BILINGUAL LANGUAGE PROFICIENCY, HISTORY, AND WORD RECOGNITION

by

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THESIS ABSTRACT

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Measurements of language proficiency (accuracy, reaction time) on a lexical decision task were compared and their association with self-rated proficiency, age of acquisition, and speed of word recognition were examined. The purpose of the study is to extend the available measures used with the LexTALE lexical decision task and investigate how different measures of proficiency are related to bilingual language history and speed of word recognition within and across languages. Results revealed significant cross-language association between RT in English and RT in Spanish, but no associations within language. Furthermore, RT on the LexTALE was correlated with speed of word recognition. These results indicate that accuracy and RT index separate aspects of language proficiency, and additional investigation is necessary to further develop the construct of language proficiency.

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Table of Contents

LIST OF FIGURES

Figure Page

LIST OF TABLES

Table Page

Introduction

Bilinguals are a continuously growing population in the United States (US). Approximately 22% of people in the US speak a language other than English at home (U.S. Census Bureau, 2019). Second-language learning, whether at birth or into adulthood, is increasing to accommodate for a globalized world (Gándara & Escamilla, 2017). Yet, there remain gaps in our understanding of bilingualism. A growing body of research examining bilinguals has proposed several theoretical models that describe an integrated lexicon that can be accessed through either language's input, with parallel activation and processing during language comprehension (e.g., the Bilingual Interactive Activation plus model or BIA+, Language Mode framework, Inhibitory Control model; van Heuven & Dijkstra, 2010). In general, bilinguals form a highly interactive system across their two languages.

As bilingual research is a growing area of interest, various factors have been examined in relation to bilingual language processing. The present study aims to understand how different measures of proficiency capture variability in the bilingual population, how strongly they are associated with language history, and word competition dynamics in a lexical decision task.

LexTALE as a Language Proficiency Measure

Language proficiency is an often-studied construct in bilingual research. For the purposes of this paper, language proficiency refers to the "degree of skill with which a person can use a language, such as how well a person can read, write, speak, or understand language" (Gharbavi & Mousavi, 2012). One recently proposed measure of language proficiency is the Lexical Test for Advanced Learners of English (LexTALE; Lemhöfer & Broersma, 2012). Originally created for adult second-language learners, LexTALE is a lexical decision task that measures English language proficiency as a function of word and nonword identification. Accuracy on the

LexTALE is measured as the number of trials with correct identification (i.e., correctly identified words and correct rejection of nonwords); higher accuracy indicates higher proficiency. Although there are many measures of proficiency used in the literature, the LexTALE task is unique and sometimes preferred because it is relatively efficient compared to large omnibus language proficiency tests and does not rely on self-report but rather direct observation. Along with proficiency, LexTALE has been shown to indicate English vocabulary knowledge. In addition, LexTALE has been shown to accurately discriminate between low and high proficiency language users (i.e., native speakers and second-language learners; Ferré & Brysbaert, 2017). These and other extant findings show that the LexTALE captures significant variability in language proficiency in a relatively efficient way.

More recently, the LexTALE has been adapted for Spanish (LexTALE-Esp; Izura et al., 2014). The adapted task has also been shown to accurately discriminate among bilinguals that are highly proficient. A study examining the discrimination power of LexTALE-Esp (Spanish) in highly proficient bilinguals (native speakers of both Catalan and Spanish) found that Spanish-dominant bilinguals had significantly higher scores than Catalan-dominant bilinguals (Ferré & Brysbaert, 2017). These findings suggest that the LexTALE captures variance even in bilinguals that are highly proficient, thereby supporting the ability of the LexTALE to capture variability across the continuum of bilingual experience. Furthermore, LexTALE has increased in use in recent years and has successfully been adapted into various other languages, such as German and Dutch (Lemhöfer & Broersma, 2012).

