Attention in Bilingual Children With Developmental Language Disorder

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Purpose: Attention and language are hypothesized to interact in bilingual children and in children with developmental language disorder (DLD). In children who are bilingual, attentional control may be enhanced by repeated experience regulating 2 languages. In children with DLD, subtle weaknesses in sustained attention may relate to impaired language processing. This study measured attentional control and sustained attention in monolingual and bilingual children with and without DLD in order to examine the potential influences of bilingualism and DLD, as well as their intersection, on attention.

Method: Monolingual English-only and bilingual Spanish–English children aged 6–8 years were categorized into participant groups based on eligibility testing and parent interviews. Parent interviews included standardized assessment of language environment and parent concern regarding language. Participants completed 2 nonlinguistic computerized assessments: a flanker task to measure attentional control and a continuous performance task to measure sustained attention.

Results: One hundred nine children met all eligibility criteria for inclusion in a participant group. Regression models predicting performance on the attention tasks were similar for both sustained attention and attentional control. For both tasks, DLD was a significant predictor, and bilingualism was not. Measuring bilingualism continuously using parent-reported exposure did not alter results.

Conclusions: This study found no evidence of a "bilingual cognitive advantage" on types of attention among sequential Spanish–English bilingual children but also found a negative effect of DLD that was consistent across both types of attention and both bilingual and monolingual children. Results are consistent with the broader literature on subtle nonlinguistic deficits in children with DLD and suggest these deficits are minimally affected by diverse linguistic experience.

Language and attention represent two crucial cognitive processes in developing children. The relationship between these two cognitive processes has led to discussion in recent literature devoted both to typical development and to a range of developmental disorders in children (e.g., Calvo & Bialystok, 2014; Jongman, Roelofs, Scheper, & Meyer, 2017; Mahurin-Smith, deThorne, & Petrill, 2017). Language and attention may interact and shape each other in multiple ways. Two prominent examples of such interactions are the proposed influence of dual language exposure on the development of attention and the possible influence of attention on the development of language skills in children with developmental language disorder (DLD).

This study considers both of these influences as well as their interaction. That is, we examine the attention skills of monolingual and bilingual children with and without DLD in order to explore how language exposure may influence aspects of developing attention, how specific attentional weaknesses may influence language development, and how these two phenomena may interact with each other. Before introducing the current study, we outline the relevant aspects of attention and review the literature on attention in developing bilingual children and in children with DLD.

A Framework for Attention

Attention can be very broadly defined as a set of cognitive processes involved in the selection of internal and external stimuli for processing (Gomes, Molholm, Christodoulou, Ritter, & Cowan, 2000). This critical cognitive construct has been conceptualized in many different ways (see Ebert & Kohnert, 2011, for a review). Here, we adopt the framework proposed by Posner and colleagues (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Petersen & Posner, 2012;...
Posner & Petersen, 1990) in order to interpret recent work on two specific components of attention: sustained attention and attentional control. These components of attention are the focus of the current study because of their prominence in the literatures on bilingualism and on DLD and their potential to highlight interactions between attention and language.

Posner’s model includes three separate attentional networks: alerting, orienting, and executive (Petersen & Posner, 2012). Sustained attention, which typically refers to the ability to correctly select relevant stimuli for processing over time, is not an explicit component of the model (cf. Gomes et al., 2000; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991); however, it has been interpreted to be an aspect of the alerting network (e.g., Jongman et al., 2017), which supports the maintenance of an alert state over time (Fan et al., 2002; Petersen & Posner, 2012). The most common method of assessing sustained attention is the continuous performance task (CPT; also known as a go/no-go task), in which a subject monitors a stream of visual or auditory stimuli and responds only to certain targets (see Roebuck, Freigang, & Barry, 2016, for a review of CPTs). For example, the participant might view a series of shapes (e.g., circles and squares) appearing on a computer screen and be asked to respond only when the shape is a square. Individuals with poor sustained attention skills should have difficulty in selecting target stimuli over time, resulting in missed targets, spurious responses to distractors, or both.

Attentional control is a term used to characterize the ability to focus on relevant stimuli in the face of irrelevant information, particularly information that presents a cognitive conflict (Adesope, Lavin, Thompson, & Ungerleider, 2010; Yoshida, Tran, Benitez, & Kuwabara, 2011). This skill falls within the executive network of attention, which is devoted to conflict resolution (Fan et al., 2002; Petersen & Posner, 2012). Three classic paradigms for measuring attentional control are Simon tasks, Stroop tasks, and flanker tasks (Nelson, de Haan, & Thomas, 2006). These assessments vary, but all share the need to simultaneously ignore some stimuli in order to focus on others. For example, flanker tasks (Eriksen & Eriksen, 1974) are so named because of the need to ignore distractor stimuli that “flank” a central target. When the flankers present conflicting information, participants respond more slowly than when the flankers are consistent with the central target (e.g., Treccani, Cubelli, Della Sala, & Umiltà, 2009), a phenomenon known as the flanker effect. Individuals with better attentional control exhibit smaller flanker effects; that is, they are less influenced by conflicting or incongruent stimuli.

In the model proposed by Posner and colleagues, the executive and alerting attentional networks are supported by distinct neural circuitry. Thus, the model suggests that sustained attention and attentional control should be separable, with potentially distinct interactions with other cognitive systems such as language. The prototypical assessments of these skills overlap; however, both require active selection of targets and inhibition of responses to distractor stimuli. In general, assessments of sustained attention emphasize performance over time, whereas assessments of attentional control emphasize conflict.

When considering the relationship between attention and language, one additional dimension becomes relevant to the assessment of attention: the linguistic content of assessment tasks. That is, it may be optimal to assess attention skills using tasks with nonlinguistic stimuli in order to consider attention and language skills separately (Kaushanskykaya, Park, Gangopadhyay, Davidson, & Weismer, 2017). This is particularly important for children with DLD—the population of interest in this study—because they inherently perform poorly on language-based tasks. Thus, we focus our review of the literature on nonlinguistic assessments of attention.

