

Phonological Remapping in Native English Speakers



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Abstract

The purpose of this study is to examine the effects of length of residency on native English speakers' perceptions of speech sounds from their native and second languages. Based on methodology from Barrios et al.'s 2016 study, the present study tested English speakers (with Spanish as a second language) against a Spanish monolingual control group in an AX discrimination task of the phones [d], [ð], and [r]. These sounds occur in both languages, but with different distributions and phonological status. After the discrimination task, and an identification test, results showed that native English speakers' perceptions of these speech sounds had, in fact, been "remapped" to the phonological distribution found in Spanish, and that the longer the length of residency, the more similarly participants scored to the monolingual Spanish control group. These results confirm findings from previous studies regarding phonological perception and second language learning, and also contribute to the literature about the effects of second languages and immersion on the native language (L1).

Keywords: L1 (native language), L2 (second language) phonological mapping, phonological status, second language acquisition, attrition, length of residency, immersion

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1. Introduction

One of the fundamental parts of learning a second language is acquiring nonnative speech sounds, and consequently learning the phonological rules that accompany them. In other words, second language learners must not only learn the acoustic details of foreign speech sounds, but also learn the environments in which certain sounds can and cannot occur.

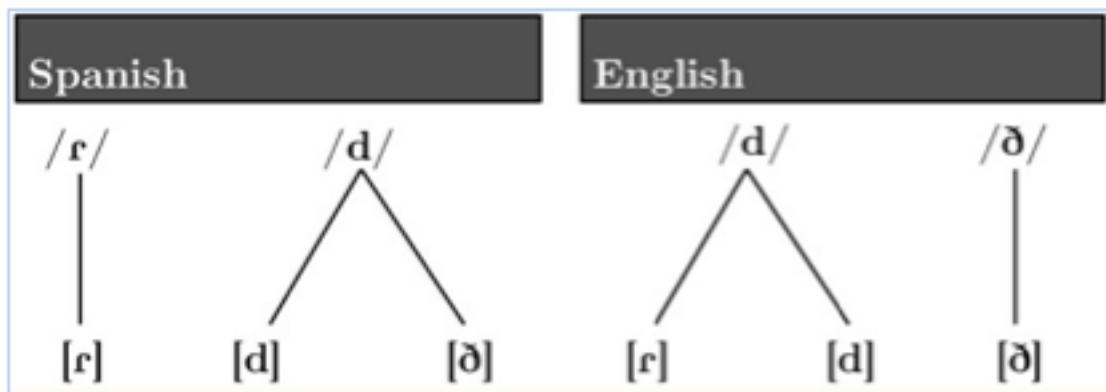
2 Theoretical Background

2.1 Phonology: Phonemes and Allophones

In the field of speech sound category learning and perception, it is important to distinguish the difference between phonemes and allophones. Phonemes are contrastive, and distinguish word meanings. Allophones, on the other hand, are situationally dependent variants of phonemes, and can only occur in specific environments. Take for example, the three phones [d], [ð], and [ɾ]. In English, [d] and [ð] are phonemic whereas [ɾ] is perceived as an allophone of [d], occurring in post-tonic, intervocalic environments (Patterson & Connine 2001). This is demonstrated in the pair of words “day, they”; [d] and [ð] (respectively) are phonemic, as they are contrastive between words. [ɾ], on the other hand, occurs in words such as riding, adding, etc. as a variant realization of [d]. Though the phones [d], [ð], and [ɾ] occur in Spanish as well, their functional categories differ (Barrios et al. 2016). In Spanish, [d] is phonemic and [ð] is its allophonic variant; [d] becomes [ð] when in an intervocalic environment, as seen in words such as “edad”, following Spanish’s intervocalic spirantization pattern (Walton 2005). However, [ɾ] is phonemic as is [d], as seen in the contrastive word pair “cara” -“cada”.

This means that in intervocalic environments, although an acoustically different sound occurs, [ð] is perceived as a variant of [d] in Spanish. In the same intervocalic environment, in English [r] is perceived as [d]. Thus, despite the occurrence of the three phones in both languages, there are distributional variances, as well as contrastive differences. The mapping of these phonemes and allophones can be seen in Figure 1 from Barrios et al. (2016) below:

Figure 1: Phonemic and Allophonic Distributional Differences in Spanish and English



2.2 Phonological Split and Remapping

This means that, when acquiring nonnative speech sounds, particularly when they overlap with those that occur in their native language, learners must “remap” their phonemic and allophonic distribution. This scenario is described by Eckman et al. (2001) as an allophonic split: learners must redistribute, or remap, sounds that are only allophones in their L1, to phonemes in L2, and vice versa. When adapting to new environments, or rather, remapping phonemes, learners must detect and suppress their L1 positional variants (Barrios et al. 2016).

As previously discussed, allophonic split phenomenon can be observed in Spanish and English, particularly in the phonemes [d], [ð], and [r]. Spanish speakers learning

English must learn to alternate [d] with [r] intervocalically, rather than with [ð] from their native language's phonological patterns. English speakers learning Spanish must do the reverse. Essentially, second language learners must adapt their phonological rules to those of the new language. In other words, they must undergo phonological "remapping".

This concept has been explored in previous studies such as in Whalen et al. (1997), Pegg and Werker (1997), and Peperkamp et al. (2003): using AXB and AX discrimination tasks, the research has shown that listeners, regardless of the language at hand, discriminate phonemic contrasts more accurately than allophonic contrasts. This indicates that despite knowledge of nonnative phonemes and allophones, the "weight", or rather, the significance of phonemic contrasts is greater than that of allophonic contrasts, and learners who have correctly adapted to nonnative contrasts should perceive phonemic and allophonic contrasts in a similar way to native speakers of the target language. With this in mind, native English speakers should more readily discriminate between [d] and [ð] due to their phonemic status, and between [d] and [r] less readily since it is an allophonic contrast. Differently, Spanish speakers should more easily perceive the difference between [d] and [r], and perceive [d] and [ð] as less contrastive. This idea was supported by Shea & Curtin's 2010 investigation, which found that English speakers learning Spanish with high proficiency levels were able to place stress on syllables with stop onsets, following allophonic distribution in Spanish, meaning that given time, learners can indeed detect new phonological rules while suppressing those of their native language. In a similar study, Boomershine et al. (2008) used similarity rating and an AX discrimination task to show that for both Spanish and English speakers, allophones were rated as more similar than phonemes respective to participants' native languages with the

three phones [d], [ð], and [r]. Both Spanish and English groups rated [ð] and [r] as the most different pairing of the three phones.

