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The Relationship Between Cognitive And Linguistic Abilities In Bilingual Children

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THE RELATIONSHIP BETWEEN COGNITIVE AND LINGUISTIC ABILITIES IN BILINGUAL CHILDREN

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BY

INÉS ELENA MARTÍN

Submitted to the Faculty of the Graduate School of

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DEDICATION

To my parents Francisco and Amelia , for always supporting me through my goals and education. To my little brother Fran for being the biggest pilar in my life and to my Yayos for loving me unconditionally how far we might be – Kentucky, Heaven, or Teruel.

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ABSTRACT

We examined the relationship between cognitive and linguistic abilities in bilingual children (English – Spanish). In particular, we measured the effect of attentional control (the ability to maintain an operative goal, and goal-relevant information, in the face of distraction) and educational experience (amount of time reading) on reading ability (the ability to recognize words and discard misspelled non-words). The sample included 82 developing bilingual children from an immersion school in the United States. Participants were presented with two tasks: the Flanker task as the measure of attentional control (resistance to distractor interference) and the Lexical decision task as the measure of reading ability (processing words and discarding pseudohomophones). Performance in the Flanker task predicted performance in the lexical decision task. However, the amount of time practice reading (measured with a self-report questionnaire) did not predict performance in the lexical decision task. Lastly, performance in Spanish predicted performance in English. These findings point to a close connection between cognitive function and reading ability. Furthermore, the results support the linguistic interdependence hypothesis, as literacy skills are transferred across the two languages of developing bilingual children.

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1. Introduction

Bilinguals are those who use two or more languages (or dialects) in their everyday lives (Grosjean, 2010). Nowadays, there are more bilingual than monolingual people in the world (Grosjean, 2010). In the United States many children speak a language other than English at home (Kim et al., 2015b). In the American classrooms over 10% of the public school's population – more than 5.3 million of children– are English language learners (Jepsen, 2009).

Research has shown that it is a misconception to think that children raised with input from two languages are at a disadvantage, or that mixing two languages is pathological (Bialystok & Craik, 2010b; Byers-Heinlein et al., 2010; Kroll et al., 2014). In contrast, bilingual research has shown improvements in attentional tasks, cognitive skills, cognitive control, executive functioning, and executive attention (Sorge et al., 2017; White & Greenfield, 2017). Attentional control is the ability to maintain an operative goal, and goal-relevant information, in the face of distraction (von Bastian et al., 2020). It is important to understand the potential bidirectional relationship between attentional control and bilingualism. It is likely that attentional control plays a role in bilingualism, while being bilingual can shape attentional control. In addition, it is important to keep in mind the possibility of a publication bias. Research has shown that studies supporting the bilingual advantage are more likely to be published than studies supporting a bilingual disadvantage (Blom et al., 2017).

The *bilingual advantage hypothesis* refers to enhanced attentional control in bilinguals relative to monolinguals. Evidence of this advantage has been found in infants, children, and adults (Bialystok, 2017; Bialystok & Craik, 2010). The bilingual advantage takes place because in order to switch back and forth between languages,

bilinguals have to (1) control the selection of the target language and (2) resolve the conflict between competing languages (Bialystok, 1999; Green, 1998; Macnamara & Conway, 2014). Researchers have reported that both languages are always active in bilinguals (i.e., non-selective activation), so the domain-general cognitive functioning system is incorporated into language and, in so doing, becomes reorganized, fortified, or both (Kroll et al., 2014) Therefore, the use of two languages in bilinguals is a way of exercising the brain networks responsible for cognitive control. The bilingual advantage hypothesis states that practice switching between languages enhances cognitive control. However, the unique structure of the bilingual mind might result in advantages in some tasks and disadvantages in others. Researchers have argued for a bilingual disadvantage in verbal fluency, as there is between-languages interference and competition in language production that causes bilinguals to perform worse in certain linguistic tasks (Sandoval et al., 2010).

Nature or Nurture?

In psychology, debates are often framed as to whether biological or educational influences are key determinants of specific cognitive processes. However, this is a false dichotomy and a much more appropriate approach would be "it is a bit of both." It is possible to think of biological and educational influences as feedback loops, where a positive (or negative) influence in one factor will mean a similar influence in the other factor (Mitchell & Frith, 2019). For example, a positive feedback loop will occur when a child with high attentional control learns to read sooner, thus is more comfortable reading and spends more time reading, which in turn increases their attentional control. The question is no longer whether a particular ability is innate or acquired; instead, the goal is to explore to what extent different biological and educational experiences

influence the outcome of interest (in this study "reading ability"). A better understanding of the biological and educational influences at play is key to determine the most effective interventions to enhance children's cognitive and linguistic abilities.

