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Attention Control and Inhibition Influence Phonological Development in a Second Language

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Abstract

This study investigated the role of attention control and inhibition in L2 learners' phonological processing. Participants were 16 L1-Spanish/L2-English learners, and 18 L1-English/L2-Spanish learners. We measured attention and inhibition through a novel speech-based attention-switching task and a retrieval-induced inhibition task. L2 phonology (perception and production) was assessed through a speeded ABX categorization task and a delayed sentence repetition task. We used a measure of L2 vocabulary size to partial out L2 proficiency effects. A more efficient attention control was associated with more accurate performance in ABX (for the L2-English learners), and higher inhibitory skill was related to higher ABX accuracy in both learner groups. No clear relationship emerged with the production scores. These results suggest that a more efficient attention control and inhibitory skill enhance the processing of phonologically relevant acoustic information in the L2 input and may lead to more accurate L2 speech perception and production.

In second language acquisition, the first language (L1) background (e.g., Flege, Bohn, & Jang, 1997), age of acquisition or the length of exposure to the second language (L2) (e.g., Flege, Yeni-Komshian, & Liu, 1999), and the amount of L2 usage (e.g., Guion et al., 2000)—all influence outcomes in phonological development, for instance, in the acquisition of segmental or suprasegmental categories, or of phonotactic restrictions. But these factors fall under learning conditions, and indeed, when these variables are controlled, individual differences remain in both L2 speech perception and production (e.g., Pallier, Bosch, & Sebastián-Gallés, 1997). In terms of underlying cognitive abilities, working memory (e.g., Papagno & Vallar, 1995; Masoura & Gathercole, 1999), attention control (e.g., Guion & Pederson, 2007), and inhibition (Lev-Ari & Peperkamp, 2013) have also been shown to be related to L2 learning. However, what is still not well understood is how these factors specifically relate to L2 phonological development, both in perception and production. The goal of this study is to further explore this relationship, focusing particularly on two cognitive abilities that appear to play a role in L2 phonological development: attention control and inhibition.

Attention control is generally defined as the ability to switch attention between different dimensions relevant to a task. Such attentional flexibility is generally thought to play an important role in L2 learning, along with selective attention (Francis et al., 2000). For example, Segalowitz and Frenkiel-Fishman (2005) demonstrated a link between attentional flexibility and L2 proficiency (operationalized by an animacy classification task). This ability appears to be potentially very important for the success of L2 phonological learning because individuals with more efficient attention control will be able to bring relevant acoustic information to the foreground during speech processing while keeping irrelevant information in the background.

The second ability that may be related to L2 phonological development is inhibition. Inhibition may be defined generally as the deliberate, controlled suppression of predominant responses (Miyake et al., 2000) or more specifically in bilingual speech production as the mechanism responsible for suppressing the activation of lexical representations of the non-response language (Costa, Santesteban, & Ivanova, 2006). Inhibitory control is thus responsible for the inhibition of the first language when using the L2, effectively minimizing L1 phonological interference in L2 speech perception and production. There are few studies examining the link between attention control and L2 phonological development (e.g., Darcy, Park & Yang, 2011; Safronova & Mora, 2013) or between inhibition and the acquisition of L2 speech (Lev-Ari & Peperkamp, 2013). In the present study, we hypothesize that a more efficient attention control and a stronger inhibitory skill may enhance the processing of acoustic-phonetic information in the input and lead to higher performance in L2 speech perception and production.

THE PRESENT STUDY

We obtained measures of phonological development in production and perception for 35 L1-Spanish/L2-English speakers (tested in Seville, Spain), and for 26 L1-English/L2-Spanish speakers (tested in Bloomington, USA). In addition, we tested 10 Spanish and 10 English native speakers as control participants (without knowledge of English or Spanish respectively) to validate the tasks. For each participant, we obtained measures of attention control and inhibition, as well as demographic background information. In addition, we used an estimate of receptive vocabulary size as a phonologically-related measure of overall proficiency. A larger vocabulary is related to L2 phonological competence (Bundgaard-Nielsen, Best, & Tyler, 2011). We included vocabulary size as a covariate in the analyses, in order to control for the effects of proficiency.