Using the same phones ([d], [ð], and [r]) as stimuli, Barrios et al. (2016) used a behavioral task (AX discrimination) and MEG recordings to explore the phenomenon of phonological mapping in an immersion context. Studying native Spanish speakers living in the U.S. and their acquisition of English phonological patterns, this study found that Spanish speakers learning English had remapped the phones [d], [ð], and [r] from their native language's distribution to the distribution found in English. In other words, the learners were able to accurately discriminate the English phonemic pair [d] and [ð] in an intervocalic environment, while maintaining sensitivity to their own allophonic and phonemic pairs ([d]-[ð], and [d]-[r], respectively). The non-English learning control group (Spanish monolinguals), on the other hand, was not sensitive to the difference in the pair [d]-[ð]. These findings indicate that learning a second language's phonological mapping, especially in an immersion setting, can create new phonological categories and mapping for L2 learners.

2.3 Attrition

What happens to the native language phonology, then, when second language learners are immersed in the L2 environment for long periods of time? Various studies have shown that being immersed in a nonnative language environment can have effects on learners' native languages; Baus, Costa, and Carreiras (2012), for example, found that in short L2 immersion periods, changes in frequency of usage of lexical items caused participants to perform more slowly in naming tasks and show an overall decline in L1 word accessibility. Similarly, Linck (2009) showed that native English speakers

immersed in a Spanish speaking environment produced fewer exemplars in an English fluency task than their nonimmersed counterparts, and these effects were seen even after the immersion period had ended; the participants had undergone L1 attrition.

Attrition has been observed in L1s at the phonological level as well. Stoehr et al.'s 2017 study, which investigated VOT in native speakers of German learning Dutch, showed that while L2 immersion helped participants acquire L2 speech sounds, it resulted in phonological changes in the native language. Similarly, Major (1990) found native English speakers living in Brazil to have difficulties preserving native-like phonology in their L1 and L2 simultaneously: adult learners of Portuguese had attrition in their native English phonology. In a later study, Major (2010) observed that native English speakers from the United States who were long term residents of Brazil perceived foreign accents in English differently than non-immersed native English speaking control participants. A similar situation occurred in de Leeuw (2010): native German speakers who had been living in an L2 setting for an extended period of time were more often perceived as having a foreign accent than their monolingual control counterparts (as rated by other native German speakers), as a result of quantity and quality of L2 input in a migrant context.

Overall, these studies indicate that while L2 learners have native and second language constructs, when immersed in a second language context, they could have a bias towards the L2, leaving the L1 vulnerable to alterations. Flege's 1987 model explains how this phenomenon can occur: when learners can associate similar phones in the L1 and in the L2, a merger occurs, combining categories for sounds in both their native and other languages. Major (1990) also supported this construct, saying that one's native

language is not a concrete system but is subject to change and influence just as a second language is; in fact, the two can impact each other. Lord (2008) supports this, saying that the L1 and L2 interact, making a hybrid phonological system, which is then subject to modification. This means that in the case of English speakers learning Spanish, and L2 learners in general, not only phonemes, but also allophones, can combine under different functional categories. In the case of L2 immersion, these effects could be amplified. Native English speakers living in a Spanish speaking environment, for example, could merge the phonological functional categories from Spanish and English for the phonemes [d], [ð], and [r].

2.4 Research Questions and Hypothesis

Considering the concepts of phonological remapping and L1 attrition, the purpose of the present study is to examine the phonological attrition of native English speaking L2 learners of Spanish, living in Barcelona. Replicating methodology found in Barrios et al. (2016), the main focus of the investigation will be the mapping of L1 to L2 phonemic and allophonic categories, specifically regarding the phonemes [d], [ð], and [r]. In addition to the variables studied in Barrios et al. (2016), the current study will examine the perceptual differences of the mentioned phonemes in native English speakers with different lengths of residency in Barcelona. Ultimately, the main effect to be observed should be attrition in long-term residents, independent of proficiency levels. Consequently, their phonemic/allophonic category mapping should resemble that of monolingual Spanish speakers more than that of monolingual English speakers and short-term English speaking residents.

3. Methodology

The specific question to be addressed in this study is, in a discrimination task, will L1 English long-term residents of Barcelona perceive phonemes and allophones (specifically, [d], [ð], and [r]) more similarly to native Spanish speakers than to shorter-term L1 English residents? If residency does have an effect on phonological remapping, then long-term residents should respond to phonological contrasts more similarly to native Spanish speakers than short-term residents, who will perform more like monolingual English speakers in a discrimination task.

3.1 Participants

Two groups of participants were used for this study: a control group of native Spanish speakers and an experimental group of native English speakers (the latter to be analyzed with Spanish proficiency and length of residency as continuous variables). The Spanish control group consisted of 9 monolingual native Spanish speakers, between the ages of 19-53, with an average age of 25 (SD = 10.6). Seven of this group were bilingual in Spanish and Catalan. Since Catalan has the same phonological patterns as Spanish (in relation to the phonemes being tested), this was not a confounding factor. Eight of the Spanish control participants were from Spain and one was from Colombia. One of the participants was left-handed and none reported having any hearing impairments or past speech therapy. Two of the participants were male and seven were female. None of the Spanish monolingual control group had spent time living abroad in a non-Spanish-speaking country.

The English participant group was composed of 30 native English speakers, from the United States, Canada, England, and Ireland. 6 of the 30 were left handed, and none

reported any speech or hearing impairments or treatments. 16 were male and 14 were female. The average age was 29.5, with a range of 20-55 (standard deviation 8.55). The time spent living in Spain ranged from 0-16 years (Appendix A). In a two-sample t-test, the populations did not differ in age. However, given the small sample size, an additional transformation was performed (box-cox transformation, Appendix B). With this transformation, the groups were found to be statistically different ($p=0.045$), with the mean ages differing by 4 years. However, considering the small difference in mean age and given the language context (all adult, non-simultaneous bilinguals), this study will treat the groups as non-different in age.

The proficiency of all participants (control and experimental groups) was measured by self-report (as done in Barrios, et al. 2016) in the language questionnaire filled out prior to the main experiment. In this questionnaire, subjects were asked to rank their skills in English, Spanish, and other languages on a scale from 1-10 in the areas of comprehension, reading, writing, speaking, and listening. The mean ratings in the participant groups are as follows: The Spanish control group's average rating for English comprehension was 5 (SD=2.1), reading 5.2 (SD=2.2), fluency 4 (SD= 2), pronunciation 3.7 (SD=1.7), writing 4.3 (SD= 1.8), and the overall average of their English skills was 4.5 (SD=1.9). Of the participants that knew some (though reportedly little) English, the average age of onset was 6 (SD=2.9).

The English control group's average rating for Spanish comprehension was 6.7 (SD= 1.9), reading 7.1 (SD=1.8), fluency 6.4 (SD=2.1), pronunciation 6.7 (SD=1.9), writing 6.1 (SD=2.1), and the overall average of their Spanish skills was 6.6 (SD= 1.7). The average age of L2 (Spanish) onset for those who knew Spanish was 15.4 (SD=4.7).

