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Brief article

Does bilingualism twist your tongue?

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ABSTRACT

The current study investigated whether bilingualism affects the processing of sub-lexical representations specifying the sound structure of words. Spanish-English bilinguals, Mandarin-English bilinguals, and English-only monolinguals repeated English tongue twisters. Twister materials had word or nonword targets (thus varying in whether lexical information did or did not support sound processing), and similar or dissimilar sounds (thus varying in difficulty with respect to competition at a sub-lexical level). Even though bilinguals had learned English at an early age, and spoke English without an accent, Spanish-English bilinguals produced significantly more twister errors than monolinguals, particularly in the absence of lexical support. Mandarin-English bilinguals were also disadvantaged, but more consistently across all twister types. These results reveal that bilingual disadvantages extend beyond the lexical level to affect the processing of sub-lexical representations. More generally, these findings suggest that experience with sound structures (and not simply their intrinsic complexity) shapes sub-lexical processing for all speakers.

1. Introduction

One of the more challenging tasks in second language acquisition is learning to produce target language sounds fluently. Native speakers of foreign languages seem to do amazing things with their articulators, producing sounds that seem impossible to produce, and on the receptive side, hearing distinct differences between sounds that seem undistinguishable. Perhaps even more amazing are bilinguals who learned two languages early in life. These speakers seem to comfortably navigate back and forth between sound systems without any noticeable accent in either language. Setting these casual observations aside, relatively little is known about how (if at all) proficient bilingualism affects on-line retrieval and planning of speech sounds. Research on bilingualism has focused on lexical retrieval, revealing a number of processing differences between bilinguals and monolinguals and leading to two explanations of those differences.

On one view, by virtue of speaking each language only some of the time, bilinguals have used each language less frequently than monolinguals – the *frequency-lag* hypothesis (Gollan, Slattery, Van Assche, Duyck, & Rayner, 2011; also known as the *weaker links* hypothesis; Gollan, Montoya, Cera, & Sandoval, 2008). This view predicts that bilingual disadvantages should emerge at processing loci where frequency effects are strongest, (e.g., in lexical processing tasks (Jescheniak & Levelt, 1994; Kittredge, Dell, Verkuilen, & Schwartz, 2008). Supporting frequency lag, bilinguals name pictures more slowly than monolinguals, particularly when producing low-frequency names (Gollan et al., 2008, 2011; Ivanova & Costa, 2008). Disadvantages have also been reported in other language production tasks, including reduced category fluency (Rosselli et al., 2000), and more frequent tip-of-the-tongue states (Gollan & Brown, 2006).

A second explanation of bilingual disadvantages relies on the more obvious possibility that bilinguals might need to overcome competition between translation equivalents

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– the *interference* hypothesis. This account was inspired by experimental evidence that bilinguals can never "shut a language off" so that even when they speak in just one language, words in both languages are activated (Kroll, Bobb, Misra, & Guo, 2008). Also supporting the interference account are bilingual *advantages* on non-linguistic tasks that require resolution of competition (e.g., Costa, Hernández, Costa-Faidella, & Sebastian-Galles, 2009; for review see Bialystok, Craik, Green, & Gollan, 2009). Although bilinguals are usually disadvantaged in language tasks, they sometimes outperform monolinguals in this domain in tasks that emphasize competition (e.g., Stroop interference; Bialystok, Craik, & Luk, 2008).

The current study extends this research to explore whether bilingualism affects sub-lexical processing levels during production of English tongue twisters. Although frequency-lag and cross-language interference are generally assumed to arise at the lexical level, these general mechanisms could also influence sub-lexical processing levels. With respect to frequency-lag, recent studies suggest that there may be frequency effects within sub-lexical processes (Goldrick, 2011; Goldrick & Larson, 2008). If so, bilinguals might have more difficulty retrieving language-unique sounds than monolinguals. With respect to cross-language interference, difficulty could arise when selecting between co-active representations (Colomé, 2001; Costa, Roelstraete, & Hartsuiker, 2006) of subtly different sounds. Typically, in different languages even sounds that are largely the "same" are produced with distinct acoustic/articulatory properties (Pierrehumbert, Beckman, & Ladd, 2000). For example, the Spanish /d/ is a prevoiced stop whereas in English it is an unaspirated, short-lag stop. Even just momentary confusion about which segment to select (i.e., which language is the target language) could disadvantage bilinguals (e.g., when producing the /d/ in *dog*).