Participants

Out of the 81 tested participants, only those with valid data in all tasks were selected for analysis. Thirty-two participants were excluded because they either failed the audiometry test, reported a speech pathology/hearing loss, were fluent in another language using our test contrasts, or were not English/Spanish native speakers. In addition, participants whose performance on the control conditions of our phonological or cognitive tasks was beyond 2 SD from the group mean were considered outliers and not included in the analysis (n = 3 for attention control, n = 2 for inhibition, and n = 4 for ABX). This procedure left a total of 40 participants: 16 L2-English, 18 L2-Spanish, and 6 native speakers (either language). Overall, as shown in Table 1, compared to the L2-English learners, L2-Spanish learners were significantly younger, less motivated, spoke the L2 less, had studied for less time, and started using Spanish earlier.

Table 1. Summary of demographic characteristics for the selected L2 learners.

Measure	L2	*N*	*M*	*SD*	lowest	highest	*p* value
Age	English	16	23.3	*5.38*	18	40	t(15.4) = 2.77
(years)	Spanish	18	19.6	*0.70*	18	21	.014*
LOR	English	16	5.4	*10.1*	0	39.1	t(32) = -.11
(weeks)	Spanish	18	5.9	*15.2*	0	52.2	.911
L2 use	English	16	17.4	*5.93*	4	25	t(32) = 3.7
(max 36)	Spanish	18	9.1	*7.06*	3	28	.001*
First exp.	English	16	7.6	*2.13*	6	12	t(26.2) = -1.15
(age)	Spanish	18	8.8	*4.09*	1	14	.259
First use	English	16	13.5	*4.40*	6	21	t(32) = 2.29
(age)	Spanish	18	10.2	*3.96*	3	15	.029*
Years of	English	16	11.9	*2.77*	6	16	t(32) = 3.21
study	Spanish	18	8.8	*2.94*	5	15	.003*
proficiency	English	16	4.0	*0.37*	3	5	t(28.9) = .67
(1-5)	Spanish	18	3.9	*0.58*	3	5	.506
Motivation	English	16	6.0	*0.71*	5	7.11	t(23.3) = 2.11
(1-9)	Spanish	18	5.6	*0.41*	4.89	6.33	.046*

Note: LOR = length of residency or stay in a country where the L2 is spoken, exp = exposure to L2; Proficiency is self-evaluated.

Methods and procedures

Speeded ABX Discrimination Task to Measure Phonological Processing

To assess L2 perceptual learning, we administered a speeded ABX categorization task (e.g., Gottfried, 1984). Participants heard three stimuli in a row and had to choose if the last token (X) was more similar to the first token (A) or to the second token (B). To increase task demand, the stimuli consisted of trisyllabic non-words in both Spanish and English with the structure CV.ˈCV.CV(C). Furthermore, physically different tokens produced by two female early balanced bilinguals (Mexican Spanish and American English) were used in each trial: one voice was used for the first two tokens (A & B), and the other for the X token.

The contrasts tested in this task are detailed in Table 2. The design was such that the test contrasts for L2 speakers of one language were the control contrasts for L1 speakers of that language and vice versa. For example, /i-ɪ/, which is phonemically contrastive in English but not in Spanish, was a test contrast for the L1-Spanish/L2-English speakers, and the results of the L1- English/L2-Spanish speakers on that contrast served as the control measure. In addition, the perception of two contrasts that are utilized in both languages was also examined.

Table 2. Set of stimuli for the ABX task.