3.2 Materials

To test the phonemes [d], [ð], and [r] equally for Spanish speaking and English speaking participants, each phoneme was placed in an intervocalic position to create the nonword tokens [idi], [iri], and [iði]. The vowel [i] was chosen since it is the most phonetically similar vowel in Spanish and English (Flege et al., 1994). Since there are no contexts in which all three of these phones occur naturally in both languages, but [ð] and [r] occur in Spanish and English intervocalically (respectively), the VCV pattern was chosen, as seen in Barrios et al. (2016). The phoneme [d] does not occur in either language intervocalically, but since it is not seen in Spanish or English, there is no expected bias towards either one of the two languages. The tokens were read out loud by three female speakers who are fluent in Spanish and English, and whose native languages were Hungarian, Greek, and Turkish. The speakers were instructed on the pronunciation of the phonemes, and the variety of voices and accents allowed for more natural stimuli, to ensure there would be no bias towards a more “English” or a more “Spanish” pronunciation of the tokens. The tokens were then spliced to lengths of 451 ms [idi] (range 390-485), 400 ms [iði] (range 407-460), 369 ms [iri] (range 309-403). The stimuli were also normalized for intensity. Length and intensity were manipulated in Praat, and the readings were recorded through Audacity with a microphone in a quiet, soundproofed room. All tokens used in the experiment were approved by native speakers of Spanish and English, and the three highest rated tokens from each speaker for each of the three nonwords were chosen for the experiment (27 total). Additional filler tokens (nonwords [ibi] and [ili]) were recorded in Audacity to be used for pretest practice and as fillers in the posttest, and were read by a native English speaker of the American dialect.

3.3 Procedure

3.3.1 AX task

Prior to the experiment, participants were given verbal and written instructions (Appendix D) along with consent forms. Participants also completed the language questionnaire (Appendix C) before beginning the experiment. The procedure took place at the CBC Neuroscience labs, in a quiet room in front of a computer. Sennheiser headphones (model PC 3 Chat) were provided, with adjustable volume. The stimuli were presented through Matlab, in an AX discrimination task. In this task, stimuli were presented in token pairs, which had to be identified as the same nonwords ([iði]-[iði], [idi]-[idi], and [iri]-[iri]), or different nonwords ([idi]-[iði], [idi]-[iri], and [iði], [iri]). Participants responded to a total of 192 pairs, which consisted of 32 “same” trials (16AA, 16BB) and 32 “different” trials (16AA, 16BB) per contrast. These stimuli pairs were randomized in order in four different stimuli lists, to randomize the effect of order of presentation. In each pair, the two stimuli were separated with a 500ms gap, and participants had a total of 4 seconds to respond by pressing the “1” key if they perceived the stimuli as the same “word”, and the “2” key if the stimuli were different “words”. The next pair of stimuli was automatically presented one second after the participant’s response, and after 4 seconds if no response was given. Participants were given 6 practice trials with feedback to adjust to the experiment, followed by the main experiment. The main experiment took approximately 15 minutes, with brief self-timed pauses after each block of 48 trials (3 pauses total).

3.3.2 Identification Task

After the main experiment, participants took a brief posttest (approximately 3 minutes) in which each of the 27 stimuli, along with 13 fillers taken from the practice rounds of the experiment (40 tokens total) were presented one at a time. Participants then categorized each token by keyboard responses. Spanish participants were to categorize the nonwords as “idi”, “iri”, or “other” and English participants categorized the tokens as “eady”, “eethee”, or “other”. This task served as verification that the tokens would be categorized correctly in the listeners’ respective L1s.

4. Results

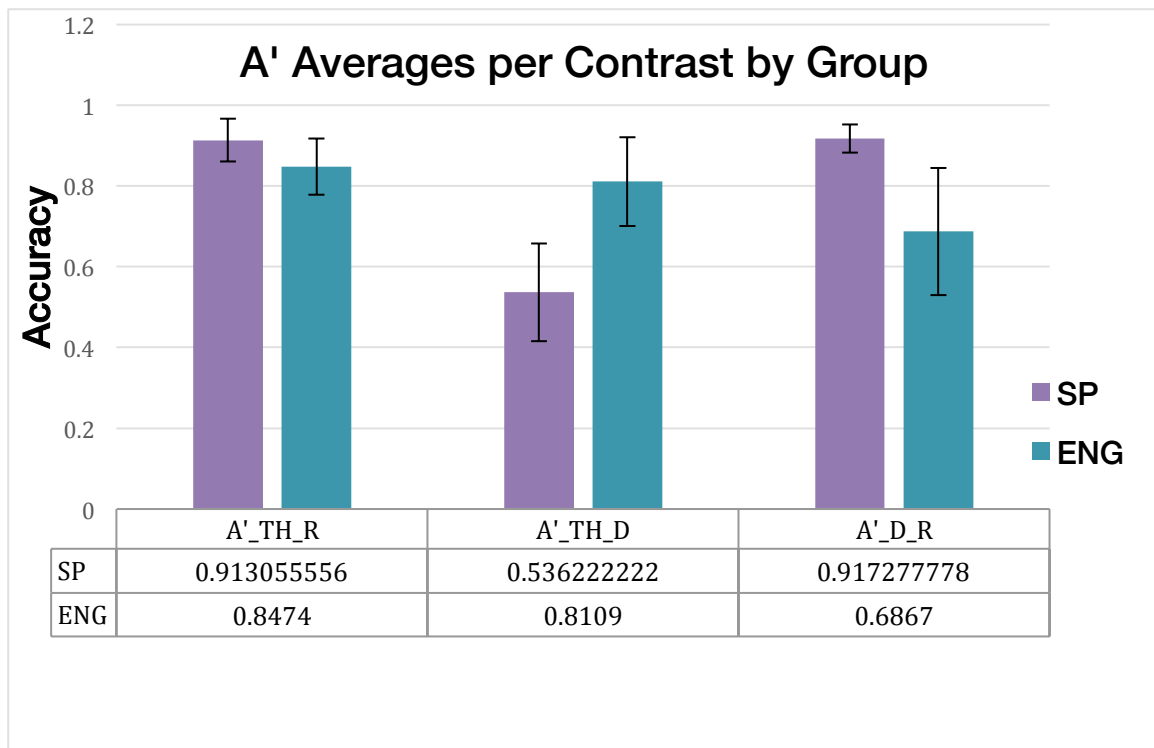
4.1 AX Task

The main variable measured in the AX test was accuracy, and both Spanish and English groups’ performance per contrast can be seen in Figure 2 below. Data from all participants was analyzed for A’ using Gaetano’s Signal Detection Theory Calculator (Gaetano 2017) to measure accuracy while taking into account individuals’ response biases. To do this, “hit rate” and “false alarm rate” were computed: hit rate being the proportion of pairs containing “different” stimuli correctly identified as “different”, and false alarm rate being the proportion of pairs incorrectly being identified as “different” when the stimuli in the pair were the same. No participant performed at extreme rates (0 or 1). A’ measures for each stimuli contrast were found by averaging A’ results from two different methods: in the first method, each “different” contrast was measured against the average of its “same” counterparts, and the second method measured the “different” pairs using the “same” pairs’ errors as a constant. Both methods were highly correlated, so an average of the two methods was used; the resulting accuracy measures for each “different” contrast served as accuracy of discriminability variables for each contrast