Biological Influences

It is important to understand that, like most cognitive processes, language has biological underpinnings. Researchers have shown that early-bilingualism alters children's prefrontal cortex for non-verbal attentional control, which impacts early life experiences (Arredondo et al., 2017). Furthermore, biological constraints interact with environmental inputs (first and second language experiences) in the early development of the cortical network for language processing, which later on helps with learning new information (Dehaene et al., 2010). In addition, other brain structures are impacted by the use of a second language. It has been suggested that actively using two languages after childhood can have accelerated dynamic effects on white matter structure, assisting in the preservation of white matter integrity at an older age (Pliatsikas et al., 2015). Bilinguals exposed to a second language before the age of five have greater tissue density in the brain areas related to language, attention, and memory than those exposed to bilingualism later in life (Mechelli et al., 2004). Taken together, these findings highlight the plasticity of the brain and how speaking two languages influences children's brain development.

Educational Influences

Bilingual education has become popular in recent years as early interventions are key to the development of children's cognitive abilities. It is crucial to start at a young age to set a strong foundation on children´s cognitive and linguistic development (White & Greenfield, 2017). Bilingual educational models, like dual-language

programs, have emerged across the US and Europe. In a dual-language program, children with two different native languages (e.g., English and Spanish, English and Mandarin) are in the classroom together. English-language speakers (L1) and English-proficient speakers (L2) share a common learning environment and both sides benefit from interacting with each other. Dual-language programs lead to the cooperation of students in cognitive tasks in both English and the other language (Murphy & Roca de Larios, 2010). Dual programs are also known as two-way immersion programs or bilingual immersion programs. While these different approaches share the same underlying educational goals, they can vary widely in their methodologies and educational approaches (Kim et al., 2015).

Children's language acquisition is the product of social interactions in which children are constantly exposed to new words and associate novel concepts to the knowledge they already have. This ecological context includes the educational environment the children are learning in (e.g., the "dual-language" programs) but it also extends to their family environment and the languages they are exposed to at home (Tamis-LeMonda et al., 2014). As previously mentioned, it is important to acknowledge the diverse population we find in the United States' classrooms: over 10% of the public school's population – more than 5.3 million of children– are English language learners (Jepsen, 2009). The majority of these children speak Spanish (73.1%), but there are more than 150 languages spoken in American schools (Batalova & McHugh, 2010). These numbers are important from an educational, social, and cultural standpoint, as teachers have to educate language-minority students. Educating an English-as-a-second-language student not only entails the process of learning a new language but oftentimes requires the introduction of students into a new culture (Kim et al., 2015).

As we dive deeper into bilingualism research, it is important to acknowledge that literacy and knowledge acquisition are highly dependent on the specific combination of languages being learned. Thus, cognitive processes are influenced by the particularities of each language and do not manifest equally across bilingual populations (Lallier & Carreiras, 2018b). Research in bilingual schools has shown some of the difficulties students face when working with two languages in the same classroom. Lirola (2006) found evidence of common mistakes bilingual students had when writing in their second language: interlingual transfer (interference with the native language), intralingual transfer/overgeneralization (interference within the target language, leading to making up grammatical rules), and false friends (using words that sound similar in both languages but have different meanings in each language). As research on bilingualism increases, so do the controversies about bilingualism and bilingual education (Antón et al., 2019). Linguistic abilities (e.g., smaller vocabulary size on the second language and slower lexical retrieval for each language) have been discussed as disadvantages of being bilingual. It is also common to encounter the linguistic phenomena known as "Spanglish" (where students create a mixture of both languages), which could lead to lexical errors (Lirola, 2006; Quinteros Baumgart & Billick, 2018). The language environment that children experience influences the quality of the development of their cognitive system (Goldin-Meadow et al., 2014). Therefore, it is to expect that attending a bilingual school during your early years of life will influence children's cognitive and linguistic skills.

The present study

Much of the research that has been conducted on the interplay between cognition and language has used adult samples. A previous study conducted with

college students examined the context in which bilinguals use language in their everyday lives (Beatty-Martínez et al., 2019). Context influences the way in which cognitive resources modulate language abilities. After evaluating participants in two lexical production tasks, Beatty-Martínez and colleagues (2019) concluded that engagement of attentional control depends on the demands of the language environment. While there is a growing body of research regarding the cognitive and linguistic abilities of bilingual children, less research has focused specifically on bilingual reading. Progress has been made in recent years as bilingual research has gained traction, but there are still many questions to answer regarding the best way to approach bilingual education. It is important to clearly determine how being immersed in a bilingual school influences children's reading ability. To better understand the processes underlying bilingualism, and the relationships between children's attentional control and reading ability, it is necessary to clearly distinguish between research on non-verbal and verbal abilities.