	Test consonant	Control consonant	Test vowel	Control vowel	Common contrasts
L1-Spanish, L2-English	/ʃ/ vs. /ʧ/	/d/ vs. /ɾ/	/i/ vs. /ɪ/	/e/ vs. /ei̯/	/a/ vs. /i/, /t/ vs. /d/
L1-English, L2-Spanish	/d/ vs. /ɾ/	/ʃ/ vs. /ʧ/	/e/ vs. /ei̯/	/i/ vs. /ɪ/	/a/ vs. /i/, /t/ vs. /d/

As for the test contrasts for L1-Spanish/L2-English, /i-ɪ/ has previously been found to be perceived either inaccurately or not at all by this group of learners and subject to developmental stages of acquisition (e.g. Morrison, 2009); the /ʃ-ʧ/ contrast has been shown to not be accurately realized in production (e.g., Anrrich, 2007) and was therefore hypothesized to be difficult in perception. For the L1-English/L2-Spanish test contrasts, the perception of /d-ɾ/ has been shown to improve with L2 proficiency (Rose, 2010), and the perception of /e-ei̯/ was hypothesized to be difficult for this group of learners based on perceptual mapping data (Morrison, 2006). All contrasts were produced using appropriate phonetic realizations for each language as exemplified in Table 3.

Table 3. Phonetic realization of example stimuli.

Stimulus language	Item A	Item B	Condition
Spanish	[saˈɾeβo]	[saˈðeβo]	Test consonant
English	[səˈʃi:dən]	[səˈʧi:dən]	Test consonant
Spanish	[faˈneða]	[faˈnei̯ða]	Test vowel
English	[fəˈni:dɪʃ]	[fəˈnɪdɪʃ]	Test vowel
Spanish	[gaˈtaso]	[gaˈðaso]	Common cons.
English	[gəˈtʰæfɪn]	[gəˈdæfɪn]	Common cons.
Spanish	[luˈpito]	[luˈpato]	Common vowel
English	[ləˈpʰi:dɪk]	[ləˈpʰædɪk]	Common vowel

In total, four non-word pairs per condition were tested; each pair was repeated in four combinations (ABA, ABB, BAA, and BAB), yielding a total of 128 trials. Trials were split into two language blocks (English – Spanish or vice-versa). The block order was counterbalanced across participants. Within each block, trials were randomized. The task was administered on a PC through headphones using the presentation software DMDX (Forster & Forster, 2003).

Delayed Sentence-Repetition Task to Measure Production Accuracy

Each participant took part in a delayed sentence repetition task (Trofimovich & Baker, 2006), either in L2 in the case of learners, or in L1 in the case of the non-learners. In this task, the participants sat in a sound-isolated recording booth equipped with headphones and a computer screen. They heard a question (prompt), followed after 250 ms by an answer (response). After a 500 ms delay, the prompt was presented again, and the participants had to repeat aloud the response heard previously. The written sentences appeared on the screen together with the first auditory presentation of the prompt/response pair, and disappeared for the second presentation of the prompt, and the recording of the answer. All L2 learners received instructions in L1, and completed a warm-up prompt in L1 before moving on to L2. Stimuli in both languages were recorded by two female early balanced bilinguals (Mexican Spanish and American English), and normalized for amplitude. In half the sets, one voice was used for the prompt token, whereas the other was used for the response tokens, and the reverse was done for the remaining sets. We examined the same contrasts as those used in perception. There were four pairs of sentences for each contrast, for a total of 16 sentences per language.

In the case of the L2 learners of Spanish, for the monophthong vs. diphthong contrast /e/ vs. /ei̯/, three measurement points (MP) were placed within the vowels, and the values for F1, F2, and F0 were extracted. We calculated the amount of tongue movement between MP2 and MP1 based on a normalized Bark-distance metric (Baker & Trofimovich, 2005; Bohn & Flege, 1990): B1-B0 for tongue height and B2-B1 for degree of tongue fronting, where B stands for Bark-converted frequency (F) values. For the /d/ vs. /ɾ/ contrast, we visually and auditorily examined the spectrogram and made a categorical decision about whether it was a tap or a spirantized [ð]. This produced a score out of eight. For the L2 learners of English and the /i/ vs. /ɪ/ contrast, F1, F2, F3 and F0 were also extracted at the vowel midpoint. The Euclidean distance (based on a Bark normalized score) was taken as a measure of accuracy in spectrally differentiating the two vowels. For the /ʃ/ vs. /ʧ/ contrast, we visually and auditorily examined the spectrogram and made a categorical decision about the presence or absence of closure, and this produced a score out of eight.