(Appendix E). The Spanish A' averages were as follows: [ð]-[r]: 0.9131 (SD=0.05), [ð]-[d]: 0.5362 (SD=0.12), [d]-[r]: 0.9173 (SD=0.04). The English participant A' averages were: [ð]-[r]: 0.8474 (SD=0.07), [ð]-[d]: 0.8109 (SD=0.11), [d]-[r]: 0.6867 (SD=0.16).

Figure 2 shows the mean A' scores (accuracy measures) for both Spanish and English participants, per contrast ([ð]-[r], [ð]-[d], and [d]-[r], respectively). The A' scores were on a scale of 0-1, with scores approaching 1 being the most accurate at discriminating the contrast between the two stimuli in a given pair, and with 0 being the least accurate.

Figure 2: Accuracy per “Different” Contrast



The variables from the main experiment were then analyzed using SPSS. A Mann Whitney U test showed that Spanish and English groups' A' scores differed significantly in all three "different" stimuli contrasts:

Figure 3: Mann Whitney U scores: Spanish vs. English A' score differences

[ð]-[r]:	[ð]-[d]:	[d]-[r]:
U 64	U 11	U 14
z = -2.35	z = 4.11667	z = -4.01667
*p = 0.01878	*p < 0.00001	*p < 0.00001

In addition to A', reaction times were also measured for each contrast. In Figure 5, reaction times appear by group per contrast. Between the Spanish group and the English group, reaction times were found to be significantly different in a Mann Whitney U test in the following pairs:

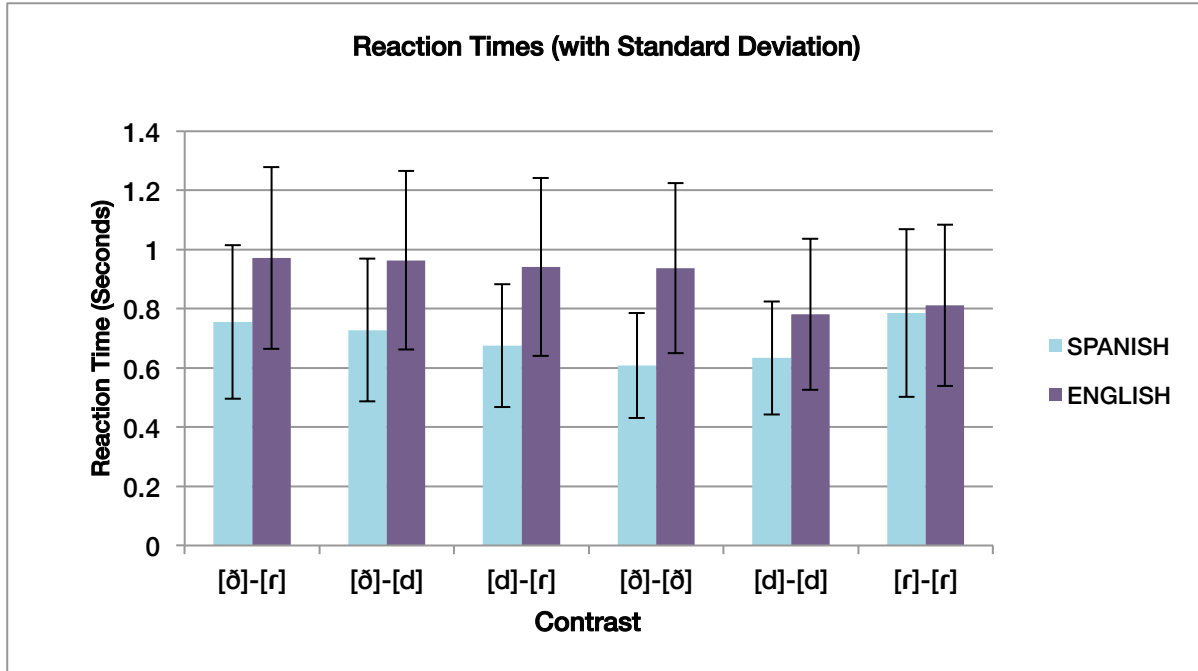
Figure 4: Mann Whitney U Scores: Spanish vs. English response times

[ð]-[d]	[d]-[r]
U 74	U 62
z = 2.01	z = 2.41667
*p = 0.04338	*p = 0.01552

Reaction times were not significantly different in stimuli pairs that were the "same" ([ð]-[ð], [r]-[r], [d]-[d]). Reaction time averages per stimuli pair (in seconds) were as follows:

Figure 5: Reaction times (in seconds) per contrast by group

	[ð]-[r]	[ð]-[d]	[d]-[r]	[ð]-[ð]	[d]-[d]	[r]-[r]
SPANISH	0.756 (SD = 0.26)	0.728 (SD = 0.24)	0.676 (SD = 0.21)	0.608 (SD = 0.18)	0.634 (SD = 0.19)	0.786 (SD = 0.24)
ENGLISH	0.971 (SD = 0.31)	0.964 (SD = 0.3)	0.941 (SD = 0.3)	0.937 (SD = 0.29)	0.781 (SD = 0.26)	0.812 (SD = 0.27)