Non-Verbal Abilities

Non-verbal abilities are those that include skills such as attention and flexibility, but that do not require the use of language. Tasks that test non-verbal abilities do not include words or sentences as the stimuli. Bilingual advantages seem to be evident on non-verbal materials and tasks. Research in high school students suggests that bilingualism promotes cognitive flexibility in general. Being a bilingual student promotes better attentional control since bilinguals showed less amount of errors when completing the same cognitive tasks as monolinguals (Christoffels et al., 2015). An example of a non-verbal measure of cognitive capacity is the Flanker task (Eriksen & Eriksen, 1974). The Flanker task is a measure of resistance to distractor interference (Friedman & Miyake, 2004). Resistance to distractor interference refers to the ability

to focus on the target stimuli while suppressing distracting information (Eriksen & Eriksen, 1974). The Flanker task has been used to investigate attentional control in bilingual children ages eight to ten (Sorge et al., 2017). Results showed that bilingualism contributes to performance in attentional control tasks. The present study builds on this work by using the Flanker task to measure children's attentional control. Furthermore, we will explore whether performance in the Flanker task correlate to performance in the lexical decision task, a measure of children's verbal abilities.

Verbal Abilities

When talking about verbal abilities, we refer to topics such as vocabulary and reading. Many bilingual children learn to read in two languages simultaneously. The interaction between the native and the second language of a bilingual child influences how they learn to read (Hevia, 2019). Hevia (2019) collected data from children in bilingual and monolingual schools in Spain. Interestingly, Spanish-English bilingual children were more efficient at inhibiting non-words that followed Spanish phonological rules (better L1 suppression), while Spanish children with less exposure to English were more efficient at inhibiting non-words that followed English phonological rules (less L2 activation). When moving beyond the activation or inhibition of specific words, children exposed to two or more languages need to learn how to map experiences to words (lexical development), combine words to create sentences (grammatical development), and use both languages in an appropriate manner (pragmatic development) (Tamis-LeMonda et al., 2014).

Phonological awareness and pseudohomophones are important topics in reading research that need to be further study in biliteracy (i.e., bilingual reading). Phonological awareness is the knowledge of the individual sounds that make up spoken words

(Wagner & Torgesen, 1987). Researchers have shown that phonological awareness is a strong predictor of English word reading (Li et al. 2018; Melby-Lervåg, Lyster, & Hulme, 2012). Phonological representations are automatically activated during early stages of visual word recognition in adult readers (Carreiras et al., 2005; Sauval et al., 2017). These phonological effects represent fast, autonomic, and nonstrategic activation of phonological representations from orthographic information. This means that when you see a written word you immediately "hear" it in your head. A common approach to study the effect of phonology on reading is the use of pseudohomophones. A pseudohomophone is a non-word that sounds the same but is written differently than a real word. Comparing how people process words (blue) and pseudohomophones (bloo) that are written differently but sound the same (are phonologically equivalent), is an effective way to study the influence of phonology in word recognition (Sauval et al., 2017). In bilinguals, it is possible to investigate how pseudohomophones that follow orthographical rules from different languages influence reading (word: blue, English pseudohomophone: bloo, Spanish pseudohomophone: blu). An important question to answer is: How does bilingualism influence reading acquisition? To date, few studies have addressed this question despite the millions of children who are learning to read in bilingual environments.

Linguistic Interdependence

In 1979 Jim Cummins, an expert in bilingual and second language education, introduced the *linguistic interdependence hypothesis*. This hypothesis suggests that bilingual development, language, and literacy skills can be transferred across the two languages of a bilingual. Cummins argued that, although the surface aspects (pronunciation or fluency) of different languages are separate, there is an existing

cognitive/academic proficiency that is common across languages. This commonality makes it possible for bilinguals to transfer cognitive, academic, or literacy-related skills back and forth between languages (Cummins, 2005). The other side of this argument is that if functionality is shared, reading difficulties might also arise across languages. The *linguistic coding differences hypothesis* aimed at explaining the relationship between native and second-language reading difficulties (Sparks et al., 1989). These authors suggested that children who have difficulty reading in their native language will also show difficulties reading in their second language. The explanation behind this reasoning is that the same skill deficits will be present because both native and second language reading depend on the same set of linguistic skills (Li et al., 2018; Sparks et al., 1989). Despite these initial theories proposed in the 70s and 80s, empirical investigations aimed at understanding the specific mechanisms underlying how one language of a bilingual influences the other are still needed.

The *grain size accommodation hypothesis* (Lallier & Carreiras, 2018b) proposes that cross-linguistic variations and cross-linguistic transfer affect bilingual reading strategies as well as cognitive function. Grain size refers to the level at which the text is processed. In particular, "fine grain" refers to orthographic coding of graphemes and their respective order in a word (e.g., children focus on letters in some languages and syllables in others), while "coarse grain" refers to the information necessary to guess full words (e.g., in less transparent languages the whole word approach is prioritized). The idiosyncrasies of each language encourage children to focus on the graphemes (more transparent languages) or the words (less transparent languages). Lallier and Carreiras (2018a) investigated the cognitive and neural aspects of reading skills (phonological decoding) and reading subskills (auditory phonology). These authors concluded that there is evidence of orthographic specific influences and cross-linguistic

interactions that influence reading in bilingual children (Lallier & Carreiras, 2018a). The main take-home message of these studies is that learning to read in two alphabetic orthographies at the same time has consequences for children's cognitive and linguistic abilities.