**Attention in Bilingual Children**

Children who must learn and use two languages, either simultaneously from birth or sequentially in early childhood, can be classified as bilinguals (Kohnert, 2013). The cognitive skills of this population have been of particular interest during recent years due to the scientific debate regarding the “bilingual advantage”—that is, the idea that bilingual experience leads to superior cognitive skills in specific areas (e.g., Martin-Rhee & Bialystok, 2008). There is currently substantial disagreement in the literature as to the existence, scope, and source of these advantages (Arizmendi et al., 2018; Barac, Moreno, & Bialystok, 2016; de Bruin, Treccani, & Della Sala, 2015; Hilchey & Klein, 2011). Here, we focus specifically on studies that have examined attentional control or sustained attention in bilingual children, although some of the studies we review have conceptualized these tasks within an executive function rather than an attention theoretical framework.

Attentional control has been a major focus of the literature on cognitive advantages in bilingual children (Adesope et al., 2010; Arizmendi et al., 2018). It has been hypothesized that the routine need to focus on the target language system and to inhibit the nontarget language system results in an increased demand for attentional control, thus enhancing this ability over time (Bialystok, 2009). Within the attentional network framework (Fan et al., 2002; Petersen & Posner, 2012), such an advantage could result from increased efficiency in the neural circuitry supporting the executive network.

In a 2010 meta-analysis of related work to date, Adesope et al. found evidence for a significant bilingual advantage in the area of attentional control, with a larger effect size ($g = 0.96$) for attentional control than for any other construct examined (including working memory, metalinguistic awareness, or abstract and symbolic representation). Since this meta-analysis, a number of studies have considered attentional control in typically developing (TD) bilingual versus monolingual children (Antón et al., 2014; Barac et al., 2016; Blom, Boerma, Bosma, Cornips, & Everaert, 2017; Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012; Kapa & Colombo, 2013; Ross & Melinger, 2017; S. Yang & Yang, 2016). A few studies
have found no effect of bilingualism on the development of nonlinguistic attentional control (Antón et al., 2014; Ross & Melinger, 2017), instead arguing that bilingual cognitive advantages in children have been artifacts of specific samples or tasks. One specific concern has been that differences in socioeconomic status (SES) may confound investigations of bilingual cognitive advantages (e.g., Arizmendi et al., 2018; Calvo & Bialystok, 2014; Paap, Johnson, & Sawi, 2015). However, a number of other investigations conducted after the Adesope et al. (2010) meta-analysis have continued to indicate that bilingual children outperform their monolingual peers specifically on flanker tasks of attentional control (Barac et al., 2016; Blom et al., 2017; Engel de Abreu et al., 2012; Kapa & Colombo, 2013). Conflicting results in the literature on bilingual cognitive advantages have sparked significant discussion. One particularly relevant point for the current study is the idea that bilingual advantages only appear in individuals with high proficiency in both languages (e.g., Bialystok, 2018).

Unlike attentional control, sustained attention in bilingual children has received relatively little scrutiny. There is little basis to assume that experience with two languages would enhance the neural attention system devoted to alertness. Indeed, most of the existing literature comparing the performance of monolingual and bilingual children on a CPT frames the task as one of inhibition or switching rather than sustained attention (i.e., Bonifacci, Giombini, Bellocci, & Contento, 2011; Foy & Mann, 2014; Krizman, Marian, Shook, Skoe, & Kraus, 2012). These investigations have produced mixed results, with two (Foy & Mann, 2014; Krizman et al., 2012) finding a bilingual advantage in CPT performance and one finding no advantage (Bonifacci et al., 2011). More recently, Boerma, Leseman, Wijman, and Blom (2017) examined sustained attention skills in 128 bilingual and monolingual children using a combined auditory and visual CPT. This study found no significant advantage in sustained attention for bilingual children.

Thus, a substantial—though controversial—literature suggests that exposure to two languages in early childhood may enhance the executive attention network and lead to improved attentional control. There is little theoretical support for enhancements to the alerting attention network (including sustained attention), and results of studies comparing monolingual and bilingual children on measures of sustained attention have been mixed.

**Attention in Children With DLD**

Children with DLD have difficulty with language acquisition without an obvious cause (Leonard, 2014). This disorder has been known by a host of names in the literature, including specific language impairment, primary language impairment, and language learning impairment. Here, we adopt the terminology endorsed by the CATALISE Consortium (Bishop, Snowling, Thompson, Greenhalgh, & the CATALISE-2 Consortium, 2017). The cognitive skills of this population have been of scientific interest because children with DLD, by definition, score broadly within normal limits on tests of nonverbal cognition, yet as a group, they typically demonstrate subtle deficits in comparison to their unaffected peers on various nonverbal cognitive processing tasks. The presence of these deficits has led to hypotheses that the language deficits apparent in DLD relate directly to subclinical difficulties with general information processing (Boerma et al., 2017; Leonard et al., 2007).

Deficits in sustained attention, specifically, could cause affected children to miss relevant linguistic input, slowing their language acquisition (Boerma et al., 2017). Montgomery, Evans, and Gillam (2009) also linked sustained attention directly to language acquisition deficits in children with DLD, arguing that poor sentence comprehension can be at least partially explained by sustained auditory attention. Within the attentional network framework (Fan et al., 2002; Petersen & Posner, 2012), subclinical weaknesses in the alerting network could lead to failure to process less salient stimuli; this pattern is consistent with theories that children with DLD show the most difficulty acquiring grammatical features with the least perceptual salience (Leonard, 2014).

There is ample evidence to support the theoretical links between DLD and deficits in sustained attention. A 2011 meta-analysis (Ebert & Kohnert, 2011) synthesized 28 effect sizes from published comparisons between children with DLD and their TD peers on CPTs. On average, children with DLD fell 0.69 SDs below their peers on assessments of sustained attention; moreover, significant differences between children with and without DLD persisted across both linguistic and nonlinguistic stimuli, as well as across both auditory and visual modalities.

Studies published after 2011 have reported similar results. For example, Boerma et al. (2017) compared the performance of 5- and 6-year-old children with DLD to their TD peers on a combined auditory and visual CPT. Children with impairment performed below their TD peers, with impairment status accounting for approximately 15% of the variance in signal detection accuracy on the CPT. Jongman et al. (2017), too, found evidence of poorer sustained attention in 7- to 9-year-old children with DLD in comparison to their TD peers, again across both auditory and visual modalities. Overall, the evidence supports the presence of sustained attention deficits in children with DLD. However, it is important to note that, with the exception of Boerma et al., studies of sustained attention in children with DLD have included only monolingual children.