Accuracy and Reaction Time as Outcome Measures

Previous literature regarding LexTALE has focused on accuracy as a main outcome measure. As mentioned previously, accuracy is operationalized based on the number of trials in

which the target word was correctly identified as a word or non-word. Specifically, accuracy describes the total number of correct identifications and rejections. Accuracy, in part, reflects the product of the language process: the more words you know, the more accurate you are in identifying real words in a lexical decision task (Meara & Buxton, 1987). In psycholinguistics, another common language proficiency outcome measure used in computer-based tasks is reaction time (Jiang, 2013). The use of reaction time may provide a complementary and potentially more sensitive measure of proficiency as the measure is often used as an index of language processing in terms of speed of lexical access. According to some models of language representation, whereas accuracy is thought to reflect a static proficiency score, reaction time involves a more dynamic process involving the underlying perception and response to a stimulus (van Heuven & Dijkstra, 2010). Reaction time is thought to reflect the strength of word representations and the facility with which competition is resolved during language comprehension over time (Blumenfeld & Marian, 2013; Lemhöfer & Dijkstra, 2004; Segalowitz & Segalowitz, 1993; Veivo et al., 2016). Reaction time has historically been used as the main outcome of lexical decision tasks (e.g., Lambert et al., 1959; Lemhöfer & Dijkstra, 2004, etc.). To our knowledge, there are no published peer-reviewed findings reporting reaction time on the LexTALE task. The present study seeks to compare accuracy and reaction time simultaneously within adult Spanish-English bilinguals.

Examining accuracy and reaction time simultaneously among bilinguals affords a unique opportunity to compare constructs of accuracy and reaction time within and across languages. As mentioned previously, accuracy is thought to index the *product* of proficiency whereas reaction time reflects more of the *process* of language comprehension. A large body of literature has shown that accuracy and reaction time are closely associated and indeed share wide variance

such that strong word comprehension accuracy is related to fast word processing and reaction times (Blumenfeld & Marian, 2013; Marslen-Wilson, 1987; Veivo et al., 2016). We expect to extend these findings to the LexTALE task such that accuracy and reaction time should be strongly associated within Spanish and English among Spanish-English bilinguals. Furthermore, given that we will examine Spanish and English performance independently, the present study will examine within- and cross-language associations. We expect that accuracy and reaction time in Spanish will predict accuracy and reaction time in English and vice versa. However, consistent with prior research, we anticipate that within-language associations will be stronger than cross-language associations. This hypothesis is consistent with findings regarding inhibition of the non-target language during activation of the target language; during presentation of the target word in either English or Spanish, the target language will be more active, and the non-target language is suppressed to promote processing of the target (Kroll et al., 2012).

In addition to comparing accuracy and reaction time within and across languages, the present study seeks to compare the degree to which each measure is associated with (a) bilingual language history and (b) speed of word recognition. Regarding (a) bilingual language history, it is well established that measures like Age of Acquisition (AoA) and cumulative language experience predict bilingual language proficiency. Research has shown that language experience is multifaceted, such that composite language histories that include AoA, self-ratings of proficiency across multiple language domains (speaking, reading, writing, comprehension), and language dominance form a more comprehensive measure of language history compared to any single variable (Dimitropoulou et al., 2011; Reichle & Birdsong, 2014; Shi, 2011). Thus, the present study seeks to examine how language history variables predict performance on the LexTALE task. We expect that prior language experience predicts current language proficiency

on the LexTALE such that participants with more prior language experience will perform better on the LexTALE, thereby informing our understanding of the content validity of accuracy and reaction time as measures of proficiency on the LexTALE. That is, if the LexTALE is indeed a valid measure of language proficiency among highly proficient bilinguals, it should be associated with key language history variables. Moreover, such an analysis provides descriptive information about the influence of language history on two complementary but unique proficiency measures: accuracy vs. reaction time.

In terms of (b) speed of word recognition, we expect that measures of proficiency like accuracy and reaction time will predict faster word recognition. Specifically, word recognition involves matching a spoken word with its phonological form stored in the lexicon from which information is retrieved to provide meaning (Assche et al., 2012). The process of recognizing words involves resolving competing activation from other related words that have similar phonological, semantic, or orthographical representations. A common measure of word recognition in studies examining competition is reaction time as a measure of the speed of spoken and written word recognition in the context of related word competitors. This body of work has shown that the amount of time spent considering competing words is increased when words presented are similar to the target word, as similar words are activated during language processing before arriving at the correct referent (e.g., cat when the spoken word is cab; Allopenna et al., 1998; Marslen-Wilson, 1987; McClelland & Elman, 1986).