On the other hand, several considerations suggest that bilingualism might not affect sub-lexical processing as much as it affects lexical processing. First, with respect to frequency-lag, bilingual disadvantages in lexical retrieval are much smaller for retrieval of high-frequency than low-frequency words (Gollan et al., 2008, 2011; Ivanova & Costa, 2008). Individual phonemes – which appear in many different words – have likely been retrieved more frequently than even the highest frequency words. Thus, if bilingual disadvantages become smaller and smaller with progressively higher frequency, then it would seem unlikely that bilinguals should be disadvantaged for retrieval of individual phonemes. Indeed, all proficient speakers of a language, whether bilingual or monolingual, might be at ceiling levels of ability for such retrieval events. Second, since phonological competition is strong between similar phonemes (and weaker between dissimilar phonemes; Wilshire, 1998, 1999), cross-language interference at the phonological level might be more likely to occur when translation equivalents share similar sounds. However, most translation equivalents are non-cognates i.e., they do not do not resemble each other in phonological form (e.g., the Spanish word for *dog* is *perro*). More specific to our study, interference effects would further be minimized by our English-only materials with sound combinations that are unlikely in the bilingual speakers' other language.

To examine this issue, we compared bilinguals' and monolinguals' production of word and nonword twisters with similar versus dissimilar phonological representations. Prior studies revealed *lexicality* and *similarity* effects, such that monolinguals produced more errors when repeating nonword than word twisters, and when repeating twisters with similar than with dissimilar sounds (e.g., Wilshire, 1998, 1999). If bilingualism affects speech production exclusively at a lexical level, bilinguals should have no particular difficulty with sub-lexical processing, and should produce the same number of errors as monolinguals on nonword twisters (which should be unaffected by disadvantages in lexical retrieval). Alternatively, frequency-lag or competition between languages could arise at a sub-lexical level as well, in which case bilinguals should produce more twister errors than monolinguals for both word and nonword twisters. To test these hypotheses, as well as the generality of any bilingual effects observed, we tested both Spanish-English and Mandarin-English bilinguals.

2. Method

2.1. Participants

Forty-eight undergraduates at UCSD in each of three language groups (Spanish-English bilinguals, Mandarin-English bilinguals, and English speaking monolinguals) participated for course credit. Data from a small number of participants were excluded due to experimenter or recording errors (4 Spanish-English bilinguals, 2 Mandarin-English bilinguals, and 1 monolingual) or persistent failure to maintain production tempo (1 Spanish-English bilingual, and 1 monolingual).

Table 1 shows self-reported participant characteristics, vocabulary (Shipley, 1946) and non-verbal reasoning scores (Matrices subtest, KBIT-2; Kaufman & Kaufman, 2004), and accent ratings [i.e., recordings of each participants' English picture-naming responses were rated by three research assistants (one monolingual, one Spanish-English bilingual, and one Mandarin-English bilingual)]. Most bilinguals were rated as having no accent, or only a very slight accent, and bilingual groups did not differ on accent scores ($t < 1$). Bilingual groups differed from monolinguals on a number of characteristics but these did not have robust effects on performance (see below).

2.2. Materials and procedure

Tongue twisters were taken from Wilshire (1998) and included 32 alliterating word and 32 alliterating nonword twisters with four words or nonwords in each twister. Word and nonword twisters were evenly divided between phoneme-similar (*dirt bus boot dose*) and phoneme-dissimilar[1] twisters (*date fern foot den*), and between ABBA

[1] Wilshire (1998) defined similarity empirically by the rate of segment interactions in spontaneous speech errors.

Table 1
Means and standard deviations of participant characteristics.