The nonlinguistic attentional control abilities of children with DLD have received less consideration in the literature. Recent work comparing monolingual preschool children with and without DLD on a flanker task (H. C. Yang & Gray, 2017) found no evidence of an attentional control disadvantage for children with DLD. Similarly, a Stroop task modified to reduce its verbal load (Lukács, Ladányi, Fazekas, & Kemény, 2016) also did not reveal any performance differences. However, as noted previously, inhibition has often been viewed as a close variant of attentional control, and a recent meta-analysis of studies comparing children with and without DLD (Pauls &
Archibald, 2016) on measures of inhibitory control found significant differences ($g = 0.56$) between affected and unaffected children. Theoretically, a weak executive attention network could lead to difficulty in managing multiple sources of information when learning language (e.g., processing linguistic labels along with multiple object properties when learning new words; see Kapa & Colombo, 2014). However, discussion of this possibility in the context of DLD has been limited.

**Intersection and Current Study**

Although attention and language are hypothesized to interact in both bilingual children and children with DLD, the proposed effects work in opposite directions. That is, language learning is proposed to influence attention in bilingual children, and attention is proposed to influence language learning in children with DLD. Although the hypothesized influences are controversial in both literatures. Furthermore, it is not yet clear how these effects might interact in children who are both bilingual and affected by DLD. If children with DLD demonstrate weak or inefficient attentional networks, can an experience that enhances some networks (i.e., bilingualism) counteract these effects? Phrased alternatively, can bilingual advantages accrue in a population that is defined by poor linguistic proficiency? The potential for interaction also has practical significance for the numerous children with DLD who are exposed to more than one language in childhood.

To date, we are aware of only one study that has examined attention in children who are both bilingual and affected by DLD. Both monolingual and bilingual children participated in Boerma et al.’s (2017) investigation of sustained attention in children with DLD. In both monolingual and bilingual groups, sustained attention performance was lower for children with DLD than for their unaffected peers. There were no overall differences between monolingual and bilingual groups and no interaction between bilingualism and DLD. However, this study examined only one attentional network, alerting, which has rarely been associated with bilingual advantages. In contrast, this study examines two attentional networks, alerting and executive attention, which generate distinct predictions about bilingual advantages and about deficits associated with DLD.

The aim of the current study is to contribute to the emerging literature on attention in bilingual children with DLD. We consider both sustained attention and attentional control, using nonlinguistic stimuli in the visual modality, and compare four groups of children: monolingual children with typical language development (MO-TD), monolingual children with DLD (MO-DLD), bilingual children with typical language development (BI-TD), and bilingual children with DLD (BI-DLD). This design allows us to consider both potential influences on attention and their interaction within a clinically relevant population. We also examine the role of age, SES, and nonverbal IQ, as these variables may play an important role in the study of bilingualism and DLD. Our study addresses the following research questions:

1. Does bilingualism predict sustained attention (1a) or attentional control (1b) skills?
2. Does DLD predict sustained attention (2a) or attentional control (2b) skills?
3. Does the interaction between bilingualism and DLD predict sustained attention (3a) or attentional control (3b) skills?

We anticipate that the interaction between bilingualism and DLD does not predict sustained attention. If bilingual experience does not enhance the alerting network, bilingual children with DLD should not differ from their monolingual peers with DLD in sustained attention. For attentional control, results may be different. If bilingual experience affects children with and without DLD similarly, the interaction between DLD and bilingualism will not predict attentional control. If, however, language skill drives the ability to gain bilingual advantages, then there should be an interaction in which bilingual children with typical language development outperform their monolingual peers in the area of attentional control, whereas bilingual children with DLD do not.

**Method**

This study was approved by the Rush University Medical Center Institutional Review Board. Written consent to participate was obtained from the parents or guardians of all participants, and written assent was obtained from all participating children who were at least 7 years old, consistent with institutional policy.

**Participants**

One hundred ninety children in the greater Chicago metropolitan area were recruited to participate. Children were recruited via a combination of strategies, including flyers and electronic advertisements, partnership with local
community centers providing after-school care to school-age children, identification of children with known or suspected DLD by speech-language pathologists or special education managers in local schools, and referrals from a language screening project implemented in a large urban pediatric clinic. Eligibility criteria included chronological age between 6;0 and 8;11 (years;months); exposure to English or to Spanish and English; no history of sensory loss (vision or hearing); no known history of brain injury or of neurodevelopmental conditions, including autism spectrum disorder, intellectual developmental disability, and cerebral palsy; and no known diagnosis of attention-deficit/hyperactivity disorder (ADHD). Children with an ADHD diagnosis were specifically excluded because these children have clinical deficits in attention skills that would be expected to impair performance on study tasks. The other eligibility criteria ensured that children had either typical development or language difficulties that could not be explained by an obvious cause (i.e., DLD). All recruited children were born in the United States per parent report.

In order to verify children’s eligibility, we conducted a hearing screening at 1000, 2000, and 4000 Hz at 25 dB HL in each ear (American Speech-Language-Hearing Association, 1997). We also administered the Test of Nonverbal Intelligence–Fourth Edition (TONI-4; Brown, Sherbenou, & Johnsen, 2010) to verify that all participating children demonstrated nonverbal intelligence within normal limits. In order to participate, all children were required to pass the hearing screening and to obtain a standard score of no more than 1.25 SDs below the mean on the TONI-4 (i.e., a standard score of 81 or higher). Finally, we administered the Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS; American Academy of Pediatrics & National Initiative for Children’s Healthcare Quality, 2002) to a parent or caregiver. Children who met VADPRS criteria for any of the ADHD subtypes (i.e., predominantly inattentive, predominantly hyperactive/impulsive, or combined) were excluded, even if parents had not reported a previous ADHD diagnosis. Thirty-six children who were consented into the study were excluded from further analysis based on failing to meet initial eligibility criteria for a final total of 154 eligible participants. See Figure 1 for a complete depiction of the participant flow through each step of the recruitment, eligibility, and grouping processes.

