contained a relatively high number of children with Chinese and Korean backgrounds. However, this was not the case. We therefore consider it unlikely that our findings were biased by a relatively high number of children with an Asian background in our bilingual sample.

We also note that the sample size of children with DLD was relatively small compared to the sample sizes of the other groups (which motivated us to use statistical techniques that are particularly suitable for small and unequal sample sizes; Muth et al., 2016). Future studies should endeavor to include larger and more balanced sample sizes, as well as different tasks motivated by the attentional network framework to increase external validity.

Summary

The current study provides the first empirical evidence differentiating the three attentional subcomponents with regard to differences in language abilities and bilingual experience. Regardless of language experience, children with DLD exhibited poorer executive control than TD children. Thus, language abilities, but not bilingual experience, are linked to executive control, at least within the age range studied here. We conclude that the link between the domain-general mechanism, executive control, and language learning may be constrained by

biological factors rather than external factors (i.e., language experience). On the other hand, we found that the bilingual DLD group showed an orienting effect similar to the TD groups while this was not the case for the MO-DLD group. This finding suggests that bilingualism might confer a benefit in orienting for children with DLD.

The findings have important clinical implications. Given that executive control was associated with DLD status, but not bilingual status, future studies addressing diagnostic accuracy should examine if executive control can be used to identify risk of DLD in children coming from diverse linguistic backgrounds. In intervention, it is important to consider the fact that these children have difficulty suppressing irrelevant information. It is therefore advisable to reduce distractions in the learning environment. Finally, given that bilingual experience did not exacerbate weaknesses in executive control and perhaps even improved orientation skills, we conclude that bilingual children with DLD should not be discouraged from learning and using their dual languages.

Acknowledgments

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Table 1. Children's demographic information and performance on the standardized tests.

	MO-TD						BI-TD						MO-DLD		BI-DLD	
	Total		Pennsylvania		Ontario		Total		Pennsylvania		Ontario		Ontario		Ontario	
Variable	(35)		(15)		(20)		(23)		(7)		(16)		(17)		(9)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Age	10.45	1.43	10.32	1.63	10.55	1.29	10.08	1.42	10.40	1.50	9.94	1.42	10.19	1.18	10.00	1.80
SES[a]	16.71	2.37	17.47	2.20	16.15	2.39	17.09	3.04	19.14	2.73	16.19	2.79	14.88	1.90	12.89	2.03
IQ[b]	110.94	13.96	115.73	13.55	107.35	13.48	116.04	13.71	114.57	13.08	116.69	14.35	89.76	11.94	97.33	13.50
CLS[c]	111.37	12.91	116.33	10.57	107.65	13.48	111.74	11.45	111.86	10.11	111.69	12.31	72.71	15.58	75.56	7.81
RLI[d]	111.89	13.67	117.27	10.51	107.85	14.59	114.61	11.96	113.57	12.58	115.06	12.07	76.82	10.16	84.00	8.60
ELI[e]	112.71	14.95	118.67	13.40	108.25	14.79	112.35	12.04	111.29	7.93	112.81	13.66	76.88	15.39	71.00	5.75
PPVT-4[f]	113.66	14.31	122.00	11.86	107.40	12.90	111.91	14.00	115.86	10.25	110.19	15.33	89.88	7.43	88.44	10.29
EVT-2[g]	114.54	12.85	120.00	12.87	110.45	11.50	109.87	13.10	113.86	10.27	108.12	14.10	88.94	10.66	84.56	5.15
Age of Acquisition[h] (English)							3.30	2.40	5.00	1.73	2.56	2.31			2.33	2.46
Daily Exposure[i] (Hearing)							64.00	20.72	62.86	17.99	64.50	22.35			41.25	22.32
Daily Exposure[i] (Speaking)							50.43	28.84	51.43	25.45	50.00	30.98			25.56	21.86

Note. MO-TD = monolingual typically developing; BI-TD = bilingual typically developing; MO-DLD = monolingual with developmental language disorder; BI-DLD = bilingual with developmental language disorder.

[a]Socioeconomic Status: quantified as maternal years of education.

[b]Nonverbal Intelligence Quotient: The Perceptual Reasoning Index of the Wechsler Abbreviated Scale of Intelligence Scale - Second Edition (WASI-2; Wechsler, 2011).

[c]Core Language Score on the English Clinical Evaluation of Language Fundamentals – Fourth edition (CELF-4; Semel et al., 2003).

[d]Receptive Language Index on the English CELF – 4.

[e]Expressive Language Index on the English CELF – 4.

[f]Peabody Picture Vocabulary Test – Fourth Edition.

[g]Expressive Vocabulary Test – Second Edition.

[h]Age of Acquisition: parental report of when child began hearing English.

[i]Daily Exposure: parental estimate of percentage of time the child is exposed to home language during typical weekdays at home.