Speeded Set-Switching Task to Measure Attention Control

The speech signal is complex, and listeners have to learn what dimensions are relevant for making certain distinctions. An efficient attention control is here seen as a built-in cue enhancement device by means of which the appropriate relevant phonetic cues are brought to the perceptual foreground in L2 speech processing. None of the currently available methods of assessing attention control targets exclusively phonological dimensions (but see Safronova & Mora, 2012). This, however, is crucial in order to link attention and phonological acquisition. In this study, we have developed a novel, fully phonologically oriented version of an attention control task.

In this version, we used two phonological dimensions which can be considered comparable in difficulty across both languages. One dimension is whether a stimulus initial is a nasal sound (/n/ or /m/) or not. The other dimension targets whether or not a stimulus is spoken in the first language of the listener or in another. This decision can only be based on the phonetics of the stimuli since all items were phonotactically legal non-words in the two languages we used. That is, participants had to focus their attention on minute phonetic/phonological dimensions: for example, on the presence of a nasal resonance at the beginning of the word ([ˈnole]), indicating that the initial segment was a nasal sound, or on the diphthongization of the vowels (e.g., [ˈdoʊfeɪ]), indicating that the non-word was spoken in English (spoken in Spanish [ˈdofe] would be monophthongal) (see Table 4).

We created 10 nasal-initial items, and 10 nonnasal-initial items. All non-words were disyllabic with a CVCV structure. We chose to mainly use "shared" categories for English and Spanish so as not to disadvantage one group over another by having to process too many unfamiliar sounds. These 20 items were recorded with English and Spanish phonetics to build the two stimuli sets. Two female balanced early bilinguals who spoke Mexican Spanish and American English recorded both sets of stimuli, so that voice identity could not be used to determine the stimulus language.

Table 4. Non-word stimuli sample.

Spanish Nasal	English Nasal	Spanish Nonnasal	English Nonnasal
[ˈnoma]	[ˈnoʊmə]	[ˈpiɣo]	[ˈpʰɪgoʊ]
[ˈnole]	[ˈnoʊleɪ]	[ˈdofe]	[ˈdoʊfeɪ]
[ˈniso]	[ˈnɪsoʊ]	[ˈsaso]	[ˈsæsoʊ]

Participants were asked to answer one of two possible questions: "Nasal?" vs. "English?" (or "Nasal?" vs. "Spanish?" for L1-Spanish speakers) with respect to an auditory stimulus, by pressing two assigned buttons (yes or no) on a computer keyboard. A trial consisted of a fixation sign displayed for 500 ms, followed by a question displayed in the center of the screen for 500 ms (e.g., "Nasal?"). This question was immediately followed by an auditory stimulus (e.g., [ˈnofe], spoken with Spanish phonetics). The correct answer to the question "Nasal?" in this example would be "yes". If the auditory stimulus were [ˈdofe], the answer would be "no". The task was administered with the software DMDX.

There were two kinds of trials: repeat trials "R" (i.e., showing the same question as the previous trial), and shift trials "S" (i.e., showing a different question from the previous trial). Switch trials required participants to refocus their attention onto a different dimension in order to make their answer. Trials were arranged in a predictable alternating SRSR sequence. This sequence was the same for both groups. The 80 available audio tokens were then randomly ordered to match the SRSR alternating sequence, resulting in two lists, one for each L1. The only restriction was that two "similar" tokens (e.g., /dofe/ spoken in Spanish and English) could not follow each other. Tokens from either voice were randomly assigned to roughly an equal number of items in each list.