Word recognition in bilinguals is similar but with some additional considerations. As lexical access in bilinguals is shown to be nonselective (i.e., both languages are activated upon presentation of a word), the participant must then sift through competitors in both languages before correctly matching the word and its lexical representation (Marian & Spivey, 2003).

However, the speed of this access is predicated on multiple factors, such as AoA of L2, proficiency in both languages, and similarity of words in each language (e.g., cognates, homophones, etc.; Blumenfeld & Marian, 2013). For example, findings show that bilinguals can access words in their more dominant language faster and more accurately than words in their non-dominant language; in studies examining both spoken and written comprehension, it was found that L2 proficiency facilitates activation of both phonological and orthographic competition during processing and recognition of words (Blumenfeld & Marian, 2013; Veivo et al., 2016). Even in unbalanced bilinguals, both within- and cross-linguistic competition has been found; late-onset L2 learners show higher initial fixation of L1 words and more thorough suppression of L1 words, indicating incomplete L2 lexicon suppression and possible incomplete competition resolution (Sarrett et al., 2021). Furthermore, the same study also found a strong correlation between high proficiency and faster fixation on the target word, such that more proficient L2 speakers recognize target L2 words more quickly (Sarrett et al., 2021).

Previous research indicates that proficiency is intertwined with lexical activation and competition resolution when processing language. As an extension of the first research question, we are interested in investigating whether proficiency, as measured on the LexTALE, predicts the speed of word recognition in the context of within- and cross-language competition. To that end, the current study proposes the following research question: what is the association between the LexTALE task (accuracy and reaction time) and word recognition dynamics? If the LexTALE indeed indexes proficiency, it should predict variance with measures of word recognition. Additionally, we hypothesize that reaction time will explain more variance than accuracy in speed of word recognition; that is, reaction time scores on the LexTALE as a measure of proficiency will correlate more strongly with speed on a word recognition task

compared to accuracy alone. We predict that higher proficiency (faster reaction time, higher accuracy on the LexTALE) correlates with greater speed of word recognition with and across languages to arrive at the target word referent. This would also provide further insight into measures of proficiency as indexed on the LexTALE as well as inform our understanding of the sources of variability during word recognition.

The Present Study

The present study seeks to examine accuracy and reaction time simultaneously in the LexTALE task in both Spanish and English among bilingual adults. The purpose of the study is to extend the available measures used with the LexTALE task and investigate how different measures of proficiency are related to bilingual language histories and word recognition within and across languages. To summarize, this study investigates two questions. Firstly, we examine the associations between accuracy and reaction time on the LexTALE task (both English and Spanish versions) within and across languages to describe how bilinguals manage their two languages as they process words in each language during such a lexical decision task. Secondly, we examined the relationship between accuracy, reaction time, and several key language history factors, as well as associations with speed of word recognition.

Method

Participants

There was a total of 20 Spanish-English bilingual speakers participating in the present study. Participants were aged between 18-27 and identified with a variety of cultures. See specific demographic information in Table 1 below. Participants acquired English on average around 3.5 years of age (range 0 – 12 years) and Spanish on average around 1.91 years of age (range 0 – 14 years).

Table 1

Participant (N = 20) characteristics

Participant Characteristics	*n*(%)	*M*(*SD*)
Age in Years		20.5(2.74)
Gender		
Male	5(25%)	
Female	15(75%)	
English AoA (years)		3.5(3.04)
English Speaking Proficiency		9.41(.85)
English Understanding Proficiency		9.59(.85)
English Reading Proficiency		9.5(.86)
Spanish AoA (years)		1.91(3.78)
Spanish Speaking Proficiency		7.73(1.93)
Spanish Understanding Proficiency		9.14(1.08)
Spanish Reading Proficiency		7.73(1.78)
Global Proficiency Score		
English Dominant	16	
Spanish Dominant	2	
Equally Dominant	2	
Culture[1]		
American	16(40%)	
Chilean	1(2%)	
Ecuadorean	1(2%)	
Hispanic	4(10%)	
Latinx	5(13%)	
Mexican	9(22%)	
Mexican American	2(5%)	
Nicaraguan	1(2%)	
Puerto Rican	1(2%)	
Russian	1(2%)	

[1] Participants were able to identify with more than one culture

Participants were recruited through the University of Iowa psychology and communication sciences participation pools. A minimum rating of 3 for English and Spanish proficiency was required on the Language Experience and Proficiency Questionnaire (LEAP-Q) to ensure the range of bilingual proficiency of participants was consistent with criteria from prior research (e.g., Ansaldo et al., 2015). Participants had no history of neurological disorders and had normal or corrected-to-normal vision and hearing. These participants received course credit or $15 per hour of participation.