Table 2. Children's performance on the three attentional networks measured by the ANT

Subcomponents	Performance	Types	All		TD		MO-TD		BI-TD		DLD		MO-DLD		BI-DLD	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Alerting	ACC	Double	0.95	0.23	0.96	0.19	0.96	0.20	0.97	0.18	0.91	0.29	0.92	0.27	0.88	0.32
		No	0.93	0.26	0.95	0.21	0.95	0.21	0.95	0.21	0.88	0.33	0.89	0.31	0.85	0.36
	RT	Double	607	147	573	116	556	109	599	123	683	178	678	139	693	239
		No	651	141	623	105	611	104	640	107	716	185	717	167	714	219
Orienting	ACC	Spatial	0.94	0.23	0.97	0.17	0.97	0.17	0.97	0.18	0.89	0.31	0.88	0.33	0.91	0.29
		Central	0.94	0.24	0.96	0.19	0.96	0.20	0.97	0.17	0.88	0.33	0.89	0.31	0.85	0.36
	RT	Spatial	598	147	562	111	539	101	595	118	679	184	696	173	646	204
		Central	622	147	586	108	572	103	608	113	700	188	684	159	732	235
Executive Control	ACC	Congruent	0.96	0.19	0.98	0.15	0.98	0.15	0.97	0.16	0.93	0.26	0.95	0.23	0.90	0.31
		Incongruent	0.92	0.28	0.95	0.22	0.94	0.23	0.95	0.21	0.85	0.36	0.85	0.36	0.85	0.36
	RT	Congruent	586	135	557	104	541	94	582	114	652	168	652	137	651	218
		Incongruent	653	151	615	113	598	112	639	110	738	187	735	170	742	220
Overall	ACC	All	0.94	0.24	0.96	0.19	0.96	0.20	0.96	0.19	0.89	0.32	0.90	0.30	0.87	0.33
	RT	All	620	147	586	112	570	107	611	116	695	183	694	159	696	222

Note. TD = typically developing; MO-TD = monolingual typically developing; BI-TD = bilingual typically developing; DLD = developmental language disorder; MO-DLD = monolingual with developmental language disorder; BI-DLD = bilingual with developmental language disorder; ACC = accuracy; RT = reaction time.

Table 3. Generalized Linear Mixed-Effects Models for Accuracy and Reaction Times

Attention	Variable	Accuracy			RT		
		Estimate	*SE*	*t*	*Estimate*	*SE*	*t*
Alerting	Intercept	2.91	0.13	22.00*	680.17	18.68	36.42*
	SES	0.11	0.13	0.81	0.90	19.18	0.05
	Cue (double vs. no)	-0.34	0.18	-1.91	37.74	8.93	4.23*
	MO vs. BI	-0.06	0.25	-0.23	25.59	34.63	0.74
	TD vs. DLD	-0.78	0.28	-2.78*	102.32	39.78	2.57*
	Cue x MO vs. BI	-0.14	0.28	-0.50	-11.43	17.47	-0.65
	Cue x TD vs. DLD	-0.18	0.29	-0.60	-21.75	17.7	-1.23
	MO vs. BI x TD vs. DLD	-0.28	0.50	-0.55	-22.27	56.91	-0.39
	Cue x MO vs. BI x TD vs. DLD	0.37	0.57	0.65	3.47	33.93	0.10
Orienting	Intercept	3.1	0.16	19.36*	672.32	20.19	33.31*
	SES	-0.1	0.16	-0.64	5.64	20.62	0.27
	Cue (spatial vs. central)	-0.18	0.21	-0.86*	26.79	6.58	4.07*
	MO vs. BI	0.08	0.3	0.26	29.79	38.02	0.78
	TD vs. DLD	-1.3	0.35	-3.75*	126.93	44.21	2.87*
	Cue x MO vs. BI	-0.22	0.3	-0.72	27.14	12.92	2.10*
	Cue x TD vs. DLD	-0.11	0.3	-0.35	7.22	13.03	0.55
	MO vs. BI x TD vs. DLD	-0.21	0.61	-0.35	-30.41	65.37	-0.47
	Cue x MO vs. BI x TD vs. DLD	-1.27	0.6	-2.12*	90.62	25.57	3.54*
Executive Control	Intercept	3.12	0.13	23.59*	694.23	19.94	34.82*
	SES	0.03	0.13	0.27	13.3	19.69	0.68
	Flanker (Congruent vs. Incongruent)	-1.01	0.17	-5.99*	79.15	6.74	11.74*
	MO vs. BI	-0.08	0.25	-0.34	43.25	35.15	1.23
	TD vs. DLD	-0.92	0.28	-3.26*	142.21	45.13	3.15*
	Flanker x MO vs. BI	0.47	0.29	1.62	16.18	13.13	1.23
	Flanker x TD vs. DLD	-0.15	0.29	-0.52	34.25	13.38	2.56*
	MO vs. BI x TD vs. DLD	-0.17	0.50	-0.34	3.40	74.07	0.05
	Flanker x MO vs. BI x TD vs.DLD	-0.02	0.58	-0.03	23.10	25.57	0.90

Note. SES = socioeconomic status; MO = monolingual; BI = bilingual; TD = typically developing; DLD = developmental language disorder.

