

*It takes two to make a thing go write:* Within-population differences in Spanish reading and writing among Spanish-English bilingual young adults and relationships with digit span and stroop task performance.

Sara A. Smith

Department of Teaching and Learning

University of South Florida

Tampa, Florida, USA

Jessica Briggs Baffoe-Djan

Department of Education

University of Oxford

Oxford, UK

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Address for correspondence: Dr. Sara A. Smith, Department of Teaching and Learning, 4202 E. Fowler Ave., Tampa, FL 33620, USA, Email: [sarasmith3@usf.edu](mailto:sarasmith3@usf.edu)

Abstract: The current study examined first language (Spanish) language reading and writing ability and behavior and relationships with digit span and stroop task performance. A battery of assessments and questionnaires was administered to 81 sequential Spanish-English bilingual university students in the U.S., for whom the sole language of education is English. .

Hierarchical regression models revealed amount of Spanish used for academic writing uniquely accounted for 17% of variance in digit span forward scores, controlling for non-verbal IQ. Self-reported Spanish reading and writing ability also significantly predicted higher digit span forward scores and stroop task performance. Findings indicate that vectors of within-population difference related to L1 academic reading and writing are associated with differences in verbal short term memory and inhibition. Findings underscore the importance of considering diversity within bilingual samples and further support theories of a continuum of bilingual experience intensity, which is related to outcomes.

Keywords: short term memory, inhibition, biliteracy, Spanish-English bilinguals, young adults.

## Introduction

Approximately one third of children aged 0-8 in the U.S. (more than 11.5 million children) speak a language other than English at home; this population has increased 24% since 2000 and is predicted to continue to increase further (U.S. Census Bureau 2014; Park, Zong, and Batalova 2018). The majority of these dual language learners are Spanish speakers (approximately 60%), most of whom will acquire academic literacy in their second developing language (L2), English (Park, Zong, and Batalova 2018; August and Shannahan 2006). Prior research has sometimes presented U.S. bilinguals as a homogeneous group, yet research among younger learners increasingly demonstrates multiple profiles, even among bilinguals from the same first language (L1) communities (Hammer et al. 2014; Kim et al. 2018). Growing evidence indicates that academic and cognitive outcomes are differentially related to? within-population vectors of difference including language characteristics, usage, and exposure.

Bilingual experiences are multidimensional, and fine-grained differences between bilinguals are likely relevant for academic, cognitive, and language outcomes (Hammer et al. 2011; Hammer et al. 2008; Hartanto, Toh, and Yang 2018). As a result, there have been increasing calls for research exploring bilingual within-population diversity, especially among U.S. Spanish-English bilinguals (Hammer, Jia, and Uchikoshi 2011; Hammer et al. 2014; Kim et al. 2018; Surraín and Luk 2017). Comparing monolinguals to bilinguals is not just comparing *apples to oranges*, it is comparing apples to a fruit salad. As such, investigations of within-population factors that contribute to differences between bilinguals may also be *fruitful*. The current study examines relationships between differences in L1 (Spanish) reading and writing (self-reported ability, amount of academic reading and writing) and performance on digit

span tasks (forward, backward, sequencing) and an inhibition task (*color-word stroop*) among a sample of early sequential Spanish-English bilinguals.

### ***Theoretical Frameworks***

A developing body of research demonstrates that higher engagement in dual language environments bears a positive relationship to some features of cognition, including executive function, among bilinguals (Hartano and Yang 2016; Hartanto, Toh, and Yang 2018; Smith et al. 2017; Verhagen, Mulder, and Leseman 2015; Wu and Thierry 2013; Yow and Li 2015).

Executive Function (EF), is the umbrella term used to describe the various skills needed to manage and allocate cognitive resources during activities such as high-level thought, multitasking, focusing attention, ignoring distractions, and suppressing impulses. EF plays a key role in individual differences in self-control and ability to regulate thoughts, impulses, and behavior.

According to the *unity/diversity* model of EF, three components (inhibition, cognitive flexibility/switching, updating working memory representations) are responsible for complimentary control (Miyake et al. 2000; Gruber & Goschke, 2004; Ofoe, Anderson, and Ntouriou 2018): EF results from the interaction of these separable functions (Miyake et al. 2000). Working memory (WM) refers to the dedicated system that allows the individual to retain and manipulate stored information during a short, fixed period of time (Baddeley 2003; Klingberg, Forssberg, and Westerberg 2002). Two modality-specific systems store information: 1) the visuospatial sketchpad for storing visuo-spatial material; 2) the phonological loop for storing auditory-verbal material, also called verbal short term memory (STM; Baddeley 2000, 2012). The field generally, though not unanimously, views STM and WM as distinct but related (Baddeley 2000; Cowan 1995; Engle et al. 1999; Engle and Kane 2004). WM is implicated when

another operation must be carried out using stored information (e.g., reciting the digits sequenced from smallest to largest; Baddeley 2003; Turner and Engle 1989). WM and STM tasks overlap with regard to the activities they involve (Swanson, Zheng, and Jerman 2009); however, research indicates that there exist processes for which STM and WM operate independently (e.g., Brainerd and Kingma 1985; Cantor et al. 1991).