Measures
Language Measures
All children completed subtests of the Clinical Evaluation of Language Fundamentals–Fourth Edition, English (ECELF4; Semel, Wiig, & Secord, 2003). The majority of children completed the four subtests that make up the Core Language score for 6- to 8-year-old children: Concepts & Following Directions and Recalling Sentences, Word Structure, and Formulated Sentences. Throughout study enrollment, all children with bilingual exposure and all children with reported language concerns completed these four subtests. In the earliest stages of enrollment, children who were monolingual English speakers with no concerns regarding language development completed only two subtests (Concepts & Following Directions and Recalling Sentences), in order to verify language skills within the average range. This decision was subsequently altered in order to obtain a more complete and consistent data set. Thus, of the 154 children determined to be eligible, 10 completed two subtests on the ECELF4, and the remaining 144 completed all subtests.

Children with exposure to Spanish also completed the Clinical Evaluation of Language Fundamentals–Fourth Edition, Spanish (SC ELF4; Wiig, Secord, & Semel, 2006). The four subtests that make up the Core Language score for 6- to 8-year-old children were administered; these subtests are equivalents of the ECELF4 Core Language subtests. Specific cutoff criteria for the language measures were one component of the participant grouping process; this process is described in detail in the section below.

Parent Report Measures
Four formal and informal questionnaires were administered to parents for the purposes of describing and classifying participants. All questionnaires were administered in either English or Spanish, according to parent preference. First, a brief background questionnaire was administered to collect demographic information, basic information on language exposure, and medical history. Next, the 18 questions of the VADPRS that are related to ADHD were administered. For interviews in Spanish, the University of North Carolina Spanish translation (American Academy of Pediatrics & University of North Carolina at Chapel Hill, 2005) of the VADPRS was used. The remaining two questionnaires were used to assess language development and the home language environment, respectively.

Language development. The Alberta Language Developmental Questionnaire (ALDeQ; Paradis, Emmerzael, & Sorenson Duncan, 2010) was designed to collect information about development and possible delay in a child’s first language. It includes 19 questions within four sections: early developmental milestones, current language abilities, activity patterns and preferences, and family history of communication and learning difficulty. In this study, the ALDeQ was modified to refer specifically to either Spanish or English (i.e., the primary home language), rather than the “language of the home country” as originally written. For parents who preferred to complete the interview in Spanish, the questionnaire was translated by a study staff member fluent in Spanish; the translation was then reviewed by the second author, with minor adjustments made following discussion with the study team (Ebert & Rak, 2016). The ALDeQ provides individual scores for each of the four sections and an overall score. Paradis et al. (2010) provide guidelines for scores suggestive of DLD based on a sample of 4- to 9-year-old children. Following these guidelines, children were considered to have evidence of parent concern regarding language if they obtained both an overall score at or below 1.25 SDs below the mean and a subsection score more than 1 SD below the mean on at least one
of the following subsections: developmental milestones, activity patterns, and family history. In other words, children who received a low score on the ALDeQ solely because of a low score on the current home language abilities subsection did not meet the criterion for parent concern on the ALDeQ; this restriction is designed to ensure that loss of fluency in the first or home language resulting from transition to English dominance is not interpreted as a language disorder (Paradis et al., 2010). The evidence of parent concern from the ALDeQ was also used in the participant grouping process, as described below.

**Home language environment.** For parents who reported Spanish use in the home, the Alberta Language Environment Questionnaire (ALEQ; Paradis, 2010) was administered to capture the proportion of Spanish (vs. English) used in the home environment. As with the ALDeQ, the ALEQ was translated and checked by study staff for parents who preferred to complete the interview in Spanish. The ALEQ collects information about the frequency of input and output in Spanish for each conversational partner in the home (i.e., mother, father, other caregivers, other noncaregiving adults, siblings) and also collects an estimate of Spanish use in school and after-school settings. The ALEQ provides a “Language Use in the Home” composite score that equally weights the input and output of parents, other caregivers, and siblings. For this study, an alternate composite score was created that differed from the “Language Use in the Home” score in several ways. First, only input estimates were included (rather than both input and output) to avoid underestimating the Spanish environment for bilingual children with DLD who may be at higher risk of losing expressive Spanish skills (Kohnert, 2013). Both home and school/after-school estimates were included, rather than home estimates only, in order to create a single value that captured all aspects of the Spanish environment. Finally, instead of equally weighting the input from all household members, the composite score for this study doubled the weight of maternal input in order to capture the relative importance of maternal input on language development (e.g., Hurtado, Marchman, & Fernald, 2008). This score was used as one component in the determination of whether children qualified for a bilingual or monolingual group (see Participant Groupings section).

For parents who reported no significant exposure to a language other than English at home, a simple questionnaire was administered to verify that exposure to other languages was minimal. The questionnaire asked about current exposure to languages via relatives, television, and school classes, as well as historical exposure to other languages. Participants with significant exposure to languages other than English or Spanish were excluded from the study (see Figure 1).
Measures of Attention

Two visual nonlinguistic tasks were administered via laptop computer. The first, attentional control, was implemented in E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2007), with responses collected via a serial response box for accurate measurement of reaction time (RT). The second task (sustained attention) was a commercially available assessment, the Test of Variables of Attention (TOVA, 2013), and was administered using the TOVA equipment (including a microswitch for capturing responses). For both tasks, training trials were first completed to ensure participants understood the task and could complete trials accurately before moving on to the main task.

Attentional control. A modified version of the children’s attentional networks task (ANT; Rueda et al., 2004) was used as the measure of attentional control. The ANT is an implementation of the flanker task, in which participants must attend to a central stimulus while ignoring conflicting information from the stimuli that flank it. In the children’s ANT, each trial presents a fixation cross followed by an image of five fish in a horizontal line. Participants are instructed to report the direction of the central fish via button press on the response box. On congruent trials, the four fish surrounding the central (target) fish face the same direction; on incongruent trials, the four fish face the opposite direction from the central fish. Sixty-four trials were presented, split evenly between congruent and incongruent trials and presented in random order.

The most common dependent variable in flanker tasks is the flanker effect, which is calculated as the difference between correct incongruent trials and congruent trials in terms of RT (Fan et al., 2002). However, the use of RT as a dependent variable assumes that participants slow down in order to maintain high accuracy, and younger children may not demonstrate this pattern (Zelazo et al., 2013). Initial analyses of the present data indicated that accuracy rates ranged from 30% to 100% on the flanker task. This range suggested that a measure combining RT and accuracy was appropriate; for children with low accuracy, RT may represent trials that are correct by chance, whereas for children with high accuracy, RT may be needed to capture the speed-accuracy trade-off described above (Zelazo et al., 2013).