Measures

Language Proficiency: LexTALE

The Lexical Test for Advanced Learners of English, hereby referred to as LexTALE, is a lexical decision task consisting of 60 items used to measure language proficiency as a function of single-word vocabulary (Lemhöfer & Broersma, 2012). Two versions of the task were used for this experiment: the original English version, and the adapted Spanish task (LexTALE-Esp, Izura et al., 2014). The LexTALE is typically administered on pen and paper.

The LexTALE tasks consist of strings of letters making real words and probable nonwords. Existing words are those words that are of valid phonotactic construction and hold meaning in a language. Nonwords are orthographically legal and pronounceable strings created by changing several letters in an existing word or recombining existing morphemes. There are nearly double the words than nonwords on each task due to the words being so low in frequency that a significant number of the word items are treated as subjective nonwords by participants. The items are between four and twelve letters long, and the nonwords are orthographically legal and pronounceable strings created by changing several letters in an existing word or recombining existing morphemes. An example of a real word presented on the LexTALE is *generic*, while a

nonword presented is *platery*. As a lexical decision task, the participants are tasked with deciding whether each item presented is a word or nonword.

Reliability and validity measures for the English version of LexTALE were examined by Lemhöfer and Broersma (2012). The English LexTALE was validated on a population of 189 college-aged English language learners (with L1 being either Dutch or Korean). Split-half reliability in the mean percentage correct scoring was found to be high (Lemhöfer & Broersma, 2012). Similarly, the LexTALE was found to have moderate-large correlations with other measures of vocabulary (Lemhöfer & Broersma, 2012). Reliability and validity measures for the Spanish version of LexTALE-Esp were examined by Izura et al. (2014). The Spanish LexTALE was validated on a population of 214 college-aged L1 and L2 Spanish speakers. Reliability was strong (α = .88; Izura et al., 2014). Similarly, criterion validity was measured by comparing the performance of L1 and L2 (native and non-native Spanish speakers) on the task. It was found that L1 speakers received significantly higher scores than L2 speakers, and these scores were also positively correlated with self-assessment ratings of proficiency (Izura et al., 2014).

For the purposes of the present study, the items across the English and Spanish LexTALE were adapted to be delivered on a desktop computer and coded through MatLab to facilitate reaction time measurement. The English and Spanish tasks were presented separately. Two dependent variables were extracted from each language: accuracy (mean percentage correct) and reaction time (mean speed between the word presentation and button press on correct trials only).

Language History and Self-Ratings of Proficiency: LEAP-Q

The LEAP-Q is a widely used self-report questionnaire of language history and proficiency in bilingual populations (Kaushanskaya, Blumenfeld, & Marian, 2020). The questionnaire prompts respondents to report on ages of acquisition of each language, length of

immersion in different contexts, and estimates of proficiency in speaking, reading, and understanding among other variables. Reliability and validity of the LEAP-Q were examined by Marian et al. (2007). Factor analyses revealed clusters of questions targeting fundamental bilingual constructs (L1 competence, L2 competence, etc.) suggesting strong construct validity. Cronbach's alpha calculations of all constructs labeled by a factor analysis indicate a highly reliable questionnaire (Marian et al., 2007). Furthermore, correlations between self-reported and behavioral proficiency measures indicated moderate positive associations for L1 relationships and strong positive correlations for L2 relationships (Marian et al., 2007). Language history and self-proficiency ratings from the LEAP-Q provide a valid and reliable measure of general language skill (Kaushanskaya et al., 2012).

For the purposes of this study, several key variables were extracted from the LEAP-Q in order to investigate the associations between measures of language experience and history against observed proficiency (i.e., accuracy and reaction times on the LexTALE). Variables extracted were based on prior research (Shi, 2011) and included: Age of Acquisition of Spanish vs. English as well as a global proficiency score (average of speaking, understanding, and reading proficiency ratings, e.g., Dimitropoulou et al., 2011; Krizman et al., 2014; Reichle & Birdsong, 2014; Marian, Chabal, Bartolotti, Bradley & Hernandez, 2014).