	Monolinguals (n = 46)		Spanish-English (n = 43)		Mandarin-English (n = 46)		Monolingual versus Spanish-English	Monolingual versus Mandarin-English	Mandarin-English versus Spanish-English
	M	*SD*	*M*	*SD*	*M*	*SD*			
Age	20.5	2.2	19.9	2.0	19.9	1.3			
Age of Acquisition of English	0.3	1.1	3.7	2.7	3.6	4.0	**	**	
Self-rated spoken English proficiency[a]	7.0	0.1	6.5	0.6	6.5	0.9	**	**	
Self-rated spoken other language proficiency[a]	2.8	1.3	6.2	0.9	5.8	1.1	**	**	
Percent of English use during childhood	92.0	15.7	57.3	22.3	63.7	17.5	**	**	
Current percent of English use	97.9	6.5	80.1	16.1	86.9	12.5	**	**	*
Primary caregiver English proficiency[a]	6.5	1.0	4.0	1.5	4.4	1.3	**	**	
Secondary caregiver English proficiency[a]	6.1	1.5	4.3	1.5	4.3	1.4	**	**	
Primary caregiver education level	14.7	3.4	10.5	4.2	15.7	3.1	**		**
Secondary caregiver education level	14.5	3.9	10.8	4.3	16.3	3.3	**	*	**
Years lived in non-English speaking Country	0.5	1.8	1.1	2.5	4.5	5.0		**	**
Shipley English vocabulary test score	31.3	4.0	28.7	3.4	30.8	3.0	**		**
Matrices test score	38.8	5.9	37.3	4.1	39.7	3.8			**
Accent score[b]	–	–	1.8	0.7	1.7	0.6			

For all comparisons not marked with ** or * $p \geqslant .12$.
* Significant difference at $p < .05$ level.
** Significant difference at $p < .01$ level.
[a] Proficiency-level self-ratings were obtained using a scale from 1 (little to no knowledge) to 7 (like a native speaker).
[b] Degree of foreign accent was rated by three raters for each bilingual using one of the following classifications: 1 (no accent), 2 (very slight), 3 (definitely noticeable but not strong), 4 (very strong accent). Scores shown are averages across the three raters.

Table 2
Mean percent of trials per condition with one or more segment or dysfluent errors.

Language group	All errors							
	Words				Nonwords			
	Dissimilar		Similar		Dissimilar		Similar	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mandarin-English	25.1	13.0	39.7	18.0	42.4	19.3	60.6	20.5
Spanish-English	23.3	12.5	36.6	13.9	47.5	20.7	56.5	23.2
Monolingual English	18.2	11.9	35.1	15.5	31.5	21.1	49.2	21.5

(*moss knife noose muff*) and ABAB (*moat nap mop nut*). Each participant repeated each word twister, and each nonword twister, in presentation blocked by word or nonword in counterbalanced order between participants, and within word or nonword blocks in one of two different fixed random orders. Note these syllable sequences are quite distinct from commonly occurring tongue twisters (e.g., nursery rhymes), making it unlikely that any of these participant groups had experience producing these specific twisters. Given that practice effects on tongue twister production do not generalize to novel twisters (Dell, Burger, & Svec, 1997), prior experience with English tongue twisters is unlikely to underlie any differences between the participant groups.

Stimuli were presented using PsyScope X software (Build 51; Cohen, MacWhinney, Flatt, & Provost, 1993; http://www.psy.ck.sissa.it) on an iMac 7 computer with a 20-in. color monitor. On each trial all four twister stimuli appeared centered on the screen, and at the same time a series of 4 high-pitched warning beeps was presented followed by 16 low-pitched beeps presented at the rate of 100 beeps per minute (see Wilshire, 1999), with each beep presented for 200 ms (and a 400 ms silence between beeps). Participants were instructed to say the words or nonwords aloud in order four times in a row while keeping pace with the low-pitched beeps. Participants completed four practice trials before each block (word or nonword).

3. Results

All errors were transcribed by a single research assistant. A second coder transcribed 196 across one subject from each of the three participant groups. Across error types agreement rates exceeded 92% (overall error rate: 92.2% agreement; segment errors: 92.7%; dysfluencies: 94.3%).

Errors included mostly segmental errors (e.g., anticipations such as producing *feat pick fat fork* instead of *feat pick pat fork*), and also some dysfluencies (e.g., hesitations, omissions, failure to maintain tempo). Because production of an error can induce speakers to make more errors on the same trial (and produce dysfluencies), we examined accuracy at the level of entire trials, examining overall accuracy as well as segment errors alone (ignoring the presence or absence of timing errors) and dysfluencies alone (ignoring the presence or absence of segmental errors). We report the results of these analyses only where they yielded different results from the combined errors analysis.