Therefore, accuracy and RT were combined into a single score on the flanker task in this study following the procedures established by Zelazo et al. (2013). Both accuracy and RT for incongruent and congruent trials were rescaled into scores ranging from 0 to 5. Because there were 32 congruent trials and 32 incongruent trials, each correct response earned 5/32 of one point:

\[
\text{Congruent Accuracy Score} = \frac{5}{32} \times \text{number of correct congruent trials} \quad (1)
\]

\[
\text{Incongruent Accuracy Score} = \frac{5}{32} \times \text{number of correct incongruent trials} \quad (2)
\]

RT was included in the flanker task score only if overall accuracy was at least 80% (Zelazo et al., 2013). To rescale RT, individual mean RT was calculated separately for correct congruent and incongruent trials. RTs from incorrect trials, trials completed in less than 50 ms, and trials with RTs more than 2 SDs outside the individual mean were trimmed before calculating the mean RT; these steps are needed to reduce the likelihood of including spurious trials in the RT mean. The resulting individual mean RTs ranged from 586 to 1605 ms. Using these data, it was estimated that the possible range of RTs was 500–2000 ms (cf. Zelazo et al., 2013, who used a possible range of 500–3000 with slightly younger children). Each child’s mean RT was then linearly transformed from a scale of 500–2000 ms to a scale of 0–5, inverting the scale so that higher scores corresponded to better performance:

\[
\text{Congruent RT Score} = 5 + \frac{(0 - 5)}{(2000 - 500)} \times (\text{mean RT congruent trials} - 500) \quad (3)
\]

\[
\text{Incongruent RT Score} = 5 + \frac{(0 - 5)}{(2000 - 500)} \times (\text{mean RT incongruent trials} - 500) \quad (4)
\]

The accuracy and RT scores were then summed to create one composite score for congruent trials and one for incongruent trials. The difference between the incongruent and congruent scores indexed the flanker effect in the current study and was used as the outcome measure for the attentional control task.

Sustained attention. The TOVA Version 8.1 (TOVA, 2013) was used as the measure of visual sustained attention. The TOVA is a 22-min standardized CPT. In each trial, a black box flashes on the computer screen; participants are instructed to respond via microswitch button press to each box that flashes at the top of the screen and to ignore any boxes that flash at the bottom of the screen. In the first half of the task, targets appear infrequently, whereas the second half of the program presents the target boxes frequently; for this reason, the first half of the task is considered the best test of sustained attention (TOVA, 2013).

In the study of sustained attention in children with DLD, accuracy appears to be a better index of difficulty than RT (Ebert & Kohnert, 2011), and therefore, an accuracy measure, \(d'\) (Macmillan & Creelman, 1991), was selected as the measure of sustained attention in this study. This measure combines accuracy in detecting targets...
(i.e., boxes at the top of the screen) with accuracy in ignoring distractors (i.e., boxes at the bottom). \( d' \) is an advantageous outcome measure for CPTs because it controls for individual biases in response patterns (Montgomery et al., 2009). Because of this and the design of the TOVA, \( d' \) from the first half of the TOVA was used as the measure of sustained attention in this study.

**Procedure**

All study tasks were completed in one or two sessions lasting 60–90 min each. The sessions were completed individually at a table in a quiet space at the child’s school or after-school program site, or at the investigator’s laboratory. For bilingual children, each session was conducted exclusively in English or Spanish with the order of language assessments counterbalanced across participants. Spanish assessments were administered by study staff fluent in Spanish.

Parent interviews were conducted via phone or in person, in either English or Spanish according to parent preference. Parent interviews were conducted by the second author, a fluent Spanish speaker with expertise in cultural and linguistic considerations in Hispanic populations (e.g., Ebert & Rak, 2016).

**Participant Groupings**

To answer the research questions, participants were categorized as monolingual or bilingual and as having typical language development or DLD. Participants with no reported Spanish exposure were categorized as monolingual. For participants with minimal Spanish exposure (e.g., a noncaregiving relative providing some bilingual input), the ALEQ was completed to quantify any exposure and the SCELF4 was attempted. Participants who were unable to complete any portion of the SCELF4 and had composite ALEQ environment scores of 90% English or above were considered eligible for a monolingual group (if they met the additional criteria for TD or DLD as outlined below). Participants who were able to complete the SCELF4 and had overall ALEQ composite scores of 65% English or less were considered potentially eligible for a bilingual group; again, children were only included in a bilingual group if they met additional criteria for TD or DLD as outlined below).

To meet criteria for DLD, participants had to demonstrate both language skills below expectations and evidence of functional language difficulty. Language skills below expectations were defined as an ECELDF4 Core Language score more than 1 SD below the mean for monolingual English-only children and as Core Language scores more than 1.25 SDs below the mean on both the ECELDF4 and the SCELF4 for bilingual children. A more stringent criterion was applied to the bilingual children to avoid over-identification. The requirement of functional language difficulty was also imposed to avoid overidentification on the basis of test scores alone. Functional language difficulty was defined as the presence of one or more of the following:

- (a) the parent reported overall concern with the child’s communication development and specified a concern related to language,
- (b) the child met criteria for parent concern on the ALDeQ, and
- (c) the school reported concerns with the child’s language. To meet criteria for typical language development (TD), children were required to have an absence of functional language difficulty (i.e., none of the three criteria presented previously) and to demonstrate language scores within the average range. For monolingual children, this was defined as an ECELDF4 Core Language standard score of 85 or higher or scaled scores of 7 or higher on both the Concepts & Following Directions and Recalling Sentences subtests (for the small subset of children who had no identified concerns and completed only those two subtests). For bilingual children, this was defined as a standard Core Language score within 1 SD of the mean in at least one language and the standard Core Language score in the other language within 2 SDs of the mean. These criteria were intended to ensure that children were both TD and had sufficient exposure to develop skills in both languages.