The results showed that, as expected, both groups were significantly faster on repeat than on switch trials. For each participant, the RT difference between S and R trials represents the shift cost, used as our measure of attention control.

Inhibitory Skill Task

Inhibitory skill is most commonly associated with a differential activation of the two languages in production. Bilinguals must inhibit the language not in use (e.g. Green, 1998), leading to interference from the inhibited language when incomplete (e.g. Spivey & Marian, 1999). This type of inhibition is proportional to the level of activation of the representations to be suppressed (which is higher for L1 than for L2), so that much stronger inhibitory control is needed when speaking the L2 than when speaking the L1 (Costa & Santesteban, 2004). In the present study we assessed individual differences in inhibitory control measured as retrieval-induced inhibition (Anderson, Bjork, & Bjork, 1994; Veling & van Knippenberg, 2004), which has been shown to be related to proficient bilinguals' level of bidirectional phonological interference between their languages (Lev-Ari & Peperkamp, 2013).

The inhibitory skill task, based on Lev-Ari and Peperkamp's task, was administered with E-prime in the participants' L1 only. Participants memorized six words of three different categories (vegetables, occupations, or animals) presented visually on the screen, and then practiced only some items of two categories (e.g., tomato, nurse) by typing them on the screen. This was expected to cause the inhibition of the other, unpracticed *items* in these practiced categories. By contrast, the items from the unpracticed *category* were not inhibited and served as control items. Participants were then tested on the recognition of practiced as well as of two types of unpracticed items: those from the two practiced categories (inhibited), and those from the unpracticed category (control). Participants with greater inhibitory skill were expected to bring the unpracticed items in practiced categories to lower activation levels, resulting in retrieval RTs during recognition that would be longer than those of practiced and control items.

For each participant, mean recognition RT and SD were computed, and all RTs beyond 2.5 SD from that participants' mean were trimmed. The inhibition score corresponds to the median RT for inhibited items divided by the median RT for control items. The higher the score above 1, the stronger the inhibition.

Vocabulary Tasks

L2 learners' overall proficiency was measured through a receptive vocabulary score obtained from the Peabody Picture Vocabulary Test (PPVT). A computer-based version of the PPVT was administered, either in English (PPVT-4; Dunn & Dunn, 2007) or in Spanish (PPVT-3; Dunn, Dunn, & Arribas 2006), depending on the learners' L2. For each language, audio materials were recorded in two accents, British and American English and Peninsular and South American Spanish. L2 learners chose to do the test in the L2 accent they felt most comfortable with. The standard scoring method for the PPVT was considered inappropriate for L2 learners varying in L2 proficiency as this test was designed to measure receptive vocabulary knowledge by native speakers of different age ranges. Instead we used an overall error score (% of incorrectly identified lexical items). To validate this score, we also administered tests specifically designed to assess receptive lexical knowledge in L2 learners (X-lex, Meara & Milton, 2003; and Y-Lex, Meara & Miralpeix, 2007). For L2-English learners, the X-Lex and Y-Lex tests provided a combined vocabulary size estimate of 0-10,000 words, which has been shown to be related to L2 proficiency levels (Miralpeix, 2012). For L2-Spanish learners, only the Spanish version of the X-Lex (0-5,000 words) was available.

A *Pearson-r* correlation coefficient calculated between the L2-English learners' X-Lex/Y-Lex scores and their PPVT error percentage was relatively strong ($r = -.633$) and significant ($p < .01$), so we used the PPVT error percentage for both groups to partial out proficiency.

Hearing Screening

All participants had to pass a pure-tone audiometry test at octave frequencies between 500 and 8000 Hz at 20 dB HL in order to be included in the study.

General testing procedures

The L1-English/L2-Spanish participants and L1-English controls were tested in Bloomington, USA, whereas the L1-Spanish/L2-English participants and the L1-Spanish controls were tested in Seville, Spain. In Bloomington, participants were tested individually in a psycholinguistics laboratory. The order of tasks was the same for all participants. Only the L2 learners participated in the vocabulary tasks. Participants were paid for participating.