Word Recognition Task: Visual World Paradigm

The goal of this task is to measure within-language and across-language lexical competition during word recognition in English and Spanish. To that end, the authors used the Visual World Paradigm to examine how bilinguals manage lexical competition during word recognition (Huettig et al., 2011). The Visual World Paradigm (VWP) is a common psycholinguistics task often used in language processing experiments (Huettig et al., 2011). The

VWP was first described by Cooper (1974); it is known to have high linguistic and temporal sensitivity. Furthermore, this experimental setup of the VWP has been previously used to assess competition in both written and spoken word recognition (Hendrickson et al., 2021).

The task consists of 40 high-frequency English words and 40 high-frequency Spanish words, each arranged into within-language pairs that always appeared together: 20 Spanish-Spanish and 20 English-English word pairs. Each pair was matched for word frequency and phonological overlap; words in each pair had to start with at least the same consonant and vowel. Cognates, words with diacritics, and words that were greater than nine letters or four syllables were excluded.

Two pairs were combined to make a 4-item test set. A test set included the target word, its related competitor, and an additional pair of words that served as unrelated cohort words. These sets were presented as a Spanish block and an English block. Each set was created to ensure that there was no overlap between pairs in the first three sounds and no vowels occurring in the same position across pairs.

Stimuli included auditory recordings and pictorial representations for each word. The auditory stimuli were recorded in one session from a highly proficient Spanish-English bilingual adult who received consistent exposure to both languages before age four. The visual stimuli consisted of clipart matched for style and size. Consistent with typical visual world paradigm tasks, participants were presented with four pictures representing the words in the set on a computer screen; the target word was then presented auditorily (audio recording). Participants were then asked to select the correct picture matching the target word by clicking on it with a mouse. Trials were presented in a different order across participants. The key outcome variable

extracted included reaction time as measured by speed of mouse click on the target word on correct trials only.

Procedures

Research assistants collected all data for each participant in a single session. Participants were invited to the lab for the following procedures. First, consent was obtained from each participant. Participants were first given the LEAP-Q questionnaire, with instructions presented in their preferred language (Spanish or English). Participants were then sat approximately 24 inches away from a computer screen with two speakers. Tasks were completed alone in a sound-attenuated room with a one-way window. On the computer, participants completed the LexTALE English and Spanish versions, with instructions presented in both languages. The order of languages for the LexTALE task was determined based on language dominance, such that participants started first in their more proficient language based on self-ratings on the LEAP-Q. They were then introduced to the Visual World Paradigm, with practice trials completed under the supervision of a research assistant. Spanish and English blocks of the task were counterbalanced.