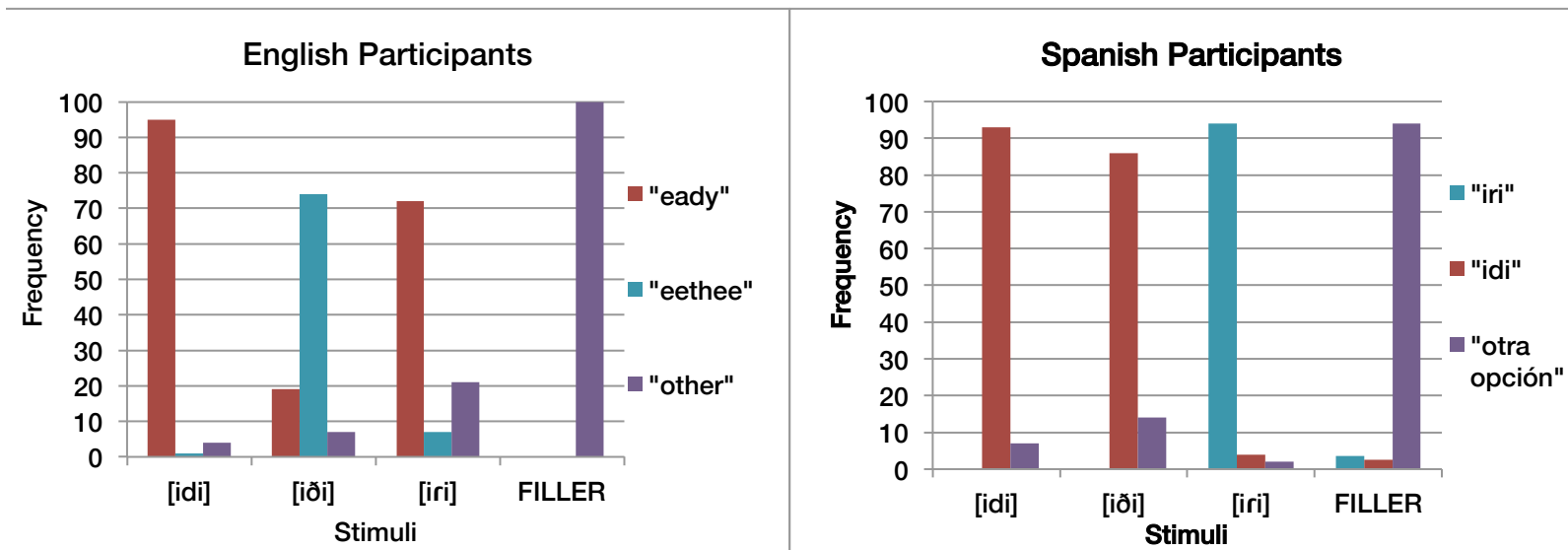


In addition to analyzing the accuracy and reaction times of participants, a within-group analysis was performed for the English participants in order to explore the composite effect of length of residency and L2 proficiency (taken from the average of the scores of language comprehension, reading, writing, fluency, and pronunciation from the language questionnaire) on accuracy (A') and reaction time (in seconds) per contrast. A regression analysis revealed a significant correlation between length of residency and A' within the contrast [ð]-[d] (p= 0.004334*) (Appendix F).

4.2 Identification Task

Frequencies of each response by stimulus type can be seen in Figure 6 below (Appendix G for Chi Square results). Both groups predominantly marked the filler items as “other” (English listeners marked all filler items as such). The Spanish listeners chose “idi” for [idi] and [iði], and “iri” for [iri]. The English listeners predominantly chose “eady” for [idi] and for [iri], and overall the English group’s choices showed more variance the Spanish control group; response distributions differed significantly in the phones [iði] and [iri] between Spanish and English.

Figure 6: Stimuli response frequency by stimulus and group



5. Discussion

The main purpose of the investigation was to investigate the remapping of the phonemes [d], [ð], and [r] to new phonemic and allophonic categories. According to this research's hypothesis, the main effect to be observed should be remapping and attrition in longer-term residents; their phonemic/allophonic category mapping should resemble that of monolingual Spanish speakers more than that of monolingual English speakers, or even that of their shorter-residency counterparts. That said, there were two main ways that English participants' perception could have changed: discrimination of the phones [ð]-[d] could worsen (as this is an allophone pair in Spanish) and [d]-[r] discrimination could improve (as these are phonemes in Spanish and allophones in English), based on influence from immersion in a Spanish-speaking context. The results from the main AX-Discrimination task supported part of this hypothesis; they showed a significant correlation of length of residency in the English participants' accuracy in discriminating the contrast [ð]-[d], thus replicating Barrios et al (2016). Additionally, a regression analysis using length of residency in conjunction with second language proficiency showed a connection between length of residency ($p=0.003$) and accuracy of responses to the [ð]-[d] contrast. Similarly to Barrios et al (2016), English groups differed significantly from the Spanish control group in reaction time and discriminability of the contrasts [ð]-[d] and [d]-[r]. Finally, results from the identification test also replicated Barrios et al (2016): Spanish and English speakers categorized tokens according to their native languages. However, English speakers' identification responses corresponded to both Spanish and English phonological patterns.

Taking a closer look at the AX task results, Spanish participants performed as expected: [idi] - [iri] contrasts were discriminated more accurately than [idi] - [iði] pairs. This follows the contextual distribution of these phones: since [ð] is an allophone of [d] in the intervocalic environment found in these stimuli, the two phones were perceived as two “same” tokens. [iri], on the other hand, carries a heavier phonological status since it contains a phoneme, not an allophonic variant. This explains why the control pair, [iði]-[iri] as well as [idi]-[iri] were perceived more accurately by Spanish participants than [idi] - [iði]. English A’ scores, on the other hand, differed significantly from each of the three Spanish scores, with the control pair [iði]- [iri] resulting in the highest accuracy. [idi]-[iri] was perceived the least accurately, likely due to the allophonic status of the pair in English. Interestingly, the pair [idi] - [iði], despite its contrastive status in English, had lower accuracy in responses than the control pair. This could have occurred as a result of the phonemes being correctly remapped from their distribution in English to the phonological patterns used in Spanish, resulting in responses similar to native Spanish speakers in some cases.

Regarding reaction times, the Spanish control group had overall faster responses, but did not differ significantly in any “same” pairs ([iði] - [iði], [idi]-[idi], [iri]- [iri]) from English speakers. English speakers had an overall slower reaction time than Spanish speakers. Interestingly, not only did the allophonic pair in English [idi]-[iri] have a slower reaction than the control pair, but the allophonic pair in Spanish ([idi] - [iði]) did as well. This could be an indication that English speakers have acquired the phonological distribution in Spanish, and “hesitate” more in discriminating closely perceived Spanish phone pairs, despite the pair’s contrastive status in English. The fact that English

speakers still differed significantly from Spanish speakers with the pair [idi]-[iri] shows that though new patterns for native phonemes can be acquired, patterns found in the L1 do not necessarily undergo attrition just because of immersion or proficiency in a second language.

In addition to the data from the AX discrimination task, the post-task identification data indicates that participants in the English group underwent phonological remapping; while [idi] and [iri] were frequently marked as “eady”, and [iði] as “eethee”, there was more variation here than was observed in the Spanish participants’ responses. The token [iri] was marked several times as “other” (similar to the responses of Spanish participants “iri” option), and [iði] was often marked as [idi]. This could indicate two things: one, that [iði] is being perceived as [idi] due to the acquisition of Spanish phonological rules, and two, that [iri] is being perceived as Spanish “iri”, and thus does not fit under the labels of “eady” or “eethee”. Both of these would indicate the acquisition of Spanish phonological distribution: a remapping of English phonemes and allophones.