At the University of Seville, the participants were tested in groups of 2 or 4 in a language laboratory. The order of tasks was the same as in Seville, except that for half of the participants, this order was switched due to the availability of the recording booth. Participants were given a USB memory drive for participating.

RESULTS

Since we are examining factors related to L2 phonological processing, only data from the L2 learner groups are included in the analysis. Descriptive statistics for the data obtained in each measure are presented in Table 5.

Table 5. Descriptive statistics for each measure obtained in each learner group.

Measure	L2	Mean	*SE*	Median	*SD*	lowest	highest	N
ABX, Accuracy (test)	Spanish	0.78	*0.03*	0.81	*0.12*	0.56	0.94	18
	English	0.82	*0.02*	0.84	*0.07*	0.69	0.91	16
ABX, RT (test)	Spanish	1191	*44.72*	1160	*189.74*	907	1596	18
	English	1241	*72.51*	1206	*290.04*	749	1695	16
Production score (consonants, max. 8)	Spanish	3.78	*0.50*	4	*2.10*	0	7	18
	English	6.75	*0.34*	7	*1.34*	4	8	16
Production score (vowels)	Spanish	1.02	*0.10*	0.92	*0.41*	0.47	2.14	18
	English	0.70	*0.09*	0.67	*0.37*	0.19	1.39	16
Attention Control (shift cost, ms.)	Spanish	100.94	*15.27*	99.18	*64.76*	-60.12	223.47	18
	English	52.52	*14.95*	60.64	*59.79*	-61.66	142.26	16
Inhibition score	Spanish	1.00	*0.03*	0.96	*0.10*	0.91	1.29	17
	English	1.05	*0.08*	1.00	*0.29*	0.44	1.69	15
PPVT (% error)	Spanish	40.63	*1.52*	40.62	*6.26*	21.88	48.96	17
	English	28.46	*2.25*	30.88	*8.70*	9.80	42.65	15
X-lex (adjusted score)	Spanish	2522	*170*	2800	*721*	700	3400	18
	English	3718	*126*	3550	*504*	2950	4700	16
Y-lex (adjusted score)	Spanish	n.A.						
	English	1978	*225*	1975	*901*	450	4000	16
X-lex/Y-lex score	Spanish	n.A.						
	English	5696	*302*	5800	*1208*	3900	8450	16

Note: PPVT = Peabody Picture Vocabulary Test (Dunn & Dunn, 2007), n.A. = This test was not available for L2-Spanish, SE = Standard Error of the mean, SD = Standard Deviation

Correlation analyses were conducted in SPSS 20. We first checked all variables for normality. After excluding one extreme value for inhibition in each group, all Shapiro-Wilk statistics values were above .9 (indicating normal distribution). None of the production or perception scores was related in significant ways with any of the background variables. There was also no correlation between the background variables and the PPVT scores. However, some of the background variables correlated with each other. The results of the correlations between attention and inhibition measures and the three phonological accuracy scores are presented in Table 6.

Table 6. Correlations between cognitive measures and phonological accuracy for each learner group.

Measure	L2	Perception (ABX)	Production (Cs)	Production (Vs)	N
Attention	Spanish	*r* = .124 *n.s.*	*r* = -.003 *n.s.*	*r* = -.257 *n.s.*	18
(shift cost)	English	***r* = -.438***	*r* = -.366 *n.s.*	***r* = .640***	16
Inhibition	Spanish	***r* = .507***	*r* = .324 *n.s.*	*r* = -.216 *n.s.*	17
(score)	English	***r* = .615***	*r* = .169 *n.s.*	*r* = .024 *n.s.*	15

In addition to these findings, the perception score for ABX in both groups correlated significantly with the accuracy score for consonants in production (r = .563, p < .023 for L2-English; r = .854, p < .001 for L2-Spanish).