Results

Accuracy and Reaction Time on the LexTALE

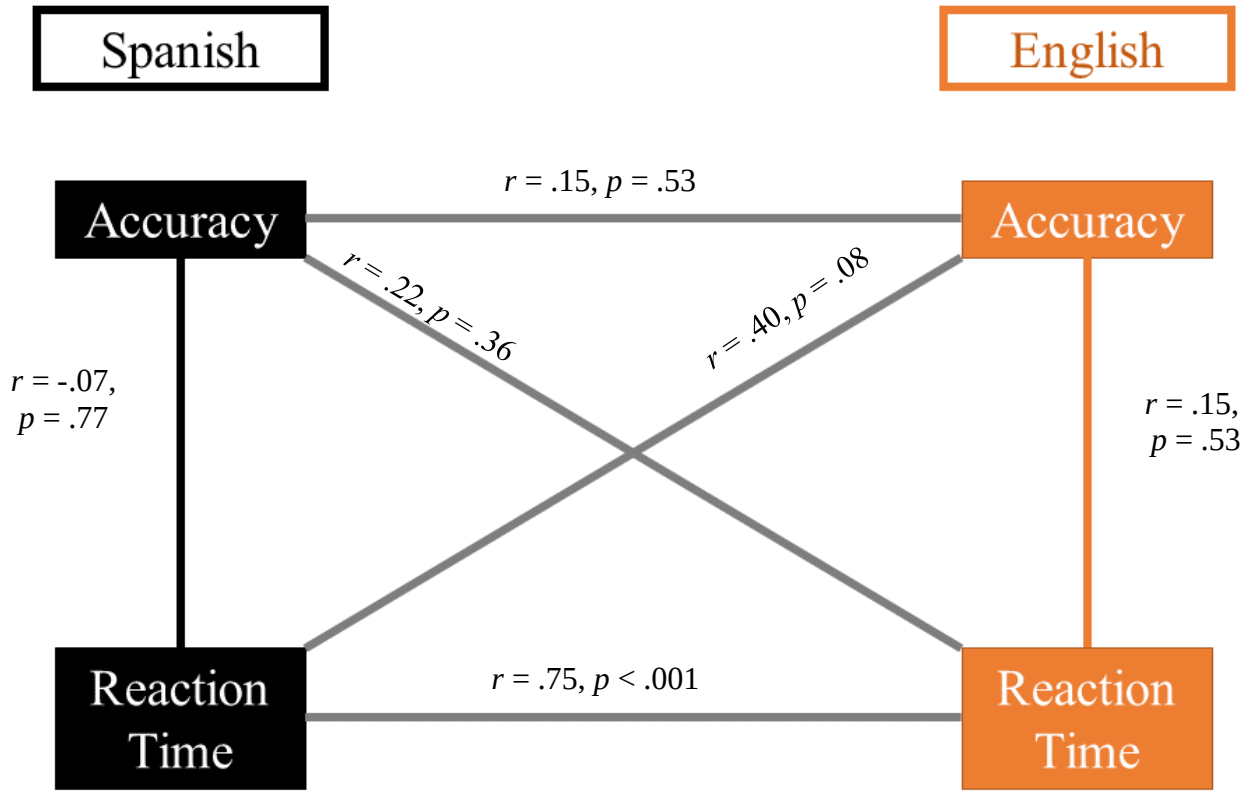
Our first question examined the relationship between accuracy and reaction time (RT) within and across languages on the LexTALE. We first examined within-language associations between accuracy and RT on the LexTALE in Spanish and English, respectively. First, we calculated the correlation between Spanish accuracy and RT on the LexTALE. Similarly, we examined the correlation between English accuracy and RT. Across both analyses, results showed no significant association between accuracy and RT in Spanish or English.

Next, we examined cross-language associations between accuracy and RT on the LexTALE. For this analysis, we computed the correlation coefficient across languages for the same measure (Spanish accuracy and English accuracy, Spanish RT and English RT). We found that there was no significant association between cross-language accuracy comparisons. However, there was a significant and positive association between Spanish RT and English RT ($r(18) = .75$, $p = <.001$). This indicates that there is a positive linear association between reaction times cross-linguistically such that faster reaction times in English indicated faster reaction times in Spanish.

Similarly, we computed the correlation across languages for different measures (English accuracy and Spanish RT, Spanish accuracy and English RT). Correlational analysis showed no significant association between Spanish accuracy when compared to English RT, however, there was a marginally significant and positive association between Spanish RT and English accuracy ($r(18) = .40$, $p = .08$). This indicates that there is a positive linear association between Spanish RT and English accuracy such that if a participant had faster Spanish reaction times, they had higher accuracy in English, but this association was not significant.

Figure 1

Within and Cross-Language Associations on the LexTALE



Accuracy, RT, and Language History

We also examined the association between accuracy, RT, and self-rating language history and proficiency variables (global proficiency score and AoA on the LEAP-Q). To that end, we performed a correlational analysis to determine whether accuracy or RT had stronger correlations with a self-reported measure of proficiency. We first examined associations between accuracy and RT on the LexTALE against self-reported proficiency on the LEAP-Q (global proficiency score in each language). Correlational analysis showed no significant association between Spanish RT on the LexTALE and global Spanish proficiency score. However, Spanish accuracy and Spanish proficiency had a significant and positive association ($r(18) = .62$, $p = .003$). This

indicates that there is a positive linear association between Spanish accuracy on the LexTALE and Spanish proficiency from the LEAP-Q such that higher accuracy scores indicated higher self-rated proficiency. Next, we conducted the same analyses in English. Correlational analysis showed no significant association between global self-reported English proficiency score and accuracy or RT.