**Analyses**

Using the children who met all criteria for inclusion in one of the four groups (BI-DLD, BI-TD, MO-TD, MO-DLD; see Figure 1), we examined the effects of bilingualism and DLD on attention task performance using theoretically derived hierarchical regression analyses. We began by examining zero-order correlations among all predictor and outcome variables. The possible predictor variables were age, nonverbal IQ, SES (as indexed by maternal education level), bilingualism, DLD, and the interaction between bilingualism and DLD. We restricted consideration of interaction terms to our main question (i.e., including only the bilingualism by DLD term); other interactions were outside the focus of the study, and sample size considerations precluded their inclusion. We conducted one analysis predicting attentional control, as indexed by the flanker effect, and one analysis predicting sustained attention, as indexed by first half \( d' \). In each analysis, we looked at all possible predictors and then removed the worst predictors one at a time, until we achieved an optimal, reduced model.

**Results**

**Participants**

One hundred nine children met all eligibility criteria for one of the four groups: 27 in the MO-TD group, 26 in the MO-DLD group, 27 in the BI-TD, and 29 in the BI-DLD group. Table 1 summarizes the participant characteristics for each group. One-way analysis of variance indicated that chronological age did not differ by group, \( F(3, 105) = 0.20, p = .894 \). However, nonverbal IQ as indexed by the TONI-4 score did differ by participant group, \( F(3, 105) = 3.76, p = .013 \). Post hoc analysis with least significant difference adjustment indicated that the MO-DLD group differed from the MO-TD group (\( p = .002 \).
and from the BI-TD group \( (p = .049) \). In addition, the BI-DLD group differed from the MO-TD group \( (p = .032) \). There were no differences between the two DLD groups, between the two TD groups, or between the BI-DLD and BI-TD groups. Finally, a chi-square test indicated that SES as indexed by maternal education levels differed across groups, \( \chi^2(12, N = 109) = 61.55, p < .001 \). There were no differences between the bilingual groups in the current proportion of home Spanish use or in the reported age of consistent English exposure.

### Tasks

Descriptive statistics for the outcome variables and correlations among outcome and predictor variables were examined before conducting regression modeling. On the flanker task, the difference between incongruent and congruent composite scores was the outcome variable, with larger difference scores indicating a stronger flanker effect and weaker attentional control. Eighty-four of 109 children \( (77\%) \) reached an accuracy level of 80% or higher and had composite scores that combined accuracy and RT; the remaining 25 \( (23\%) \) had composite scores that included only accuracy. Total composite scores ranged from 2.19 to 9.42 for congruent trials, from 1.09 to 9.39 for incongruent trials, and from −0.47 to 3.44 for the difference or flanker effect. On the TOVA, first half \( d' \) scores ranged from 1.09 to 9.39 for incongruent trials, from 2.6 (1.9) to 61.0 (11.9) for congruent trials, and from 2.9 (1.9) to 46.6 (8.4) for congruent trials. Table 2 depicts performance by group for both nonlinguistic attention tasks.

Table 2 displays the zero-order correlations among all predictor and outcome variables. As expected, both bilingualism and DLD correlated with the interaction term. Bilingualism also correlated with maternal education level, \( r(107) = -.65, p < .001 \). DLD correlated significantly with maternal education level, \( r(107) = -.24, p = .012 \), nonverbal IQ, \( r(107) = -.27, p = .005 \), sustained attention, \( r(107) = -.27, p = .005 \), and attentional control, \( r(107) = .26, p = .008 \). The correlation between nonverbal IQ and maternal education level was also significant, \( r(107) = .19, p = .047 \).

### Models of Attention Task Performance

#### Attentional Control

In the model predicting attentional control, five of the six predictors did not predict the outcome and were removed from the model: age, SES, nonverbal IQ, bilingualism, and the interaction between bilingualism and DLD. The only significant predictor of attentional control was DLD, \( \beta = 0.255, r(107) = 2.73, p = .008 \), which explained 5.1% of the variance in task performance, \( R^2 = .056, F(1, 109) = 10.9, p = .000 \). This result indicates that children with DLD demonstrated significantly larger flanker effects, indicating poorer attentional control in this group.

#### Sustained Attention

In the model predicting sustained attention, the same five predictors again did not predict the outcome and were removed from the model: age, SES, nonverbal IQ, bilingualism, and the interaction between bilingualism and DLD. DLD was again the only significant predictor of performance on the sustained attention task, \( \beta = -0.271, r(107) = -2.90, p = .005 \), explaining 7.3% of the variance in task performance, \( R^2 = .073, F(1, 109) = 8.38, p = .005 \). This result indicates that children with DLD had significantly lower \( d' \) scores during the portion of the TOVA designed to tax sustained attention (i.e., the first half).

### Post Hoc Analysis of Bilingualism as a Continuous Variable

The effect of bilingualism was not significant and accounted for very little variance in the planned analyses.

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**Table 1. Participant characteristics by group.**

| Characteristic                | MO-TD (n = 27) | MO-DLD (n = 26) | BI-TD (n = 27) | BI-DLD (n = 29) |
|-------------------------------|----------------|---------------|---------------|---------------|
| Age in years                 | 7.2 (0.7)      | 7.3 (0.9)     | 7.4 (0.9)     | 7.4 (0.7)     |
| Maternal education level     | Bachelor's degree | Some college  | High school graduate | Did not complete high school |
| Gender                       | 10M, 17F       | 15M, 11F      | 6M, 21F       | 20M, 9F       |
| Nonverbal IQ                 | 103.7 (7.5)    | 97.0 (8.2)    | 101.1 (7.4)   | 99.3 (7.2)    |
| Proportion of home Spanish   | —              | —             | 61.5% (14.9)  | 64.1% (12.0)  |
| Age of consistent English exposure | — | —         | 2.6 (1.9)     | 2.9 (1.9)     |
| English language             | 98.4 (8.7)     | 68.8 (13.7)   | 89.4 (10.2)   | 61.0 (11.9)   |
| Spanish language             | —              | —             | 91.1 (15.0)   | 62.2 (10.0)   |

Note. Values for scale variables are reported as mean (SD). Maternal education level is reported as the group median, and gender is reported as the number of males (M) and number of females (F). Nonverbal IQ is the standard score from the Test of Nonverbal Intelligence—Fourth Edition. Proportion of home Spanish is the composite score from the Alberta Language Environment Questionnaire. Age of consistent English exposure is reported in years for the bilingual groups only. English language is the standard Core Language composite score from the Clinical Evaluation of Language Fundamentals—Fourth Edition, English (ECELF4); Spanish language is the standard Core Language composite score from the Clinical Evaluation of Language Fundamentals—Fourth Edition, Spanish. MO-TD = monolingual children with typical language development; MO-DLD = monolingual children with developmental language disorder; BI-TD = bilingual children with typical language development; BI-DLD = bilingual children with developmental language disorder.