### ***Relationships with Bilingualism***

There is not yet a definitive consensus on how, or if, bilingualism impacts EF. While many studies have found EF advantages in bilingual children (Hartanto, Toh, and Yang 2018; Santillán and Khurana 2017) and adults (for a review, see Bialystok 2018), other studies have failed to see higher performance compared to monolinguals (Hilchey and Klein 2013; Lehtonen et al. 2018) or find short-lived benefits (Bosma et al. 2017). Discrepancies in findings may be related to within-population variation among bilinguals and bilingual participant sampling criteria, as ‘bilinguals differ in ways that matter’ (Baum and Titone 2014:875; Bialystok, Craik, and Luk 2012; Luk et al. 2010). Factors such as frequency and type of language use, age of acquisition, and/or achievement in each language may contribute to diversity (Baum & Titone, 2014).

Lifelong bilinguals show greater ability to ignore distracting stimuli and have greater control in inhibition tasks; this is attributed to many years engaging in the daily task of managing multiple languages competing for attention and constant context-specific suppression of a non-target language (Bialystok et al. 2012; Luk et al. 2010). Smith et al. (2017) demonstrated a positive relationship between switching task performance and more balanced (closer to 50/50) home receptive language environments among Spanish-English bilingual young adults. Similarly, Singaporean bilinguals whose environments were mainly dual-language demonstrated

lower switch costs in comparison to bilinguals who operate in single-language contexts (Hartano and Yang 2016). Among English-Welsh bilingual adults, a dual-language context induced more EF processing, as measured by a flanker task, when compared with a single language context (Wu and Thierry 2013). Taken as a whole, findings indicate that active dual-language use environments are associated with advantages.

Bilinguals with more comparable proficiency and higher achievement in both languages demonstrate advantages over bilinguals with imbalanced or lower skill, indicating that cognitive impacts of bilingualism may be moderated by degree of bilingualism and language balance (Blumenfeld and Marian 2013; Bosma, Versloot, and Blom 2017; Prior et al. 2016; Santillán and Khurana 2017; Thomas-Sunesson, Hakuta, and Bialystok, 2016; Yow and Li, 2015). Blumenfeld and Marian (2013) found that English-Spanish bilinguals with higher proficiency in their second language (Spanish) exhibited a greater extent of parallel language activation during spoken word recognition activities, and also demonstrated higher inhibition performance. Yow and Li (2015) showed that bilingual adults who had more balanced usage of and more balanced proficiency in their two languages had higher EF performance on inhibition and trail-making switching than ‘imbalanced’ bilinguals. Bialystok and Barac (2012) examined EF among children in language immersion schooling and found higher performance on EF conflict tasks was associated with higher degrees of bilingualism, as measured by proficiency in the newer language. Santillán and Khurana (2017) followed inhibition development among preschoolers (Spanish monolinguals acquiring English, English monolinguals, Spanish-English bilinguals) for 18 months. Spanish-English bilingual children had the highest inhibition performance at the outset and also demonstrated the steepest growth over the duration of the study. Spanish monolinguals were the lowest performing group at the outset, however, these emerging bilinguals demonstrated steeper

growth than English monolinguals, indicating that maintaining bilingualism and becoming bilingual confer advantages to development rate in early childhood, although impact on ultimate attainment is unclear.

Previous research has found evidence of bilingual advantage to WM (Bialystok and Feng, 2009; Blom et al. 2014; Engel de Abreu et al. 2012; Hernández, Costa, and Humphreys 2012; Morales, Calvo, and Bialystok 2013; Macnamara and Conway, 2014) although findings are not unanimous (for examples of no advantage, see Bonifacci et al. 2011; D'Souza, Moradzadeh, and Wiseheart 2018; Engel de Abreu 2011). Blom and colleagues (2014) found that Turkish-Dutch bilingual children performed better than monolingual peers on a visuo-spatial task (a matrix task) and a verbal WM task (digit span backward). Similarly, Morales and colleagues (2013) found visuo-spatial WM advantages among 5- and 7-year-old bilingual children as compared to monolingual peers using a location matrix task, however, Engel de Abreu (2011), failed to find advantages among similarly-aged bilinguals using comparable visuo-spatial tasks.