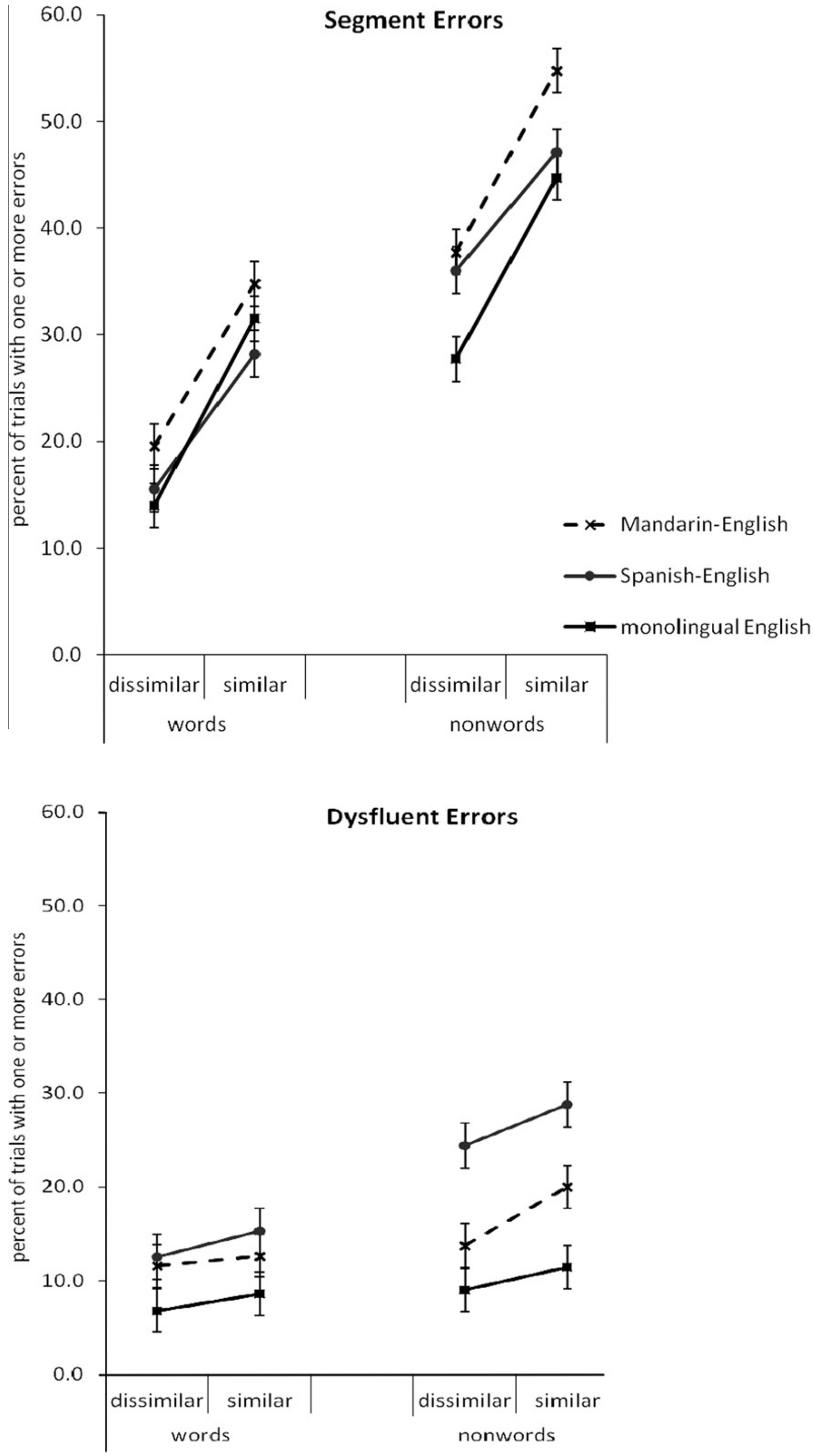

Fig. 1. Mean proportion of segment (top panel) and dysfluent (bottom panel) errors by participant group and condition. Error bars are standard errors.

Table 2 shows the average number of trials on which speakers in each participant group produced an error in each of the experimental conditions, and Fig. 1 shows the results divided by segment and dysfluent errors.