Predictions

In addition to considering the interdependence between the bilinguals' two languages (in this study English and Spanish) we also consider the interdependence of the cognitive and linguistic abilities in bilingual children. When considering the relationship between the flanker task (measuring cognitive ability) and the lexical decision task (measuring linguistic ability), we predict that "resisting interference" in the incongruent condition of the flanker task (e.g., avoid getting distracted by the surrounding arrows and focusing on the direction of the arrow in the middle) will be related to "resisting interference" in the English pseudohomophones (e.g., avoid getting distracted by the sound that is similar to a word and focusing on the incorrect spelling). Correct responses to incongruent and pseudohomophones conditions require inhibition, since participants have to stop themselves from doing something automatic (go with the surrounding arrows, go with the sound) and focus on the actual task (focus on the middle arrow, focus on the spelling). Thus, this study predicts that the two "inhibiting" condition (incongruent/pseudohomophones) would be strongly correlated across tasks. The present study focuses on the relationship between cognitive and linguistic abilities in bilingual children, as well as the relationship between the two languages (English – Spanish). Based on the literature review discussed above, our specific predictions are as follows.

- Hypothesis 1: Students' performance in the cognitive task (Flanker) will predict students' performance in the linguistic task (Lexical Decision). Cognitive and linguistic abilities are interconnected; therefore, children who perform better in the attentional control task should also perform better in the reading task.
- Hypothesis 2: Students' educational experiences (self-reported amount of reading) will predict students' performance in the linguistic task. More practice reading should result in better performance in the reading task.
- Hypothesis 3: Within the lexical decision task, students' performance in the Spanish pseudohomophones will predict students' performance in the English pseudohomophones. In line with the linguistic interdependence hypothesis (James Cummins, 1979), reading performance in one language should relate to reading performance in the other.

2. Methods

Participants

A priori power analysis using G*Power 3.1.9.4 (Faul et al., 2007) software indicated a minimum of 40 participants for the study. We sent an invitation to participate to all of the 3rd, 4th and 5th graders (n = 150) at Maxwell elementary immersion school in Lexington, Kentucky. Maxwell elementary school admits students with a lottery system. The final sample included 82 elementary schools' students who brought back the parental consent forms signed and agreed to participate in the study. Students were in 3rd (n = 33), 4th (n = 35), and 5th (n = 14) grade and their ages ranged between 8 and 11 years old (M = 9.34, SD = 0.93). All students responded to a brief questionnaire with questions about demographic information and linguistic background (see Table 1).

Table 1. Participants' demographic information.

Continuous Variables	*Mean*	*SD*
Age	9.34	0,93
Reading in English (minutes per week)	296	285
Reading in Spanish (minutes per week)	37	51
Hours speaking other languages (hours per week)	3,15	7,33
Categorical Variables	*Levels*	*Count*
Gender	Males	45
	Females	37
First Language	English	75
	Spanish	6
	Other	1
Student Born in	USA	79
	Spain	1
	Argentina	1
	South Korea	1
Parents' Linguistic Background	Bilingual	20
	Monolingual	62
Parents' 1st language	English	62
	Spanish	15
	Other	5

Procedure

All children whose parents had provided consent completed a one-time 15-minutes session that consisted of two tasks and a questionnaire. First, they were asked consent to participate in the study through an assent form (a verbal consent form specifically designed for children). Then, they were asked to complete two tasks using the computer software MouseTracker: a Flanker task and a Lexical Decision task. At the end, participants were asked questions (see Appendix) about their bilingual background (years attending immersion school, native language, age of acquisition of English, age of acquisition of Spanish, parents native language, and living with a Spanish speaker relative), and information about their reading practices (number of hours a week reading in Spanish, and number of hours a week reading in English).

Tasks

Students' cognitive and linguistic abilities were measured using the mouse-tracking paradigm (Freeman & Ambady, 2010; Marian et al., 2003). To measure students' attentional control we used a non-verbal Flanker task (Eriksen & Eriksen, 1974). This task requires the activation of attentional control, as participants pay attention to the stimuli presented in the center while ignoring the surrounding stimuli. The Flanker task consists of a target flanked by non-target stimuli which correspond to either the same directional response (congruent stimuli → → → → →), the opposite response (incongruent stimuli → → ← → →), or the control (neutral stimuli □ □ → □ □). In the Flanker task the center arrow is the target, and participants have to select the top right or left corners of the screen, depending on where the arrow in the center is pointing to (see Figure 1).