While A’ scores, reaction times, and data from the identification task replicated results from Barrios et al (2016), this study produced a new correlation: participants’ length of residency did indeed have an effect on the accuracy of responses to the pair [idi] - [iði], as we see from the regression in Appendix F. Despite its weak effect, this could be an underlying phenomenon in phonological remapping that influences second language perception: regardless of the level of proficiency, immersion over a period of time can influence native language sound perception. A larger sample size with more evenly distributed length of residency could clarify the extent of this effect in future studies.

It appears that overall, the phones in the pair [idi] - [iði] seem to be the most vulnerable to change. This pair received slower reaction times, and less accurate responses than the other stimuli pairs, suggesting that these phones could be susceptible to change prior to other phones in English (take the pair [idi]-[iri], for example, which was less affected).

Aside from phonological remapping, another potential factor influencing participants' responses is the language context of the study. Despite some of the English participants' proficiency in Spanish, instructions were given in their native language, which could have biased them from the beginning of the experiment. Garcia-Sierra et al (2012) discusses how speech environment and context can have a strong influence on speech perception choices: perhaps the length of residency and remapping effects would have been more dramatic had the instructions been given in Spanish. For example, in this case the pair [idi]-[iri] could have elicited more "Spanish-like" responses from native English speakers had they been given in a Spanish linguistic context.

Additionally, the demographics of the English group of participants could have affected the outcomes of the study's tasks. In fact, one of the main shortcomings of the present experiment is that rather than comparing two groups of English participants (a long-term and a short-term group, both with respectively uniform lengths of stay) the group had quite a skewed distribution (Appendix A). The sample did not have enough variability to properly capture the effect of length of residency; for future studies, a more balanced grouping of participants could help lead to more definitive results regarding the effect of length of residency as well as between-group differences.

Another possible confounding factor is that the filler items used in the pretest included the token [ibi], which does not occur in Spanish, due to the language's intervocalic spirantization pattern (Barrios et al 2016): in Spanish the proper realization of "ibi" is [iβi]. Consequently, this could have biased the English speakers (in addition to the English instructions) to be expecting to hear English speech sounds, rather than Spanish or any other nonnative phones.

On a related note, Barrios et al. (2016) discussed that the token [idi] is problematic in that in both Spanish and English, it does not occur naturally. That said, this should not have influenced results because 1) both languages would have been equally biased (not possible in either), and 2) due to the allophonic status of the [r] and [ð], and the intervocalic environment in which they occur in this study, they should be perceived as [d] anyways. Thus, [d] being intervocalic in experimental tokens should not be a confounding factor in the results or the perception of the speech sounds involved in the tasks.

Overall, though phonological attrition is not necessarily evident in this group of participants, results do demonstrate phonological remapping. English participants' performance showed perception of pairs of phones that approached that of native Spanish speakers. The English allophonic pair ([idi]-[iri]) was not affected, indicating that attrition had not taken place. However, according to A' measures in the AX task and responses in the identification test, it appears that learners have remapped phones from their native language to the distributional rules of the L2 environment they are immersed in.

This study and those it supports indicate that there is much to be explored in phonological acquisition and attrition. The behavioral results from this study demonstrate that even with a small group of participants, phonological changes occur as a result of second language acquisition and immersion. Future studies could explore this concept longitudinally: to be able to study participants' individual progression along the course of an L2 immersion (study abroad students for instance) could illuminate how and when immersion affects L1 perception in a more specific way. This could provide a more uniform profile of participants to study length of residency effects, while avoiding interference from individual variance.

6. Conclusion

The data from this study not only supports previous research regarding phonological acquisition and remapping (Barrios et al 2016, Boomershine et al. 2008), but also indicates that the length of immersion in a second language environment may influence perception not only of learners' second language speech sounds, but also those of their native language. In future studies, this methodology can be replicated to study the phenomenon across different languages and immersion contexts, to further understand how second languages and immersion can affect native language perception.

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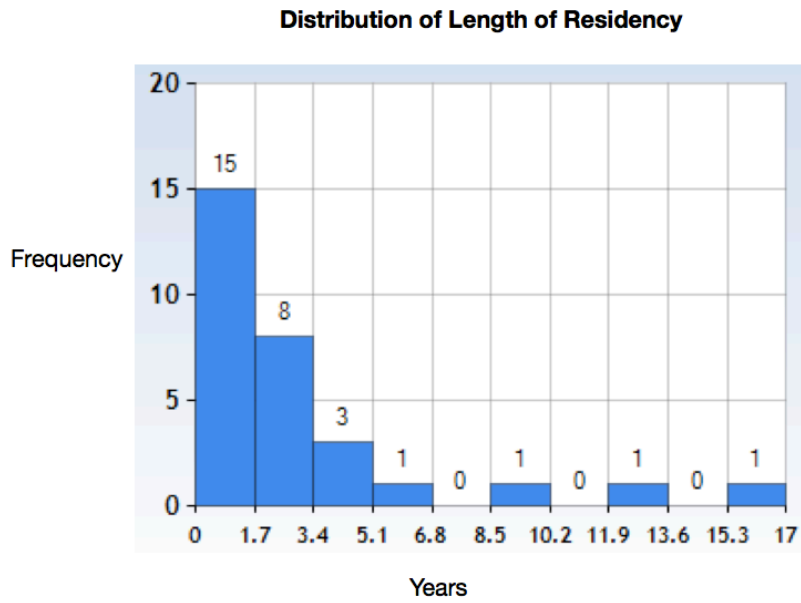
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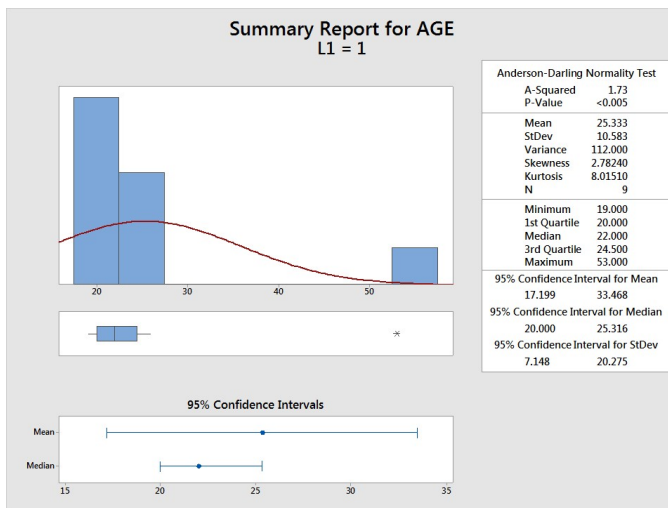
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Appendix