Next, we examined the associations between AoA (as reported on the LEAP-Q) against accuracy and RT on the LexTALE in Spanish and English. Correlational analysis showed no significant association between Spanish AoA and Spanish RT or accuracy; similarly, there was no significant association between English AoA and English RT or accuracy.

Finally, we examined how well English or Spanish language dominance differentiated RT and accuracy scores on the LexTALE. First, we examined the association between language dominance on the LEAP-Q global self-rated proficiency score (English dominant vs. Spanish dominant) and RT on the LexTALE (faster English RT vs. faster Spanish RT). Fisher's exact test was used to examine whether there was a significant association between the two categorical variables. Analysis revealed no statistically significant association between language dominance on the LEAP-Q and RT on the LexTALE. Similarly, we examined the association between language dominance on the LEAP-Q global self-rated proficiency (English dominant vs. Spanish dominant) and accuracy on the LexTALE (higher English accuracy vs. higher Spanish accuracy). Analysis revealed no statistically significant association between language dominance on the LEAP-Q and accuracy on the LexTALE.

Accuracy, RT, and Word Recognition

Lastly, we investigated whether accuracy or RT on the LexTALE would explain variance in the word recognition task, the Visual World Paradigm (VWP). To that end, we analyzed the

associations between speed of word recognition against accuracy and RT on the LexTALE. First, we examined the within-language association between Spanish and English accuracy on the LexTALE and Spanish and English word recognition speed, respectively. Correlational analysis showed no significant within-language association between accuracy on the LexTALE and word recognition speed in Spanish or English.

Next, we examined the association between Spanish and English RT on the LexTALE and Spanish and English word recognition speed, respectively. Correlational analysis showed a significant and positive correlation between Spanish LexTALE RT and Spanish word recognition speed ($r(16) = .56$, $p = .01$). Similarly, correlational analysis also showed a significant and positive correlation between English LexTALE RT and English word recognition speed ($r(16) = .51$, $p = .02$). This indicates that there is a positive linear association between reaction times on the LexTALE and word recognition speed such that faster reaction times in either language on the LexTALE also indicated faster word recognition times.

Discussion

The present study set out to explore the relationships between observed measures of language proficiency (accuracy and reaction time on the LexTALE), self-ratings of language history and proficiency, and word recognition to increase the field's understanding of bilingual language interaction. We tested adults with a lexical decision task (LexTALE), a self-rated language background questionnaire (LEAP-Q), and a word recognition task (VWP). Our research questions examined (1) associations between accuracy and reaction time on the LexTALE task (both English and Spanish versions) within and across languages and (2) the relation between the LexTALE, self-ratings of history and proficiency, and word recognition.

Accuracy and RT on the LexTALE

Regarding the first research question, no significant association between accuracy and reaction time was found within languages; furthermore, no relationship between accuracy across languages was found. This finding is not consistent with our original hypothesis, which posited that within-language associations would be stronger than cross-language associations. However, the relationship between reaction times across languages was found to be significant, indicating that the measure itself (RT vs. accuracy) was more important than language. This may be indicative of the different constructs that accuracy and RT are thought to measure: accuracy is thought to index the product of proficiency (overall breadth and depth of language representations) while reaction time reflects the process of accessing language (manipulating representations for the purposes of comprehension and production). Prior research examining Spanish-English and Finnish-French bilinguals' proficiency and spoken word competition found that proficiency is associated with competitor activation, suppression, and target word identification (Blumenfeld & Marian, 2013; Veivo et al., 2016). However, these prior studies

examined only one language among bilingual populations and in different language modalities. For example, Blumenfeld and Marian (2013) examined English word recognition only among Spanish-English bilinguals whereas Veivo et al. (2016) examined how bilinguals matched spoken words to their orthographic, written forms. Given the pattern of findings across studies, it seems that the lack of within-language associations in the present study is related to the differences between accuracy and RT. The idea that accuracy and RT index different aspects of language representation is consistent with a growing body of work in early language development where speed of word recognition and vocabulary size as a measure of proficiency have been examined (e.g., Marchman et al., 2010). Specifically, the ability to process words quickly may not necessarily be the best indicator of *language-specific* proficiency, but instead, RT may additionally index overall cognitive ability.