Logistic mixed-effects regressions (Jaeger, 2008) were used to analyze the probability of an error on each trial. Contrast-coded fixed effects included language group (bilingual, monolingual), lexicality (word, nonword), and segment similarity (dissimilar, similar), and interactions of these factors. In addition to a random intercept, correlated random slopes for lexicality, similarity, and their interaction were included for each subject. For twisters, the models included random intercepts and correlated random slopes for language group. The significance of each fixed effect was assessed via likelihood ratio tests comparing the full model to a model lacking only the fixed effect (Barr, Levy, Scheepers, & Tily, submitted for publication). Similar results were obtained using ANOVAs on error proportions.

3.1. Spanish-English bilinguals

Replicating previous studies, speakers produced more errors with nonword than word twisters ($\beta = 0.97$, SE $\beta = 0.14$; $\chi^2(1) = 37.2$, $p < .001$), and with similar than dissimilar twisters ($\beta = 0.81$, SE $\beta = 0.13$; $\chi^2(1) = 30.0$, $p < .001$). Of interest, Spanish-English bilinguals produced more errors than monolinguals ($\beta = 0.41$, SE $\beta = 0.20$; $\chi^2(1) = 3.9$, $p < .05$), and the bilingual disadvantage was larger for nonword than word twisters; i.e., an interaction between lexicality and group ($\beta = 0.44$, SE $\beta = 0.19$; $\chi^2(1) = 5.63$ $p < .03$), implying a non-lexical locus of the bilingual disadvantage.

Unlike the lexicality effect, in which more difficult items (i.e., nonwords) were particularly difficult for bilinguals, the similarity effect was significantly diminished for bilinguals ($\beta = -0.34$, SE $\beta = 0.16$; $\chi^2(1) = 4.2$, $p < .04$; possible implications of this finding are reviewed in Section 4). No other interactions were significant (χ^2s < 1).

Follow-up regressions revealed that the overall bilingual disadvantage was largely driven by dysfluencies. Spanish-English bilinguals were overall no more likely to produce a segmental error than monolinguals ($\chi^2(1) < 1$) but they were significantly more likely to produce a dysfluent response ($\beta = 0.91$, SE $\beta = 0.30$; $\chi^2(1) = 8.5$, $p < .005$). Similarly, the stronger bilingual disadvantage for nonword twisters was significant for dysfluencies ($\beta = 0.69$, SE $\beta = 0.27$; $\chi^2(1) = 5.84$, $p < .02$) but not segment errors ($\beta = 0.25$, SE $\beta = 0.18$; $\chi^2(1) = 1.9$, $p < .17$). Conversely, the diminished similarity effect for bilinguals was present in segmental errors ($\beta = -0.36$, SE $\beta = 0.16$; $\chi^2(1) = 4.74$, $p < .03$) but not dysfluencies ($\chi^2(1) < 1$).

3.2. Mandarin-English bilinguals

Again speakers produced more errors with nonword than word twisters ($\beta = 0.86$, SE $\beta = 0.14$; $\chi^2(1) = 29.8$, $p < .001$), and with similar than dissimilar segment twisters ($\beta = 0.91$, SE $\beta = 0.14$; $\chi^2(1) = 33.1$, $p < .001$). Like Spanish-English bilinguals, Mandarin-English bilinguals were overall more likely to produce an error than monolinguals ($\beta = 0.43$, SE $\beta = 0.16$; $\chi^2(1) = 6.6$, $p < .02$). However, unlike Spanish-English bilinguals, when comparing Mandarin-English bilinguals to monolinguals, no interactions were significant (χ^2s < 1.3). The Mandarin-English bilingual disadvantage was not larger for nonwords than for words, and was not attenuated by similarity. Also unlike Spanish-English bilinguals who produced more dysfluent but not more segmental errors, Mandarin-English bilinguals produced more segmental errors ($\beta = 0.40$, SE $\beta = 0.17$; $\chi^2(1) = 5.4$, $p < .03$) and more dysfluencies than monolinguals ($\beta = 0.41$, SE $\beta = 0.20$; $\chi^2(1) = 3.66$, $p < .06$).