Research indicates that bilinguals may differ from monolinguals when completing specific memory-related activities during writing. Ransdell and colleagues (2002) exposed monolinguals and bilinguals to: 1) ambient irrelevant speech (that must be ignored); 2) and/or simultaneously maintaining a 6-digit span in STM, while writing. Both quality and fluency of written work declined (Ransdell, Levy, and Kellogg 2002). Bilinguals showed decreased fluency in their written work while maintaining the 6-digit STM load but no decrease in quality and fluency when exposed to ambient irrelevant non-target language speech while writing (Ransdell, Arecco, and Levy 2001). Multilinguals highly proficient in three languages were the most skilled, able to maintain a concurrent 6-digit string in STM while in the presence of ambient, irrelevant, non-target language speech, with no impact on L1 writing quality or fluency

(Ransdell, Arecco, and Levy 2001). Authors interpret results as evidence of bilingual advantage for suppressing irrelevant information, and hypothesize that constant activation and inhibition of non-target language produces a specialized form of STM verbal span among bilinguals (Ransdell, Arecco, and Levy 2001).

### ***Current Study***

Dual language programs are becoming increasingly popular in the U.S. (Boyle et al. 2015) and have been proposed as a potential way to address persistent achievement gaps between monolingual English speakers and children who speak a language other than English in the home (NCES 2015; Superville, 2019). Currently, however, U.S. bilinguals are for the most part educated through English only, denoting that formal development of literacy skills occurs only or mainly in the L2. As such, there is likely significant variation in L1 reading and writing skills within this population. Given that our review of the literature points to a strong relationship between dual-language proficiency, achievement and environments on the one hand, and cognition on the other hand, the current study seeks to examine whether individual differences related to L1 reading and writing are associated with differences in cognitive task performance. We address the following research questions: 1) Is there a relationship between self-reported L1 reading and writing ability and performance on digit span tasks (forward, backward, sequencing) and/or a stroop task among bilingual young adults?; 2) Is there a relationship between amount of L1 used in daily reading and writing and performance on digit span tasks (forward, backward, sequencing) and/or a stroop task among bilingual young adults?

We hypothesize that more Spanish reading and writing activity, particularly in ostensibly English-only environments such as the academic setting (in which an increase in Spanish activity



denotes a more dual-language environment), will show positive relationships with performance on digit span tasks (forward, backward, sequencing) and stroop task performance.

In line with previous research demonstrating positive relationships between greater dual language proficiency and inhibition (for a review, see Bialystok 2018), we further hypothesize that greater self-reported skill in Spanish reading and/or writing will show positive relationships with inhibition as measured by a stroop task.

## **Methods**

### ***Participants***

Eighty-one early sequential Spanish-English bilingual university students took part in the current study, 66 females, ages 18 – 29 years old ( $M = 23.79$  years,  $SD = 2.98$ ). Participants spoke Spanish from birth and began learning English between 2-5 years. All had 12 years of English language public school in the U.S., 9 reported some exposure to Spanish language instruction during elementary schooling (0.5-2 years of some Spanish incorporated into primarily English schooling). Participants were students enrolled at a four-year U.S. public university where over 50% of students received Pell Grants (government grants to support individuals from households below federal income thresholds). All participants identified as Chicano/a, Hispanic, or Latino/a, and completed high school in two adjacent counties. Participants' declared academic majors were in the domains of Liberal Studies, Health Sciences, Social Sciences, Business, and Engineering. Participants reported all their classes were taught in English exclusively, no participants were taking language arts courses or foreign language courses. Participants reported no learning or developmental disabilities. 143 participants were screened for inclusion; exclusion criteria included: having ever taken courses in Spanish; being a Spanish language major; having lived in a country where Spanish was the language of communication after age of schooling

onset; having attended elementary, secondary or higher education schooling in Spanish or a Spanish-English bilingual program; have learned English in middle childhood or later; L1 language other than Spanish; lower-intermediate or better proficiency in a language not English or Spanish.

Participants were recruited via email and flyers, and were compensated in university currency for taking part in one testing session of approximately 1 hour. Assessments were administered individually, in the same order, by a trained tester in English and Spanish. Testing took place in private rooms with minimal distractions.

### ***Materials***

*Bilingual Verbal Ability Tests (BVAT; Muñoz-Sandoval, Cummins, Alvarado & Ruef, 1998)*

Participants were administered the Spanish BVAT single word picture vocabulary subtest with a total of 58 items. Participants were asked to identify which image from of a series of presented images corresponded with a single Spanish word, or were presented with an image and asked to name the verb or noun shown in the image. Test items were presented by a L1 Spanish-speaker. Answers were scored on a binary scale, 1 or 0 points. No partial points were given and no points were given for English responses.