In summary, this paper examined proficiency through two measures: a static (accuracy) and dynamic (RT) measure. In this study, we showed that RT was correlated cross-linguistically whereas accuracy was not, suggesting RT may index general processing skills used across languages better than accuracy alone. This indicates that RT and accuracy may serve as complementary measures of language proficiency that each describes separate functions of the bilingual word recognition process.

It is also possible that the reason that more within- and cross-language associations may not have been found was due to the sample size and reduced bilingual diversity. With a sample of 20, the effect size for within-language associations across accuracy and RT may have been too small to detect. Furthermore, the sample was mainly English-dominant, indicating that Spanish variability was greater. This was supported by our results, as Spanish RT was the most consistent

predictor across analyses. Future research must therefore include Spanish-dominant bilinguals and those with more balanced exposure.

Accuracy, RT, and Language History

Comparing the LexTALE outcomes to global self-rated language proficiency scores and AoA from the LEAP-Q, we found an association only between Spanish accuracy on the LexTALE and Spanish global self-rated language proficiency and not in English. This supports the construct validity of accuracy as measured on the LexTALE in capturing variability in proficiency. Indeed, we expected a significant association between the LexTALE and the LEAP-Q given that a large body of research shows that bilingual language history variables predict observed proficiency scores. However, this finding was only observed in Spanish and not in English. Similar to measures from the LexTALE, this could have been affected by the proficiency diversity of our sample. As our participants had more variability in their Spanish proficiency compared to English, this may be why we found Spanish LexTALE accuracy scores correlated with self-rated language proficiency in Spanish and not in English.

Furthermore, we found no association between RT and self-rated proficiency, consistent with within-language results from the LexTALE. As RT did not correlate with self-related measures of proficiency, this suggests that accuracy and RT do represent different constructs related to language proficiency and processing. That is, RT and accuracy each index different aspects of bilingual language representation.

Accuracy, RT, and Lexical Competition

With regards to word recognition, we found that RT, but not accuracy, from the LexTALE correlated with speed of word recognition in both English and Spanish. As word recognition in bilinguals involves quickly resolving competitors from both languages,

participants that had faster reaction times on the LexTALE lexical decision task (requiring participants to be able to quickly determine whether a string of letters is a real word) were also able to identify the correct word more quickly from its competitor during the word recognition task (Marian & Spivey, 2003). This once again supports the construct validity of RT on the LexTALE as it shows that the measure is related to other measures of proficiency, such as word recognition speed. However, recall that accuracy on the LexTALE was not associated with speed of word recognition. This is once again indicative of RT and accuracy indexing separate constructs of bilingual language representation, consistent with analyses described previously.

Limitations and Future Directions

Some limitations of our study include a limited participant population, stimuli selection, and LexTALE comparison. As the study took place in a college setting, the majority of participants are a very specific subgroup of the world's Spanish-English bilinguals (college-aged bilinguals). The population sampled was also highly skewed towards English dominance (18 English dominant participants, two Spanish dominant participants). Furthermore, while stimuli selection for the word recognition task was as thorough as possible, cross-language stimuli sets were unable to be perfectly matched (phonologically, orthographically, etc.) as Spanish and English are different languages. While we don't expect that this influenced the findings, it may limit the rigor of the study. Finally, the Spanish adaptation of the LexTALE has different items than the English version to achieve the same results; while this improves the reliability and validity of the Spanish version, it can make direct comparison between languages difficult.

Future research may choose to focus on expanding the populations studied, as different proficiencies (young children developing language, highly unbalanced bilinguals, etc.) or bilingual language combinations may yield different results (language similarity may also be

considered). Further research into underlying constructs that predict both accuracy and RT may provide more insight into how accuracy and RT index different aspects of language ability and usage.

Conclusion

This study explored accuracy and RT as measures of bilingual language processing. We investigated the relationship between accuracy and RT within and across languages in a lexical decision task, compared accuracy and RT to self-ratings of language history and proficiency, and investigated accuracy and RT as predictors of word recognition. Overall, our findings show that RT is a promising outcome in addition to accuracy on the LexTALE, as it shows some construct validity by predicting other theoretically related measures. Additionally, RT has been shown to capture different sources of variability perhaps related to general language processing skills, indicating is a good complement to accuracy measures. Together this work advances our understanding of bilingual language processing and the factors that influence it.

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