As noted above, Table 1 reveals a number of differences between bilingual groups (e.g., differences in parent education levels, in current degree of English use). Having found that both bilingual groups are disadvantaged—despite any differences between them—suggests that this result is driven by bilingualism rather than by other factors. Table 1 also shows differences between bilingual and monolinguals' experience with and knowledge of English (e.g., some bilinguals acquired English at a much later age than monolinguals, and some had accented speech). To address this issue, we repeated the analyses, excluding the small number of bilinguals who had acquired English after age 6 as well as any bilinguals with anything more than a very slight accent. Despite the reduction in power, within these subsets, we also found significant (one-tailed) bilingual disadvantages.

4. General discussion

The current study aimed to reveal if bilingualism affects the retrieval and processing of sub-lexical representations of sound structure. The results show a clear bilingual disadvantage in tongue twister production and also provide some strong hints as to the locus of processing differences between groups. Spanish-English and Mandarin-English bilinguals produced errors on a significantly higher number of trials than monolinguals. The increased error rate for bilinguals was not simply an effect of late acquisition of English or insufficient knowledge of the properties of English sounds (as indexed by accent ratings). Furthermore, because bilinguals were disadvantaged for production of nonword twisters, it appears these effects arise at a non-lexical processing locus. If bilingual disadvantages were limited to lexical retrieval, they should not have been disadvantaged on nonword twisters (which do not require lexical retrieval). Instead, Spanish-English bilinguals exhibited a significantly larger disadvantage for nonword than for word twisters, and Mandarin-English bilinguals were equally disadvantaged for both twister types.

Other aspects of the data demonstrate that the bilingual disadvantage was not consistently larger on more difficult trials. As just noted, Mandarin-English bilinguals' were equally disadvantaged for nonword and word twisters (even though all speakers produced significantly more errors with nonword than with word twisters), and in some comparisons Spanish-English bilinguals were actually significantly more disadvantaged for relatively *less* difficult twisters (i.e., dissimilar versus similar twisters; see Fig. 1). Similarity effects on tongue twister production imply competition between individual sounds that is fiercer when sounds are similar (e.g., /m/ and /n/). The attenuated similarity effect for Spanish-English bilinguals raises the possibility that bilinguals manage competition between similar sounds better than monolinguals, perhaps because they need to manage competition between variations on the same sound across languages (e.g., the Spanish versus English realization of /d/ discussed above). This possibility should be explored in future work. Though both Spanish-English and Mandarin-English bilinguals were disadvantaged, Mandarin-English bilinguals did not exhibit the attenuated similarity effect, and they patterned differently in a number of ways (e.g., only Mandarin-English bilinguals produced more segment errors than monolinguals) that could provide further clues to the mechanisms underlying bilingual effects, and twister production more generally.

These results suggest that frequency-lag, interference, or both mechanisms are at play at a sub-lexical processing locus. However, note that overt interference between languages is unlikely to be the only mechanism underlying the effects reported here. Dual-language activation was likely to be stronger for Spanish than Mandarin speakers in the tongue twister task due to overlapping orthographies and arguably more similar phonological systems for Spanish-English than for Mandarin-English bilinguals (although challenging, assessing cross-language phonological similarity is possible; Bradlow, Clopper, Smiljanic, & Walter, 2010). If interference was the primary mechanism causing bilingual disadvantages, we would have expected to see much higher error rates for Spanish than Mandarin speakers. However, as shown in Table 2, the overall error rate was nearly identical across the two groups. Thus, it seems likely that bilinguals had difficulty with sub-lexical processing because of relatively reduced use of sounds specific to each language compared to monolinguals – i.e., a frequency-lag in the retrieval of individual sounds.

With respect to sub-lexical processing more generally, bilingual disadvantages provide further support for the claim that these processes are sensitive not only to the intrinsic (articulatory/phonetic) complexity of sound structures, but to the nature of the experience individuals have had with those sound structures (Goldrick & Larson, 2008). A more practical implication of the results we reported is that they provide further evidence that nonwords cannot be used in clinical settings to avoid problems associated with testing bilinguals in a non-dominant language. Although it might seem that nonwords should be equally unfamiliar to bilinguals and monolinguals alike, nonword processing requires access to language specific knowledge of sound structure—and bilinguals have had less experience in this domain than monolinguals (Summers, Bohman, Peña, Bedore, & Gillam, 2010).

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