*Delis-Kaplan Executive Function System; color–word inhibition subtest (D-KEFS; Delis, Kaplan, & Kramer, 2001).*

The Color–Word Inhibition subtest utilizes the stroop effect (Stroop, 1935) to measure cognitive flexibility and inhibition. Trials 1 and 2 establish ability to read aloud a list of printed color names and identify a sequence of colors presented in squares. Trial 3 requires the participant to suppress the dominant urge to read a printed color name and instead say incongruent ink color the color name is printed in (e.g. the word ‘red’ printed in green ink). Trail

4 combines inhibition and switching by requiring participants to switch between naming incongruent ink colors and reading written color names, measuring cognitive flexibility and inhibition. Scores are scaled at 10.

*Modified Language and Social Background Questionnaire (LSBQ; Luk and Bialystok 2013)*

Participants were given a modified, electronic version of the LSBQ (Luk and Bialystok 2013), a validated questionnaire designed to explore language and social background heterogeneity among bilingual populations and specifically to examine variation in language environment, perceived proficiency, and usage (Luk and Bialystok 2013). Participants reported estimated proportion of Spanish or English usage in different settings (e.g., home, university, work), with various interlocutors (e.g., family, friends, co-workers, clients/customers) and for assorted activities (e.g., talking, reading, writing, watching TV) using sliding scales between 0% and 100%. Participants also reported their perceived ability levels in English and Spanish for reading, writing, speaking, and listening. Participants were additionally asked to report specific Spanish usage for academic purposes, and, if so, to estimate frequency, including if and how frequently they: 1) took notes on in Spanish on English content during class; 2) took notes in Spanish while the lecturer speaks in English; 3) read Spanish materials for class including for English content homework, group work, or assignments, and; 4) wrote in Spanish for English content homework, group work, or assignments. LSBQ was administered using Qualtrics survey software (Qualtrics 2018).

*Wechsler Adult Intelligence Scale; matrix reasoning, Digit Span, verbal comprehension, verbal similarities subtests (WAIS-IV; Wechsler, Coalson & Raiford, 2008)*

In the WAIS IV Matrix Reasoning subtest, test takers are presented with patterned sequences and must select an image from a set of options to logically complete the pattern,

measuring fluid intelligence, non-verbal abstract reasoning, and perceptual organization. These skills are collectively referred to as non-verbal IQ.

The Digit Span subtest measures STM, WM, auditory processing, and attention. There are three tasks. For the digit forward (STM span) task, a series of increasingly long numbers are spoken aloud to the participant and they were required to repeat the series as spoken. Next, a backward span task is administered, a series of numbers are read aloud and the test taker repeats back the series of numbers in reverse order. Finally, in the sequencing task, the series of numbers are read aloud and the test taker must verbally list numbers in order from least to greatest. Test administrator cannot repeat the sequence of numbers or individual numbers in the sequence after the item has been verbally administered. The subtest produces 3 scores relevant to the current study: 1) digit span forward (STM); 2) digit span backward (WM); 3) digit span sequencing (WM).

Two WAIS subtests were administered to measure English language, the Verbal Comprehension and Verbal Similarities subtests, measures of English verbal comprehension and verbal intelligence respectively. All WAIS IV subtests are administered in English, are scaled at 10, and discontinue after 3 consecutive scores of 0.

## **Results**

### ***Participant Characteristics***

Table 1 presents mean scores and standard deviations for participant performance on the assessment battery. Table 2 presents descriptive statistics on reported language environment in different settings and modalities, expressed as percentage in English (e.g., 85 indicates 85% of the language used in the described setting is English and 15% is Spanish; 100 would indicate only English is used in the described setting and modality). Table 3 presents means and standard

deviations for self-reported skill in Spanish and English across different language modalities (speaking, listening, reading, writing) on a scale of 1 to 10, with 10 being ‘native speaker’. Overall, participants reported higher skill in English than Spanish, particularly in the areas of reading and writing.

<Insert Table 1 approximately here>

<Insert Table 2 approximately here>

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Participants reported using approximately 90% English to converse with classmates at University and between 50%-60% English for home activities including speaking, listening, and listening to music. Writing behavior values ranged from 0% English used when writing at home to 100% English usage when writing at home. Writing for University purposes ranged from 50% in English (therefore 50% in Spanish) to 100% English usage, indicating that some students use Spanish for as much as 50% of university writing activity, despite taking classes entirely in English. Fifty-eight participants further detailed specific L1 use for academic reading and writing including: taking notes in Spanish while the teacher lectured in English (n=10); reading reference materials in Spanish (i.e. selecting books and articles on course topics in Spanish) (n=16); writing sections in Spanish within the larger context of assignments written in English (n=16); initially drafting written assignments in Spanish then translating into English before submission (n=8); and translating Spanish language materials into English for their final written assignments (i.e. reading and translating ‘wiki page’ in Spanish related to an assignment topic; n=24).