*\(^a_n = 18\). Nine children in the MO-TD group completed only two subtests of the ECELF4 and did not have Core Language scores.*
However, children with varying levels of exposure to Spanish (i.e., environments ranging from 35% Spanish to 85% Spanish) were considered bilingual. In order to assess the effect of this variation within the bilingual groups, we ran a second set of analyses. All parameters of these alternate models were equivalent to the original analyses, except that bilingualism was indexed as the composite score from the ALEQ rather than as a binomial variable; this variable was selected based on analyses of this sample (e.g., Ebert, 2018) and of other Spanish–English bilingual samples in the United States (e.g., Gutiérrez-Clellen & Kreiter, 2003), indicating that the current language environment is closely related to proficiency levels in bilingual children whereas age of exposure to English is not. For children without reported exposure to Spanish, a value of 1 (equivalent to 100% English environment) was used for the composite ALEQ value. Bilingualism remained nonsignificant in these alternate models: for attentional control, $F(1, 109) = 0.02, p = .882$; for sustained attention, $F(1, 109) = 0.53, p = .469$. As a consequence, the original set of models was retained.

**Discussion**

The purpose of this study was to examine the influences of DLD and bilingualism on two different types of visual nonlinguistic attention. We measured nonlinguistic attentional control and sustained attention in monolingual and bilingual children with and without DLD in order to answer three pairs of research questions.

**Differences Between Monolingual and Bilingual Children**

Our first pair of research questions asked whether bilingualism was associated with enhancements in nonlinguistic attention. Results were similar across both types

| Variable                  | Bilingualism | DLD | Bilingualism × DLD interaction | Age | Maternal education level | Nonverbal IQ | Sustained attention |
|--------------------------|--------------|-----|--------------------------------|-----|-------------------------|--------------|---------------------|
| DLD                      | .03          | —   | —                              | —   | —                       | —            | —                   |
| Bilingualism × DLD interaction | .59**        | .60** | —                              | —   | —                       | —            | —                   |
| Age                      | .07          | .03  | .05                            | —   | —                       | —            | —                   |
| Maternal education level | −.65**       | −.24* | −.44**                         | −.18 | —                       | —            | —                   |
| Nonverbal IQ             | −.02         | −.27** | −.08                          | −.15 | .19*                    | —            | —                   |
| Sustained attention      | .09          | −.27** | −.08                          | .05  | .04                     | .18          | —                   |
| Attentional control      | −.03         | .26** | −.14                          | −.14 | −.12                    | −.17         | −.14                |

*Note.* Bilingualism and developmental language disorder (DLD) are binary variables. For bilingualism, children belonging to a bilingual (BI) group (BI-TD or BI-DLD) received a score of 1, and children belonging to a monolingual (MO) group received a score of 0. For DLD, children belonging to a DLD group (MO-DLD or BI-DLD) received a score of 1, and children belonging to a TD group received a score of 0. Sustained attention is the $d'$ score from the first half of the Test of Variables of Attention. Attentional control is the difference between incongruent and congruent scores on the flanker task.

*p < .05. **p < .01.
of attention: In both models, bilingualism was not a significant predictor and was removed from the models. In other words, the group of Spanish–English bilingual children in this study did not outperform their monolingual English–only peers on either task. These results were consistent with our hypothesis for sustained attention, but not for attentional control. However, an alternative hypothesis is that bilingual cognitive advantages in children are not sufficiently robust to appear consistently across studies (Arizmendi et al., 2018; Paap et al., 2015; Ross & Melinger, 2017), and our results are consistent with this proposal.

It is clear that there are conflicting results in the literature on bilingual children’s cognitive advantages, with explanations ranging from publication bias (De Bruin, Treccani, & Della Sala, 2015; Paap et al., 2015) to task reliability differences (Arizmendi et al., 2018) to oversimplification of both bilingualism and the cognitive constructs of interest (Bialystok, 2018). A single study, such as the present investigation, cannot resolve this conflict. In order to contribute to the rapidly growing discussion regarding the existence and conditions of bilingual cognitive advantages, we highlight some of the salient features of the current study. We note that we used well-established tasks and that our sample was carefully selected and screened for disabilities such as ADHD. In particular, we took steps to carefully separate children with DLD from the TD sample, including directly assessing both languages and considering evidence of functional difficulty with language. Children with unclear results (i.e., evidence of functional difficulty in the absence of poor test scores, or vice versa) were not included in the analyses. The majority of recent work on bilingual cognitive advantages has reported minimal or informal eligibility criteria to ensure typical language development (e.g., Barac et al., 2016; Kapa & Colombo, 2013; S. Yang & Yang, 2016) or has reported assessment of only one language as a means of verifying typical language development (e.g., Antón et al., 2014). It is thus possible that unidentified DLD has been yet another confounding factor in the study of bilingual cognitive advantages. Alternatively, assessment in only the societal language with comparison to monolingual norms in that language may result in samples of “exceptional” bilingual children (i.e., only children with above average language learning capacities).

We also ran a separate analysis to examine bilingualism as a continuous variable instead of solely as a categorical one (see Bialystok, 2018, for discussion). One possible explanation is that cognitive advantages only appear in highly proficient bilinguals, and grouping children from varying environments masks these advantages (Bialystok, 2018). However, utilizing our overall measure of language environment (i.e., the alternate composite score from the ALEQ) as a continuous measure of bilingualism did not alter results, and thus, we did not find support for this hypothesis in our sample.

Finally, treatment of SES differences has been a particular point of controversy in the literature on bilingual cognitive advantages (Arizmendi et al., 2018; Calvo & Bialystok, 2014; Paap et al., 2015). Group differences in SES are common in the literature on bilingualism, and our study was no exception: We focused recruitment efforts for bilingual and monolingual children on the same metropolitan areas in an effort to recruit groups of comparable SES but, nonetheless, found robust group differences in maternal education levels. However, SES was unrelated to our outcome measures and was excluded from our models. SES is a multidimensional construct (Cheng, Goodman, & the Committee on Pediatric Research, 2014) that may not be completely captured within our proxy measure, maternal education, and it is clear that further research is needed to tease out the relationships between SES, bilingualism, and cognition.