DISCUSSION AND CONCLUSION

In this study, we examined the extent to which attention control and inhibition are associated with L2 phonological processing in perception and production.

We found that both cognitive abilities, as measured through language-based tasks, are associated with one or several phonological measures, when proficiency is partialled out. This suggests that attention and inhibition are two important executive functions implicated in phonological development.

In our sample, a more efficient attention control (operationalized as lower shift-cost scores) was associated with more accurate performance in ABX (for the L2-English learners). That is, L2 learners with greater attention control skills were better able to perceive and use contrastive vocalic and consonantal features in the categorization of L2 speech stimuli, suggesting they had developed more accurate perceptual representations for the L2 sounds. For the L2-English learners, attention control was related in surprising ways to production scores: as expected, shift costs were negatively correlated with consonant accuracy scores (indicating that lower shift costs are associated with higher production scores), but *unexpectedly*, shift costs were positively correlated with vowel accuracy scores. In this latter case, the finding indicates that a less efficient attention control (higher shift cost) was linked to higher vowel production scores. For L2-Spanish learners, there was no relationship between attention control and production scores.

We also found positive correlations between inhibition scores and ABX accuracy in both L2 learner groups. This indicates that learners with higher inhibition scores also performed with higher accuracy on the ABX task. We surmise that perhaps learners with higher inhibitory skill are able to deactivate (or inhibit) the language not in use more efficiently, and this might help them obtain higher accuracy scores in our categorical ABX task. Of note, our task implemented a language switch halfway through the stimuli items. Production of vowels and consonants was not clearly related to inhibition in either group.

Our next steps will examine the consistency of these data and investigate further the specific correlations observed between cognitive abilities and production vs. perception. We will also further examine whether such an advantage in speech processing is truly the *result* of more efficient executive control; in other words, we hope to investigate the causal relationship between cognitive abilities and L2 perception/production. It may be that stronger inhibition and more efficient attention control are facilitating not only phonological processing, but also phonological learning.

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REFERENCES

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: retrieval dynamics in long-term memory. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 20, 1063-1087.*

Anrrich, G. M. (2007). *Substitutions for English Consonants by Adult Speakers of Cuban Spanish*. (Unpublished doctoral dissertation). Georgetown University.

Arbuthnott, K., & Frank, J. (2000). Trail making test, part B as a measure of executive control: Validation using a set-switching paradigm. *Journal of Clinical & Experimental Neuropsychology, 22*, 518.

Baker, W., & Trofimovich, P. (2005). Interaction of native and second-language vowel system(s) in early and late bilinguals. *Language and Speech, 48*, 1-27.

Bohn, O.-S. & Flege, J. E. (1990). Interlingual identification and the role of foreign language experience in L2 vowel perception. *Applied Psycholinguistics, 11,* 303-328.

Bundgaard-Nielsen, R. L., Best, C. T., & Tyler, M. D. (2011). Vocabulary size matters: The assimilation of second-language Australian English vowels to first-language Japanese vowel categories. *Applied Psycholinguistics, 32,* 51-67.

Costa, A., & Santesteban, M. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of Memory and Language, 50*, 491-511.

Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*, 1057-1074.

Darcy, I., Park, H. & Yang, C-L. (2011). Suppression of L1 influence in L2 phonological processing: Cognitive abilities and individual variation. *Paper presented at the Second Language Research Forum, Ames, IA.*

Dunn, L. & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition.* Minneapolis, MN: NCS Pearson, Inc.

Dunn, L., Dunn, D. M., & Arribas, D. (2006). *PPVT-III. Peabody. Test de Vocabulario en Imágenes*. Madrid: TEA Ediciones.

Flege, J. E., Bohn, O.-S., & Jang, S. (1997). Effects of experience on non-native speakers' production and perception of English vowels. *Journal of Phonetics, 25*, 437-470.

Flege, J. E., Yeni-Komshian, G. H., & Liu, S. (1999). Age constraints on second-language acquisition. *Journal of Memory and Language, 41*, 78-104.