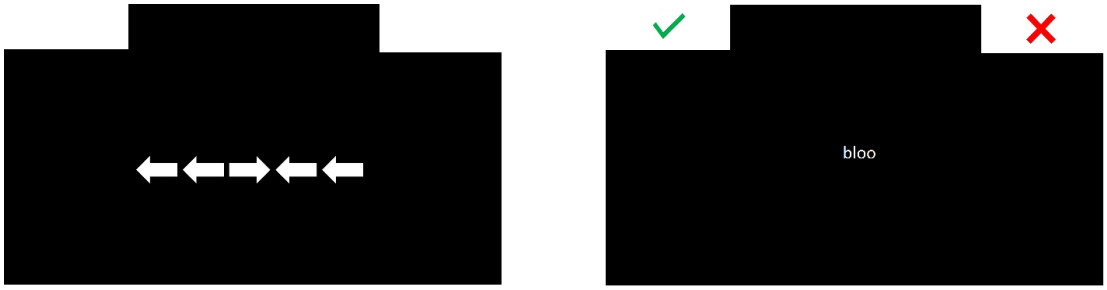

Figure 1. Mouse Tracker screen for the Flanker (left) and the Lexical Decision Task (right).

Students' linguistic abilities were measured using a visual lexical decision task (Hevia, 2019). The lexical decision task consisted of 24 stimuli: 12 real English words (e.g., blue), 4 pseudohomophones following English phonological rules (e.g,. bloo), 4 pseudohomophones following Spanish phonological rules (e.g., blu), and 4 non-words (e.g., lbeu - inexistent orthography in both languages). There were eight versions of the task to counterbalance the stimuli type (each stimulus could be presented in one of four conditions) and the position of the response options (correct responses on the top left/right of the screen). Each stimulus only appeared in one format in each version of the task: word (blue), English pseudohomophone (bloo), Spanish pseudohomophone (blu), and nonword (lbeu). The response options were counterbalanced so the green tic appeared on the left side of the screen in half the versions and on the right side of the screen in the other half of the versions (see Figure 1).

3. Results

The following analyses were performed with R version 4.0.3. All participants started by completing the baseline task. For the "Baseline" participants were asked to click on the response option where a "Smiley Face" appeared. No actual stimuli was presented on the screen for the baseline task, only a smiley face in one of the response options. Performance on the baseline correlated with performance on the English words (r = 0.24, p = 0.047) and pseudowords (r = 0.34, p = 0.003). Thus, for the following analyses we used stepwise linear regression using the baseline as the control variable. The goal is to avoid relationships due to motor movements and measure the cognitive effects that emerge beyond motor ability. We only considered significant the variables that predicted words and/or pseudowords above and beyond the variance explained by the baseline. When a variable improves model fit above and beyond the baseline, we reported the size of the correlation after controlling for the baseline. To access the dataset, questionnaire, and R Notebook for the following analyses please click on: https://osf.io/8sjb5/?view_only=c09611850bef41469668fd841844dfe7

Attentional Control

The first question is to what extent attentional control predicts reading ability (see Figure 2). When predicting responses to English words (Figure 2A), responses to the incongruent condition of the Flanker task significantly improved model fit above and beyond the effect of the baseline (F = 18.36, p < .001). There was a strong positive correlation between responses to the incongruent condition of the Flanker task and responses to English words (r = 0.44, p < .001). When predicting responses to English pseudohomophones (Figure 2B), responses to the incongruent condition of the Flanker task did not improve model fit above and beyond the effect of the baseline *(*F = 1.60, p

= .210). Thus, children's ability to resist distractor interference (→ → ← → →) predicts children's ability to process English words (blue), but it does not predict children's ability to resist the temptation of considering an English pseudohomophone (bloo) as a real word.

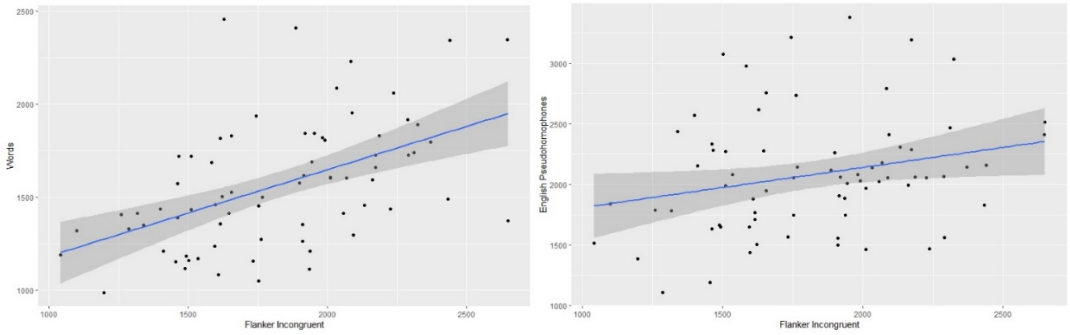

Figure 2. The relationship between the incongruent condition in the Flanker task and the English words condition in the Lexical Decision task (left). The relationship between the incongruent condition in the Flanker task and the English pseudohomophones condition in the Lexical Decision task (right).