### ***Spanish Vocabulary and Self-reports***

There were significant relationships between BVAT performance and self-reported Spanish reading and writing skills (as measured by LSBQ). Hierarchical regression analyses found that higher self-reported Spanish reading (LSBQ) significantly predicted higher Spanish single word vocabulary (BVAT), when controlling for IQ, [ $F(2,74)=4.46$ ,  $p=.007$ ,  $R^2\Delta = .16$ ;  $R^2=.18$ ], as did higher self-reported Spanish writing ability (LSBQ), when controlling for IQ, [ $F(2,74)=3.43$ ,  $p=.018$ ,  $R^2\Delta = .13$ ;  $R^2=.15$ ]. Thus, we conclude participants are able to self-assess relatively accurately, as found in previous research (Smith, Briggs, and Pothier 2017).

Outcomes for WAIS IV subtests were normally distributed. Hierarchical regression analyses, controlling for IQ (entered as first step), were conducted to test relationships between environmental and individual variables (LSBQ) and outcome variables (WAIS IV digit forward, digit backward, digit sequencing; D-KEFS color-word inhibition).

### ***Spanish Reading and Writing Ability***

Self-reported Spanish reading ability (LSBQ) predicted a significant amount of variance (9%) in digit forward scores, controlling for IQ, [ $F(2, 74)=9.63$ ,  $p=.000$ ,  $R^2=.21$ ,  $R^2\Delta = .09$ ,  $p=.006$ ]; participants with higher self-reported reading skill had higher digit forward scores. Self-reported Spanish reading ability (LSBQ) also predicted a significant amount of variance (12%) in D-KEFS color-word inhibition scores, controlling for IQ, [ $F(2, 74)=5.29$ ,  $p=.007$ ,  $R^2=.13$ ,  $R^2\Delta = .12$ ,  $p=.003$ ]. There were no significant relationships, however, between self-reported Spanish reading ability and digit backward [ $F(2, 74)=9.67$ ,  $p=.000$ ,  $R^2=.21$ ,  $R^2\Delta=.01$ ,  $p=.304$ ], or digit sequencing [ $F(2, 74)=3.67$ ,  $p=.03$ ,  $R^2=.09$ ,  $R^2\Delta=.006$ ;  $p=.47$ ].

Self-reported Spanish writing ability (LSBQ) predicted a significant amount of variance (10%) in digit forward scores, controlling for IQ [ $F(2, 74)=10.07$ ,  $p=.000$ ,  $R^2=.22$ ,  $R^2\Delta=.1$ ,  $p=.000$ ], such that participants with higher self-reported Spanish writing ability had higher digit

forward scores. Self-reported Spanish writing skill accounted for significant variance (5%) in D-KEFS Color-Word Inhibition, after controlling for IQ [ $F(2,74)=3.43, p=.018, R^2=.06, R^2\Delta=.052; p=.018$ ], again that participants with higher self-reported Spanish writing ability had higher scores. There were no significant relationships, however, between Spanish writing skill and digit backward [ $F(2, 74) = 10.32, p=.000, R^2=.22, R^2\Delta=.02, p=.15$ ] nor digit sequencing [ $F(2, 74)=3.39, p=.04, R^2=.09, R^2\Delta=0; p=.9$ ]. There was no significant relationship with D-KEFS Color-Word Inhibition [ $F(2, 74)=2.56, p=.08, R^2=.07, R^2\Delta=.05; p=.05$ ], although model was approaching significance.

### ***Spanish Reading and Writing Behavior***

School reading behavior (LSBQ) accounted for significant variance (13%) in digit forward scores after controlling for IQ. Specifically, lower percentage of English and a higher percentage of Spanish predicted higher digit forward scores [ $F(2,74)=12.95, p=.000, R^2=.26, R^2\Delta=.13; p=.001$ ]. As with self-reported Spanish reading skill, however, there was no significant relationship between Spanish reading activity for schooling and digit backward [ $F(2, 74)=10.05, p=.000, R^2=.22, R^2\Delta=.02, p=.28$ ], digit sequencing [ $F(2, 74) = 4.11, p=.02, R^2=.1, R^2\Delta=.02; p=.21$ ], or D-KEFS Color-Word Inhibition [ $F(2, 75)=.61, p=.82, R^2=.02, R^2\Delta=.0; p=.54$ ], controlling for IQ. Home reading behavior showed no relationships with digit forward scores [ $F(2,74) = 6.36, p=.003, R^2=.15, R^2\Delta=.02; p=.2$ ], digit backward [ $F(2, 74) = 10.25, p=.00, R^2=.22, R^2\Delta=.02, p=.22$ ] or digit sequencing [ $F(2, 74)=3.93, p=.024, R^2=.1, R^2\Delta=.01; p=.26$ ], controlling for IQ.