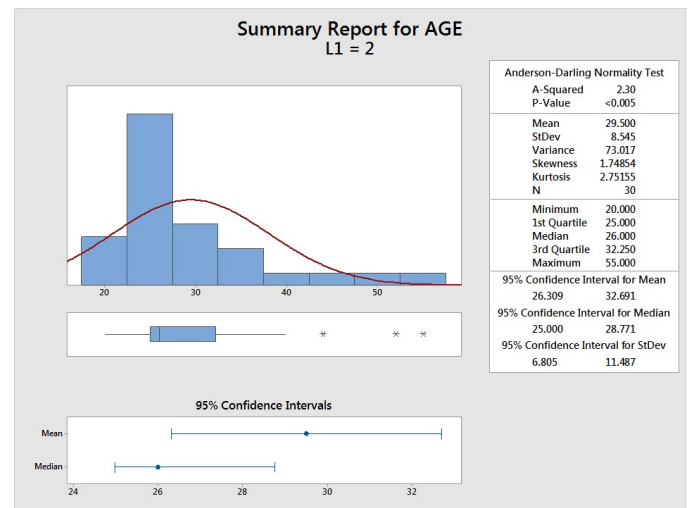
A. Distribution of length of residency in Spain (English participants)



B. T-Test: Age differences in Spanish and English groups

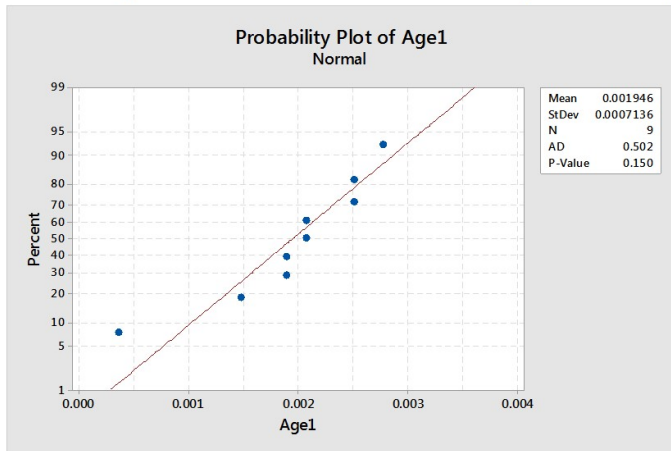


Spanish Age Distribution

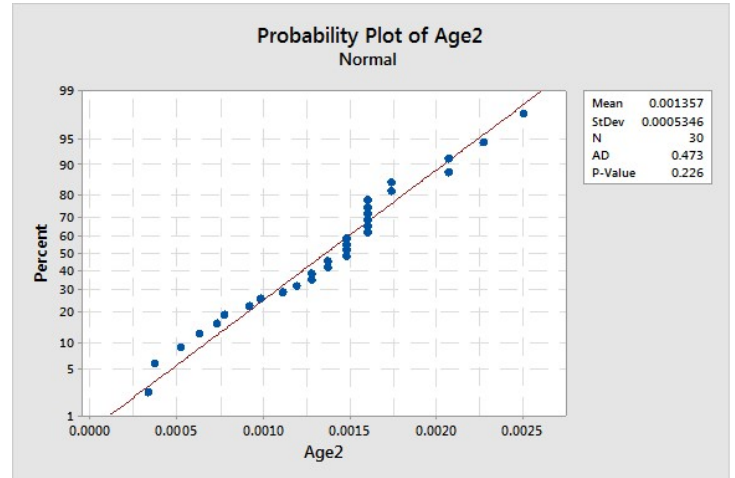


English Age Distribution

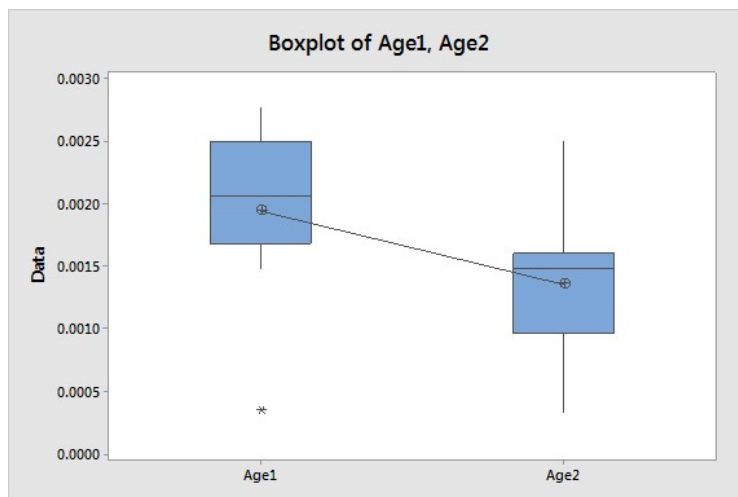
Normalize ages with box-cox transformation($\lambda = -2$)



Spanish Age Normalized



English Age Normalized



Boxplot- Spanish and English ages

C. Language Questionnaire

LANGUAGE QUESTIONNAIRE

Name.....Telephone..... Email.....

Age Birthplace.....

Current Residence (City)

If this is not your birthplace, how long have you lived in your current place of residence.....

Father's birthplace.....

Mother's birthplace.....

At what age did you start to hear English?

At what age did you begin to speak English?.....

a) Indicate the language (English or others) that you usually use to speak with:

Father: Mother: Siblings: Significant Other:

b) If as a child you spoke with your parents or others in another language than what you usually use with them, indicate the age that this change of language took place:

Father: Mother: Siblings: Significant Other:

Are you left-handed?(yes/no).....

Do you have any hearing problems/assistance?.....

Have you ever participated in speech therapy?.....

c) What other languages can you use (speak, read, write)?

.....

At what age did you start learning these languages (formally)?

Have you lived in any non-English-speaking countries and for how long?.....

Choose the option that best represents you in each of the following questions:

- 1 very low proficiency
- 10 equivalent to a native proficiency

a) What is your level of comprehension in these languages:

Spanish:	1	2	3	4	5	6	7	8	9	10
English:	1	2	3	4	5	6	7	8	9	10
German:	1	2	3	4	5	6	7	8	9	10
French:	1	2	3	4	5	6	7	8	9	10
Others:	1	2	3	4	5	6	7	8	9	10

b) What is your level of reading skills in these languages:

Spanish:	1	2	3	4	5	6	7	8	9	10
English:	1	2	3	4	5	6	7	8	9	10
German:	1	2	3	4	5	6	7	8	9	10
French:	1	2	3	4	5	6	7	8	9	10
Others:	1	2	3	4	5	6	7	8	9	10

c) How fluently do you speak these languages:

Spanish:	1	2	3	4	5	6	7	8	9	10
English:	1	2	3	4	5	6	7	8	9	10
German:	1	2	3	4	5	6	7	8	9	10
French:	1	2	3	4	5	6	7	8	9	10
Other:	1	2	3	4	5	6	7	8	9	10

d) How is your pronunciation in these languages?:

Spanish:	1	2	3	4	5	6	7	8	9	10
English:	1	2	3	4	5	6	7	8	9	10
German:	1	2	3	4	5	6	7	8	9	10
French:	1	2	3	4	5	6	7	8	9	10
Other:	1	2	3	4	5	6	7	8	9	10

e) How well do you write in these languages?:

Spanish:	1	2	3	4	5	6	7	8	9	10
English:	1	2	3	4	5	6	7	8	9	10
German:	1	2	3	4	5	6	7	8	9	10
French:	1	2	3	4	5	6	7	8	9	10
Other:	1	2	3	4	5	6	7	8	9	10

D. Instructions**INSTRUCTIONS**

Thank you for your participation!