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, 35*, 116-124.

Francis, A. L., Baldwin, K., & Nusbaum, H. C. (2000). Effects of training on attention to acoustic cues. *Perception & Psychophysics, 62*, 1668-1680.

Gottfried, T. L. (1984). Effects of consonant context on the perception of French vowels. *Journal of Phonetics, 12*, 91-114.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1*, 67-81.

Guion, S. G., Flege, J. E., & Loftin, J. D. (2000). The effect of L1 use on pronunciation in Quichua-Spanish bilinguals. *Journal of Phonetics, 28*, 27-42.

Guion, S. G. & Pederson, E. (2007). Investigating the role of attention in phonetic learning. In O.-S. Bohn & M. Munro (Eds.), *Language Experience in Second Language*

Speech Learning. Amsterdam: John Benjamins, (pp. 57-77). Amsterdam: John Benjamins.

Lev-Ari, S. & Peperkamp, S. (2013) Low inhibitory leads to non-native perception and production in bilinguals' native language. *Journal of Phonetics, 41,* 320-331.

Masoura, E. V., & Gathercole, S. E. (1999). Phonological Short-term Memory and Foreign Language Learning. *International Journal of Psychology, 34, 383-388.*

Meara, P. & Milton, J. (2003). *X_Lex, The Swansea Levels Test.* Newbury, UK: Express Publishing.

Meara, P. M., & Miralpeix, I. (2007). *D_Tools (Version 2.0; _lognostics: Tools for vocabulary researchers: lognostics)* [Computer software]. University of Wales Swansea. Retrieved on March 30, 2012 from http://www.lognostics.co.uk/tools/index.htm.

Miralpeix, I. (2012). X_Lex and Y_Lex: A validation study. *22nd VARG Conference (Vocabulary Acquisition Research Group).* Newtown, UK.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology, 41,* 49-100.

Morrison, G. S. (2006). *L1 & L2 production and perception of English and Spanish vowels: A statistical modelling approach*. (Unpublished doctoral dissertation). University of Alberta, Canada.

Morrison, G. S. (2009). L1-Spanish Speakers' Acquisition of the English /i/-/ɪ/ Contrast II: Perception of Vowel Inherent Spectral Change. *Language and Speech, 52*, 437.

Pallier, C., Bosch, L., & Sebastian-Gallés, N. (1997). A limit on behavioral plasticity in speech perception. *Cognition, 64*, B9-B17.

Papagno, C., & Vallar, G. (1995). Verbal short-term memory and vocabulary learning in polyglots. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 48*, 98-107.

Rose, M. (2010). Differences in discriminating L2 consonants: A comparison of Spanish taps and trills. In M. T. Prior (Ed.), *Selected Proceedings of the 2008 Second Language Research Forum* (pp. 181-196). Somerville, MA: Cascadilla Proceedings Project.

Safronova, E., & Mora, J. C. (2012). Attention control in L2 phonological acquisition. In Llanes Baró, A., Astrid Ciro, L., Gallego Balsá, L. and Mateus Serra, R. M. (eds). *Applied Linguistics in the Age of Globalization.* (pp. 109-114), Lleida: Edicions de la Universitat de Lleida.

Segalowitz, N. and Frenkiel-Fishman, S. (2005) Attention control and ability level in a complex cognitive skill: attention-shifting and second language proficiency. *Memory and Cognition, 33*, 644-653.

Spivey, M. J., & Marian, V. (1999). Cross Talk Between Native and Second Languages: Partial Activation of an Irrelevant Lexicon. *Psychological Science, 10*, 281-284.

Trofimovich, P., & Baker, W. (2006). Learning Second Language Suprasegmentals: Effect of L2 Experience on Prosody and Fluency Characteristics of L2 Speech. *Studies in Second Language Acquisition, 28*, 1-30.

Veling, H., & van Knippenberg, A. (2004). Remembering can cause inhibition: Retrieval-induced inhibition as cue independent process. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 315-318.