School writing behavior (LSBQ) accounted for significant variance (17%) in digit forward scores, controlling for IQ; the most of any environmental variable. Specifically, lower percentage of English and a higher percentage of Spanish predicted higher digit forward scores

[ $F(2,74)=15.82, p=.000, R^2=.30, R^2\Delta=.17; p=.000$ ]. There was no significant relationship between writing behavior at university and digit backward span [ $F(2, 74)=10.77, p=.000, R^2=.23, R^2\Delta=.03, p=.13$ ] or digit sequencing [ $F(2, 74)=4.55, p=.014, R^2=.11, R^2\Delta=.02; p=.13$ ], controlling for IQ. There was no significant relationship with D-KEFS color-word inhibition [ $F(2, 75)=9.73, p=.003, R^2=.03, R^2\Delta=.01; p=.38$ ]. Home writing activity showed no relationships with digit forward scores [ $F(2,74)=5.46, p=.006, R^2=.13, R^2\Delta=.002; p=.69$ ], digit backward [ $F(2, 74)=9.47, p=.000, R^2=.21, R^2\Delta=.003, p=.06$ ] or digit sequencing [ $F(2, 74)=3.24, p=.05, R^2=.08, R^2\Delta=0; p=.94$ ], controlling for IQ.

Amount of Spanish used for academic writing was approaching a non-normal distribution, skew=-2.53, kurtosis=1.898. A normalized z-score was computed for amount of Spanish used for academic writing, called Spanish writing z-score, and a second, confirmatory analysis was run using a z-scores, controlling for non-verbal IQ, and outcome scores. Findings were similar; Spanish writing (z-score) accounted for significant variance in digit forward scores [ $F(2,73)=15.82, p<.000, R^2=.3, R^2\Delta=.17$ ], but did not significantly predict digit backward scores [ $F(2,73)=10.76, p=.13, R^2=.23, R^2\Delta=.03$ ] or digit sequence scores [ $F(2,73)=4.55, p=.125, R^2=.11, R^2\Delta=.03$ ] or D-KEFS color-word inhibition [ $F(2,73)=9.97, p=.003, R^2=.03, R^2\Delta=.01$ ]

## **Discussion**

Our findings indicate that within-population differences relating to L1 reading and writing are associated with higher performance on a digit forward task and stroop task. Specifically, higher self reported ability in L1 reading and writing accounted for significant variance in digit span forward task performance and stroop task performance, after controlling for IQ. More ‘daily life’ L1 activity, specifically more L1 academic writing, and to a lesser degree more L1 academic reading, significantly predicted higher digit forward span task



performance, after controlling for IQ. The current study does not present evidence of a bilingual advantage when compared to monolinguals; however, findings indicate that among this sample of Spanish-English bilinguals (L2 exclusive schooling background, higher literacy in the L2), higher self-reported L1 reading and writing (ability and activity) is associated with higher performance on these specific tasks. Directionality is unclear and relationships may be reciprocal, however, our model substantiates the direction of L1 reading and writing ability and behavior to cognitive task performance. Findings provide further support for the growing body of research demonstrating a positive relationship between higher dual language proficiency and EF (Blumenfeld and Marian 2013; Santillán and Khurana 2017; Smith et al. 2017; Yow and Li 2015), in this case, inhibition as measured by a stroop task, and indicate that biliteracy skills specifically may confer benefits.

Findings are in line with Ransdell and colleagues' (2001) findings of bilingual advantage to STM verbal span, which the authors hypothesized is related to suppressing irrelevant information and constant activation and inhibition of non-target language. Specifically, bilingual participants with little to no daily language management for academic reading or writing (i.e. minimal to no use of Spanish in these domains) showed significantly lower digit forward performance than bilingual participants with higher L1 reading and writing ability and greater daily language management in the form of dual language academic reading and writing.

The participants in the current study were not so-called 'balanced' bilinguals; the L1 and L2 were associated with different experiences (L1 in home, school exclusively in L2). Participants reported differing levels of literacy in L1 and differences in environmental use. By reading and writing in the L1 for academic purposes, participants may further support language skill and build experience with language management. Engle and Kane (2004) note that

attentional processes play a role in STM tasks, as such, differences in digit span forward task performance may be related to differences in attentional control, or STM may support integrating L1 writing in academic writing.

Bialystok (2018) hypothesizes that there is a quantitative relationship between the intensity of experience and advantageous outcomes; bilingual activity is a continuum of continuous experience that leads to cognitive adaptations through a directional relationship between ‘degree of bilingualism and the degree of attention ability’ (Bialystok 2018:297). Similarly, Thomas-Sunesson and colleagues (2016) found that degree of bilingualism had a direct relationship with EF among a U.S. Spanish-English speaking children, similar our findings among adults. We therefore interpret our findings as potential evidence of adaptation on the continuum. Future research could explore small changes on the continuum of bilingual experiences and potential associations with attention.