Our original prediction emphasized that the strongest correlation would be between the incongruent condition of the Flanker task and the English pseudohomophones of the Lexical Decision task (both "inhibition" related conditions). However, the fact that the incongruent condition of the Flanker task predicted words but not English pseudohomophones, made us wonder whether other conditions within the tasks were correlated. Therefore, we performed additional exploratory analyses to determine whether the other conditions in these tasks are also related (see Table 2). Interestingly, the strongest correlation was between the congruent condition in the Flanker task and the English words in the Lexical Decision task ($r = 0.54$, $p < .001$). As it is possible to observe in Table 2, the correlations with the Flanker task are stronger for Words, followed by No Rules, English pseudohomophones, and Spanish pseudohomophones. The correlations with the Lexical Decision task are stronger for the Congruent condition, followed by the Control and the Incongruent conditions. The correlation we had predicted would be strongest (Flanker Incongruent with Lexical

Decision English Pseudohomophones) turned out to be the smallest correlation (r = 0.25) and not significant above and beyond the motor movement baseline.

		Lexical Decision		
	Words	No Rules	English	Spanish
Flanker Congruent	0.54	0.51	0.47	0.44
Flanker Control	0.53	0.43	0.37	0.34
Flanker Incongruent	0.50	0.38	0.25	0.30

Table 2. The Pearson correlation between the different conditions of the Flanker task and the different conditions of the Lexical Decision task in bilingual children.

Practice Reading

The second question is to what extent practice reading predicts reading ability (see Figure 3). For Hypothesis 2 we predicted that students' educational experiences (e.g., self-reported amount of reading) would predict students' performance in the linguistic task (e.g., process words faster / being less distracted by the English pseudohomophones). When predicting responses to English words (Figure 3A), there was a non-significant correlation, meaning that the amount of reading in English did not improve model fit above and beyond the effect of the baseline (F = 2.08, p = .154). When predicting responses to English pseudohomophones (Figure 3B), the amount of reading in English did not improve model fit above and beyond the effect of the baseline (F = 0.52, p = .475). Thus, amount of time reading in English did not predict performance for English words or pseudohomophones in the lexical decision task.

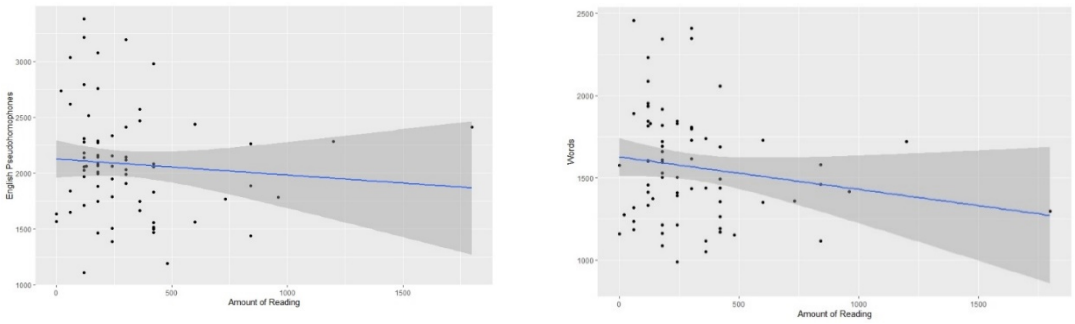

Figure 3. The relationship between amount of reading in minutes and reaction times for words in the Lexical Decision Task (left). The relationship between amount of reading in minutes and reaction times for the English pseudohomophones in the Lexical Decision Task (right).

The observant reader might have noticed that in Figures 4A and 4B there are two outliers with more than 1,000 minutes of reading time. When performing the analyses with and without the responses from these two participants (see code in the R Notebook of the OSF) the results did not vary, the relationships did not emerge.

Linguistic Interdependence

The third question is to what extent reading ability in Spanish predicts reading ability in English (see Figure 4). For Hypothesis 3 we predicted that students' performance in the Spanish pseudohomophones would predict students' performance in the English words/pseudohomophones. In line with our hypothesis, when predicting responses to English words (Figure 4A), responses to the Spanish pseudohomophones significantly improved model fit above and beyond the effect of the baseline ($F = 29.76$, $p < .001$). There was a strong positive correlation between responses to Spanish pseudohomophones and responses to English words ($r = 0.57$, $p < .001$). In addition, when predicting responses to English pseudohomophones (Figure 4B), responses to Spanish pseudohomophones significantly improved model fit above and beyond the effect of the baseline ($F = 19.14$, $p < .001$). There was a strong positive correlation between responses to the Spanish pseudohomophones and responses to the English pseudohomophones ($r = 0.51$, $p < .001$). In line with the linguistic interdependence

hypothesis, Spanish pseudohomophones predicted English words and English pseudohomophones.