**Differences Between Children With and Without DLD**

Our second pair of research questions asked whether DLD was associated with weaknesses in nonlinguistic attention. As with our first set of questions, results were similar across both types of attention: In both models, DLD was a significant factor but accounted for a modest proportion of variance (7.3% for sustained attention and 6.5% for attentional control). In this case, results were consistent with our hypothesis for sustained attention, but not for attentional control. The small body of literature utilizing classic tasks of attentional control (e.g., flanker and Stroop tasks) in children with DLD has found negative results (Lukács et al., 2016; H. C. Yang & Gray, 2017), yet we found evidence of poorer attentional control in both monolingual and bilingual children with DLD. Moreover, although the effect was modest, it was comparable in magnitude to the DLD effect in the sustained attention task, which is an established area of deficit in children with DLD (Ebert & Kohnert, 2011). As in the literature on bilingual cognitive advantages, methodological differences could account for conflicting results; for example, the children studied in H. C. Yang and Gray (2017) were younger than the children in this study, and accuracy and RT were considered separate dependent variables on the flanker task, rather than combined into a single score as they were here. Nonetheless, our results fit into the broader literature on attention and other nonlinguistic cognitive skills in children with DLD (e.g., Boerma et al., 2017; Leonard et al., 2007), supporting the presence of pervasive but subtle deficits.

This study extends the existing literature on attention in children with DLD in two ways. First, we carefully excluded children with ADHD from the sample using both parent report and a validated diagnostic tool (the VADPRS). Again, careful exclusion of ADHD from DLD samples when examining nonlinguistic skills has not been routine (see Ebert & Kohnert, 2011), yet it has clear value in examining attention skills in particular. In addition, we extend the literature on subtle cognitive deficits associated with DLD to bilingual children. Given the global prevalence of children learning two or more languages, it is critical to include these groups in research on DLD. The finding that deficits in nonlinguistic attention are relatively invariable
across monolingual and bilingual groups also has potential clinical implications, which we return to below.

**Interaction Between Bilingualism and DLD**

Our final set of research questions asked whether bilingualism and DLD have interacting effects on nonlinguistic measures of attention. We found no evidence of an interaction effect in either sustained attention or attentional control: Interaction terms were not significant in either model. Consistent with Boerma et al. (2017), our results indicate that differences in attention skills between children with and without DLD are comparable across bilingual and monolingual children. That is, there is no basis to believe that bilingualism either exacerbates or ameliorates subtle deficits in nonlinguistic attention skills that are associated with DLD.

Overall, these results carry both theoretical and clinical implications. Theoretically, they reinforce hypotheses that intact nonlinguistic attention skills may support language learning (Boerma et al., 2017; Jongman et al., 2017; Montgomery et al., 2009). In terms of the attentional networks theory, both the alerting network and the control network may play roles in the processing of linguistic stimuli that leads to language acquisition. However, we caution that the cross-sectional design of this study precludes conclusions regarding causation. Ultimately, controlled experimental designs and longitudinal studies will be helpful in illuminating more specific mechanisms of interaction between attention and language.

Clinically, the lack of interaction between language experience (i.e., bilingualism) and language ability (i.e., DLD) could benefit identification efforts. Identification of DLD is notably difficult across linguistically diverse populations because of the difficulty separating the effects of language experience and language ability on linguistic tasks (e.g., Kohnert, 2013). The presence of consistent deficits in nonlinguistic cognitive skills across children with different linguistic experiences suggests that nonlinguistic cognitive processing tasks could potentially contribute to identification of the disorder. However, several additional steps are needed before this possibility could become reality; in particular, the utility of nonlinguistic tasks in identifying DLD at the individual level, as well as their ability to distinguish between DLD and other developmental disorders, must be explored. Nonetheless, the current results are encouraging and suggest that future exploration of this possibility may be useful.

**Limitations**

As has been noted in the study of bilingualism and DLD, it is difficult to manage all of the potentially confounding variables in any study on these two factors. For example, we found between-groups differences in nonverbal IQ and in SES. Although these variables did not play a role in our regression models, it is nonetheless possible that we were not able to capture all important differences between our groups in the models. In addition, we based our decisions regarding bilingualism on the child’s current language environment, consistent with past literature and our own previous analyses; however, it is possible that other factors (such as age of English exposure) played a confounding role.

The inherent difficulty in setting analogous criteria for differentiating between children with and without DLD across both monolingual and bilingual groups is also a noted limitation of this study. We designed our group qualification criteria carefully, including the assessment of both languages and the inclusion of both test scores and functional concerns, but were limited to working with an assessment (the ECELF) that was normed for the monolingual children and not for the bilingual children. Even with perfectly normed instruments, it may be impossible to equate language skills (i.e., level of language ability in TD groups and severity of impairment in DLD groups) across children with diverse linguistic experiences.

Finally, we chose a single outcome measure for each of our tasks. Our choices were motivated by the existing literature on CPTs and the attentional networks task, yet we acknowledge the possibility that the established outcome measures on these tasks may limit task reliability (Hedge, Powell, & Sumner, 2018). That is, examining interactions between congruent and incongruent conditions may present an alternate way to consider the construct of attentional control. As our study was one of the first to examine these tasks in a new population (bilingual children with DLD) and our sample size restricted the consideration of additional interactions, we used an established task and with a single conventional measure for each construct. However, additional study of the cognitive skills of bilingual children with DLD using new measures may reinforce and extend the findings here.

**Conclusions and Future Directions**

In summary, this study found no evidence of a “bilingual cognitive advantage” on two types of attention among sequential Spanish–English bilingual children but also found a negative effect of DLD that was consistent across both types of attention and across both bilingual and monolingual children. Our results align with the broader literature on subtle nonlinguistic deficits in children with DLD and suggest these deficits are minimally affected by diverse linguistic experience. Future work can extend these results to additional cognitive skills purported to be affected by bilingualism or DLD, to additional groups of bilingual children with DLD, and to study designs that can illuminate specific mechanisms of interaction between language and other cognitive skills.

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