It is also possible that engaging in dual language writing supports development of bilingual proficiency. Goriot and colleagues (2018) posit that EF advantages may be specific to *developing* proficiency in two languages and Blom and colleagues (2014) also suggest that cognitive benefits are a result of growing bilingual proficiency (Blom et al. 2014). Bosma et al. (2017:10) hypothesized ‘once a higher degree of proficiency in both languages has been attained, bilingual monitoring becomes more automatic and bilingual experience does not further enhance EF...[there is] a limited window of development in which bilingualism enhances cognitive functioning.’ Given limited prior L1 academic experiences and weaker L1 literacy, the current sample may still be developing L1 academic reading and writing, and as such, dual language writing activities may support growing bilingual proficiency.

Neither L1 reading or writing behavior, nor self-reported L1 reading or writing ability significantly contributed to WAIS IV digit span tasks with increased executive load (digit backward, digit sequencing). This may be related to language skill and/or usage among the sample. Previous research has found that bilingual adults with more balanced usage of and proficiency in their two languages show higher EF performance than imbalanced bilinguals; advantage has been attributed to the need to deal with a more active second language (Yow and Li 2015). Balanced proficiency bilinguals require more effort to maintain the target language (Yow and Li 2015). Macnamara and Conway (2014:520) hypothesized that ‘the mechanism responsible for the bilingual advantage is the interplay between (a) the magnitude of bilingual management demands and (b) the amount of experience managing those demands.’ Evidence suggests that both languages among bilinguals are activated even in monolingual environments (Kroll et al. 2008), but bilinguals who frequently switch between their languages show enhanced cognitive control as compared with those who do not frequently switch between their languages (Calabria et al. 2011; Festman, Rodriguez-Fornells, and Münte 2010; Prior and Gollan 2011; Soveri, Rodriguez-Fornells, and Laine 2011). Previous studies of college-aged bilinguals have sometimes failed to find evidence of bilingual advantages when comparing bilinguals to monolinguals (e.g. Paap and Greenberg 2013), potentially related to relatively low daily bilingual management demands in a monolingual ambient language environment.

Much like the current study, D’Souza et al. (2018) also found no evidence of bilingual advantage to WM, measured by the one of the tasks used in the current study (WAIS digit span backward) and inhibition when comparing bilingual and monolingual musician and non-musician young adults. According to authors, ‘93% of the bilinguals included in the sample were practical bilinguals (i.e. can carry out a conversation fluently but do not use the second language

on a daily basis) or fluent bilinguals' (D'Souza et al. 2018:5). This suggests that: 1) 7% of the bilingual sample were unable to carry out a conversation fluently in one language; and 2) the bilingual sample included an unknown percentage of participants who did not regularly use one of their languages; hence not engaging in daily language management and consequently unlikely to show WM benefits associated with management experience. The participants in the current study, by contrast, can carry on a conversation fluently in both languages and regularly use both on a daily basis. Like D'Souza's sample, however, the current study sample may not have overlapping language domains that require management behavior. D'Souza et al.'s (2018) bilingual inclusion criteria addressed conversation skills but authors do not report on literacy; it is possible that participants had imbalanced literacy skills or schooling in only one language, as in the current study.

Prior research indicates that successful WM training interventions progressively increase WM demands (Diamond and Lee 2011) and adaptively change based on individual performance (Brehmer, Westerberg, and Bäckman 2012), although controversy remains regarding benefits extending beyond intervention tasks. It may be that the informal L1 academic writing behaviours in the current study (i.e. courses are not taught in the L1) are not associated with WM among bilingual young adults due to insufficient time devoted to activity and/or lack of challenge, but that other L1 writing activities might.

Previous work has found evidence of relationships between interpreting/translation and STM span: Babcock et al. (2017) sought to determine directionality between advanced cognitive capacity and interpreting/translation. They longitudinally compared memory and EF among Masters students of interpreting, as compared to Masters students of translation and a control group of Masters students in non-linguistic disciplines, and found a large interpreter advantage in

verbal (but not spatial) STM after two years of study. Interestingly, as in the present study, Babcock et al. (2017) found no differences between groups on WM. They suggest two possible reasons for this: (1) the effects of interpreting on WM take longer than two years to emerge; and/or (2) the age of their participants (young adults at peak cognitive performance) may have obscured group differences that could emerge in later adulthood. The latter explanation may also apply to the present study. Babcock et al. (2017) conceptualise experience as simply a function of time, however, we suggest that future research explores the function of activity type: activities that involve predominantly domain-specific rehearsal processes (e.g., inner speech) and domain-specific knowledge (e.g., word meanings) might implicate STM span, while more challenging activities that involve higher order processes (e.g., constructing representations and/or generating new ideas) might implicate WM capacity.