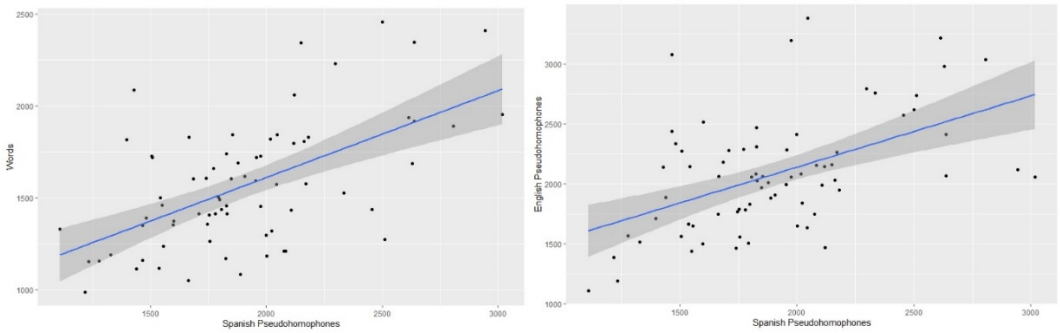

Figure 4. The positive correlation between performance in the Spanish pseudohomophones and English words (left). The positive correlation between performance in the Spanish pseudohomophones and performance in the English pseudohomophones (right).

4. Discussion

As predicted in Hypothesis 1, performance in the Flanker task predicted performance in the Lexical Decision task. Children who were able to effectively discard the surrounding arrows in the incongruent condition of the Flanker task were also more capable to effectively recognize English words. However, this effect did not emerge for the English pseudohomophones. Children's ability to resist distractor interference in the incongruent condition of the Flanker task did not predict children's ability to resist the temptation of considering an English pseudohomophone (bloo) as a real word. If "inhibition" was driving these correlations, the effect should be stronger (definitively not absent) for pseudohomophones than for words. The results of the exploratory analyses (see Table 1) suggest that activation (the correlation between the congruent condition in the Flanker task and the words condition in the Lexical Decision task) results in stronger associations between the tasks than inhibition (the correlation between the incongruent condition in the Flanker task and the pseudohomophones in the Lexical Decision task). Inhibition does not result in significant associations between tasks.

Given these intriguing results, we argue for a global mechanism of attentional control underlying performance across processes, as opposed to a more specific inhibitory mechanism driving the relationship between cognitive and linguistic abilities. The exploratory analyses reported in Table 1 support the existence of a global mechanism of attentional control at the root of these correlations. Simpler, straight forward tasks (e.g., processing words and processing the congruent condition) are more likely to be correlated than more complex tasks (e.g., processing pseudohomophones and the incongruent condition). It is possible that the more complex conditions include the compound effects of several cognitive processes, thus obscuring potential

correlations, while simpler conditions might be more clearly related because they are the result of a smaller number of cognitive processes. Future studies should explore the specific connections between attentional control and reading ability across conditions, in order to inform theories of attentional control as well as models of bilingual reading.

Against Hypothesis 2, the amount of time reading did not predict performance in the lexical decision task. The effect of practice reading did not influence performance on words or pseudohomophones. It is possible that asking participants to self-report the amount of time a week they spend reading in English is not a sensitive enough measure to detect an effect. A more specific measure of reading could be to use curriculum-based measurements (CBM) that have been shown to be a successful measurement of English reading in Spanish speaking children (Baker & Good, 1995). Future studies could also measure reading at home through tools such as reading diaries, or technology (e.g., e-books) with built-in systems that track how long children read in each language. Using observational, instead of self-report, measures of amount of time reading could prevent memory biases. Furthermore, more complex tasks to evaluate reading performance (e.g., reading sentences, reading paragraphs) might be better able to capture nuanced differences. More naturalistic measures of reading time and reading performance are likely to shed light over whether spending more time reading in each language results in better reading performance, as well as on the boundary conditions of these effects. It is possible that there is a ceiling effect, after a certain age or reading level spending more time reading might not improve reading performance.

In line with Hypothesis 3, performance in the Spanish pseudohomophones predicted both performance in the English words and English pseudohomophones. The *linguistic interdependence hypothesis* refers to the relations between processing Spanish and English stimuli in bilinguals. The fact that the correlations that support the

interdependence hypothesis emerge not only between Spanish and English pseudohomophones, but also between Spanish pseudohomophones and English words, supports the argument for a global processing mechanism that applies to both languages. These results challenge the idea of a cross-linguistic mechanism specific to inhibitory processes, in favor of a more general cognitive mechanism that emerges across processes (activation/inhibition) and languages (Spanish/English). It is possible that a global mechanism of attentional control is at the root of the correlations between cognitive and reading ability.