*p < .05.

Figure 1. Reaction time (RT) performance on orienting (Cue × Bilingual Status × Language Impairment Status). More values indicate a slower RT. Error bars represent ±1 SEM. MO = monolingual; BI = bilingual; TD = typically developing; DLD = developmental language disorder.
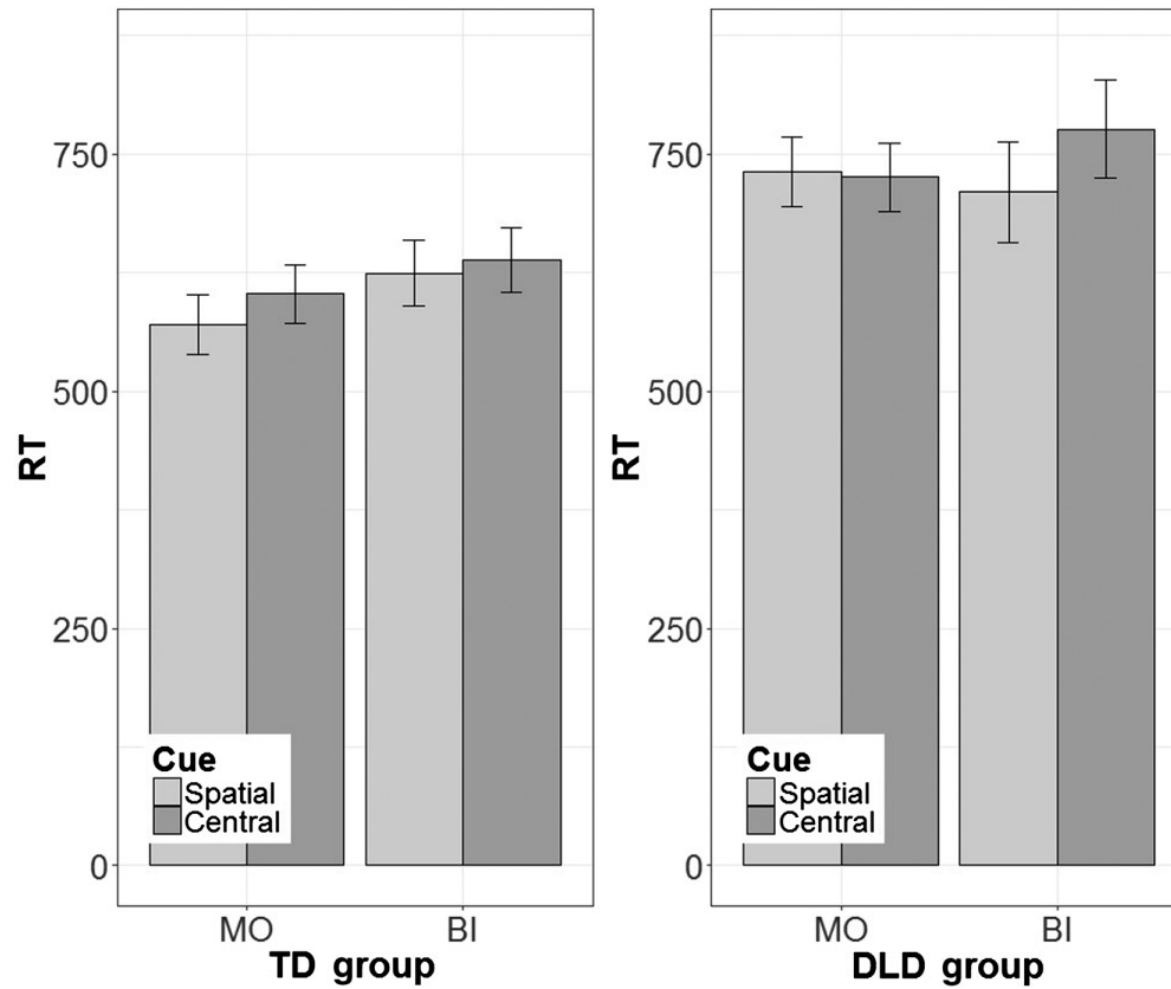
Figure 2. Reaction time (RT) performance on executive control (Flanker × Language Impairment Status). More values indicate a slower RT. Error bars represent ±1 SEM. TD = typically developing; DLD = developmental language disorder.