### ***Limitations and Future Directions***

Our results indicate within-population differences related to L1 reading and writing ability and L1 reading and writing behaviour in an L2 academic setting shows a relationship with digit span forward and stroop task performance among bilingual young adults. If further research bears out this finding, there are strong implications for the vast and ever-growing number of individuals globally who are educated through a second language (c.f. Dearden 2015), including many U.S. heritage bilinguals. Findings offer insight into STM span and inhibition associations with particular bilingual environments, specifically academic reading and writing in the L1. Longitudinal studies could follow bilingual students who take classes requiring L1 writing (for example, Spanish language courses) or receive dual language writing interventions. The sample for the current study was homogeneous (similar geographic origin, education, and language background) by design to allow identification of axes of difference between participants,

however, as a consequence, generalization is limited. In the current study, L1 (in this case, Spanish) proficiency was measured using only one objective language measure, BVAT single word vocabulary, and self-report measures. While previous research has indicated high correlations between self-reported reading skill and standardized measures of reading comprehension among a comparable sample (Smith, Briggs, and Pothier 2017) and BVAT scores showed significant relationships with self-reports in the current study, future research might consider including measures of reading and writing in the L1 and L2, particularly if appropriate standardized assessments are available. The current study also employed self-reports to measure language usage. Future research may replicate the current study using more objective methods to track writing and reading activities.

It is also possible that the tasks presented did not fully capture individual differences among young adults. It has been previously noted that cognitive task designs may not be appropriate for young adults, who may be at ceiling and as such there is a limited range of performance (Bialystok 2018). Additionally, the current study used only one measure for STM, a digit span forward measure, and 2 WM tasks (digit span backward, digit span sequencing); both were in English and all were digit tasks. Future research should be conducted with multiple tasks, including visual and spatial tasks.

The finding that students elect to engage in an L1 writing activity for university, in which they are self-reportedly less literate, should be examined further, potentially using qualitative methods. The current study does not provide insight regarding why students use Spanish for academic reading and writing or how/if incorporating Spanish increases interest and enjoyment. Factors unrelated to Spanish language activity may play a role, such as academic confidence, academic motivation, and/or metacognition. Other academic or study skills may also be

involved, and future research might consider including measures of general academic performance. Future studies could explore individual factors that contribute to the choice to incorporate Spanish into academic experiences, as well as motivations and perspectives. Elective dual language writing may be associated with more positive attitudes toward L1 maintenance, or be associated with higher self-esteem, positive perceptions of bilingualism, Spanish, or a view of the ideal self as a Spanish speaker. Results may have implications for improving university satisfaction, academic achievement outcomes, and retention rates. Pursuing this avenue has the potential to shed light on success and development (both cognitive and linguistic) for bilingual young adults in the U.S. education system, which currently is primarily English focused.

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Table 1. <i>Task performance means.</i>		
Measures	<i>M</i>	<i>SD</i>
BVAT (raw score, max 58)	20.64	4.48
WAIS IV Digit Forward*	8.64	2.9
WAIS IV Digit Backward*	8.73	2.68
WAIS IV Digit Sequencing*	7.69	2.23
D-KEFS Color-Word Inhibition*	10.61	2.66
WAIS IV Matrix reasoning (non-verbal IQ_=)	8.95	2.69
WAIS IV Vocabulary	8.29	2.16
WAIS IV Verbal Similarities	8.0	2.14
*scores scaled at 10		

Table 2. <i>Reported Language Environment, percentage of total language usage in English.</i>				
Language environment, activity	<i>M</i>	<i>SD</i>	Min	Max
<i>Home</i>				
Speaking	56.72	24.64	0	100
Listening	54.8	28.16	0	100
Reading	84.2	19.28	0	100
Writing	84.57	22.67	0	100
Watching TV at home	69.42	22.36	10	100
Listening to music	56.41	23.31	0	100
<i>University</i>				
Talking to classmates	91.86	13.09	50	100
Listening to classmates	92.99	11.96	49	100
Reading in class/at university/for university	94.52	10.81	50	100

Writing in class/at university/for university	89.43	14.08	50	100
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Table 3. <i>Self-reported ability in English and Spanish on a scale from 1 to 10, with 10 being ‘native speaker’.</i>		
	<i>M</i>	<i>SD</i>
<i>Spanish</i>		
Speaking	8.69	1.32
Listening	9.31	.98
Reading	7.8	1.74
Writing	6.83	2.29
<i>English</i>		
Speaking	9.41	.93
Listening	9.5	.96
Reading	9.24	1.05
Writing	9.1	1.2