Attentional control is the ability to maintain an operative goal, and goal-relevant information, in the face of distraction (von Bastian et al., 2020). There are three types of distraction that can interfere to a certain degree with the processing of goal-relevant information, these distractions are caused: by the perceived environment, by self-generated information, or by habits (Friedman & Miyake, 2004; von Bastian et al., 2020). In our research we measured the distraction caused by the perceived environment with the Flanker task. Participants were distracted with the surrounding arrows while focusing on the arrow in the center. We measured the distraction caused by self-generated information through the use of pseudohomophones. Participants had to inhibit the self-generated word that sounded like the pseudohomophone, while focusing on the way the pseudohomophone was written. The lack of correlation between the incongruent condition of the Flanker task and the pseudohomophone condition of the lexical decision task might be due to the fact that these measures focused on different areas of attentional control. The incongruent condition of the Flanker task measured distraction caused by the perceived environment, while the pseudohomophones of the lexical decision task measured distraction caused by self-generated information. A measure of attentional control that focuses on distraction

caused by self-generated information might be more likely to correlate with performance in the pseudohomophones of the lexical decision task.

The sample recruited included middle schoolers ages eight to 11. The small range of ages made it difficult to evaluate developmental effects of reading. It is possible that a wider spread of ages (e.g., 6, 10, and 14 years old) would provide new insights into how bilingual reading processes unfold with age. Furthermore, the students in this sample (English-speaking children immersed in a Spanish-English Bilingual school in Lexington, KY) reported little to no time reading in Spanish. More diverse samples of bilingual children, including those with more hours reading at home in each language, might show different developmental patterns. The bilingual experience is very diverse, so it is important to consider different bilingual characteristics to be able to properly determine the influences of bilingualism on reading development.

When talking about diverse bilingual experiences it is easy to imagine how some bilinguals have a lot of experience with the language (e.g., those growing up in Spanish speaking households) while others learn their second language only at school. Previous research has shown that the mere exposure to bilingual literacy materials and activities (books, music, etc.) has an impact on future second language development (Hammer Carol Scheffner et al., 2003). Better measures of bilingual experience are necessary to determine how much exposure is necessary and for how long to substantially influence reading development. It is important to distinguish diverse bilingual educational experiences from socio-economic status. While socio-economic status might not directly affect bilingualism, it does have an effect on what kind of educational experiences students are getting: Spanish tutors, studying abroad, etc. (Ladas et al.,

2015). Future studies should take these factors into consideration when investigating the relationship between attentional control and reading.

Bilingual education models could help students develop through activities that engage attentional control as well as reading across both languages. Our results support the *linguistic interdependence hypothesis*, according to which bilingual development, language, and literacy skills could be transferred across the two languages of a bilingual. Cummins argued that, although the surface aspects (pronunciation or fluency) of different languages are separate, there is an existing cognitive/academic proficiency underneath that is common across languages. This commonality makes it possible for bilinguals to transfer cognitive, academic, or literacy-related skills back and forth between languages (Cummins, 2005). Given the strong correlation between reading in one language and the other, and the fact that attentional control predicted reading performance, the specific language in which students are learning to read might not be as relevant as the cognitive and linguistic abilities students are developing while learning to read. For teachers and educators, this finding might be helpful as they could focus on either language while teaching reading. This approach will add flexibility to their lesson plans and book assignments.

Transparent languages are those with clearer phoneme-grapheme relationships (e.g., Spanish) and might be easier for children to learn than opaque languages (e.g., English). Previous studies on bilingual children show how listening comprehension in a transparent language was a powerful predictor of their overall reading comprehension (Bonifacci & Tobia, 2017). If the processes are transferable between languages, it might be best to start with the easiest language to learn to read in, or with the most dominant language for the student. In bilingual/immersion schools it might be easier to start with

the most transparent language (e.g., Spanish) and then move to more opaque languages (e.g., English). Future studies should investigate how linguistic transparency and bilingual dominance influence how bilingual children learn to read and write. Future research should further explore how many years these children have been in this educational setting, exposed to bilingualism, etc. Future studies should also investigate whether specific populations (e.g., dyslexic children) could respond differently. As we become a more diverse society, it is important to perform more research on how bilingualism impacts reading.

The relationship between cognitive and linguistic abilities is complex and full of nuances. Implementing more second language hours into the educational curriculum could help children learn a new language, as well as develop cognitive abilities that in turn could strengthen their reading abilities. This research hopes to bring schools and educators to the realization that the specific language in which reading is taught does not seem to be as relevant as the underlying abilities that students develop while learning to read. This can be freeing, as educators could choose materials based on content and interest, independently of the language in which they are written.

"Language acquisition proceeds best when the input is not just comprehensible, but really interesting, even compelling; so interesting that you forget you are listening to or reading another language."

– Stephen Krashen

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APPENDIX

Appendix A: Bilingual Children Questionnaire

Appendix A: Bilingual Children Questionnaire

Bilingual children questionnaire – Every participant responded to the following questions:

- Gender
- Age
- Is English your first language?
    - If not, what is your first language?
- What country were you born in?
- How much time do you spend reading English per week? Responses recorded in minutes
- How much time do you spend reading in Spanish per week? Response recorded in minutes
- Are any of your parents/tutors bilingual?
    - If yes, what language(s) do they speak?
- How much time do you spend talking another language per day? Response recorded in minutes