Your task will be to discriminate between different invented “words”. You will hear a word shortly followed by another. If the words are the same, press the 1 key. If they are different, press 2 (keys 1 and 2 in the number pad, on the right of your keyboard. Move the keyboard to the left if you are left-handed). Please answer as quickly and as accurately as possible. After your response, the next trial will begin.

First, there will be a practice round of 4 trials. After this, the main experiment will begin. There are 192 trials total, which will be split into 4 blocks: you will have a brief pause between each block of 48 trials.

The main experiment will be followed with a brief posttest, with instructions to follow.

POSTTEST

You will be played a list of 40 “words”, one at a time, and your task is to listen to each word and select the word that you believe it corresponds to with the numbers 1, 2, and 3 on the keyboard (keys 1, 2, and 3 on the number pad on the right of the keyboard). The next word will be played after your response.

1= “eady”

2= “eethee”

3= other

INSTUCCIONES

¡Gracias por participar!

El objetivo principal es discriminar entre varias “palabras” inventadas. Escucharás dos palabras, una tras otra, y tienes que decidir si son la misma palabra o no. Si las dos son la misma palabra, pulsa 1 en el teclado. Si son palabras diferentes, pulsa 2 (teclas 1 y 2 en el teclado de números en la parte derecha del teclado. Mueve el teclado si eres zurdo). Por favor, responde tan rápido y con tanta exactitud como te sea posible. En cuanto respondas, aparecerá la siguiente pareja de palabras.

Primero, habrá una ronda de práctica con 12 palabras. Después, empieza el experimento principal, que consta de 192 rondas en total, separado en 4 secciones de 48 rondas. Habrá una pausa breve entre cada sección.

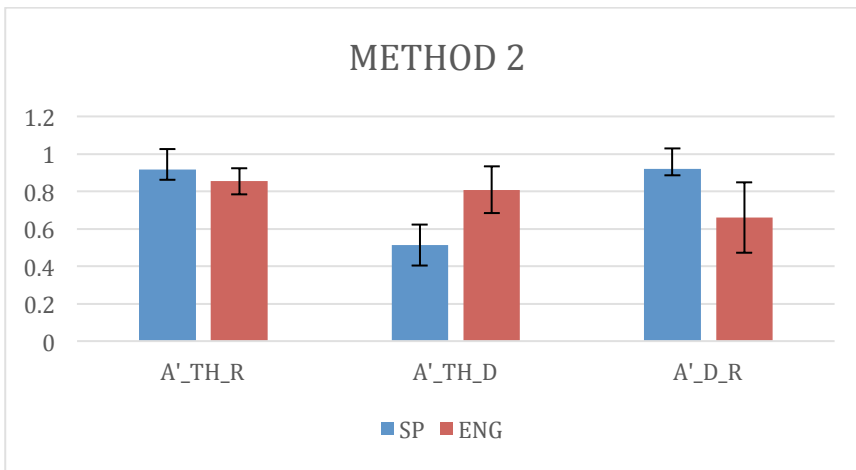
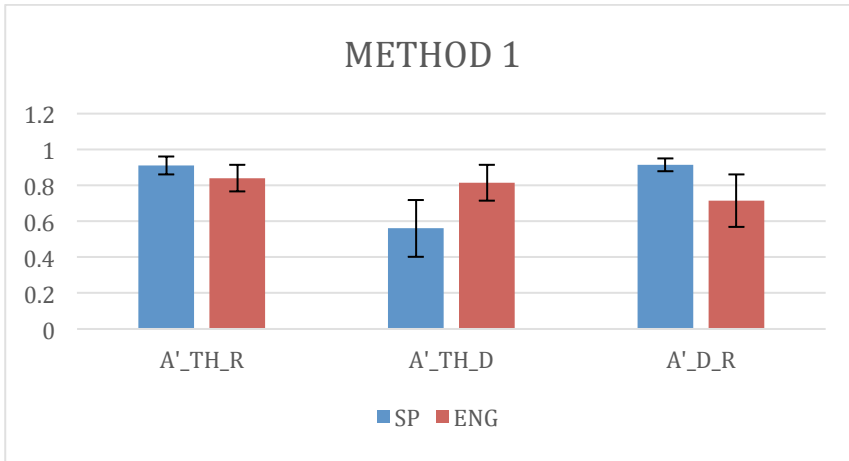
Al acabar el experimento principal, habrá una pequeña prueba. Puede encontrar las instrucciones a continuación.

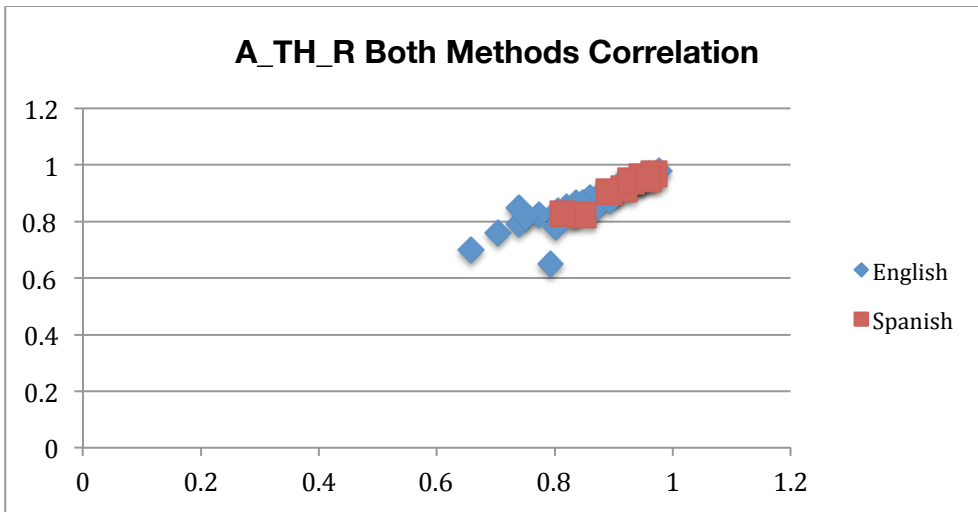
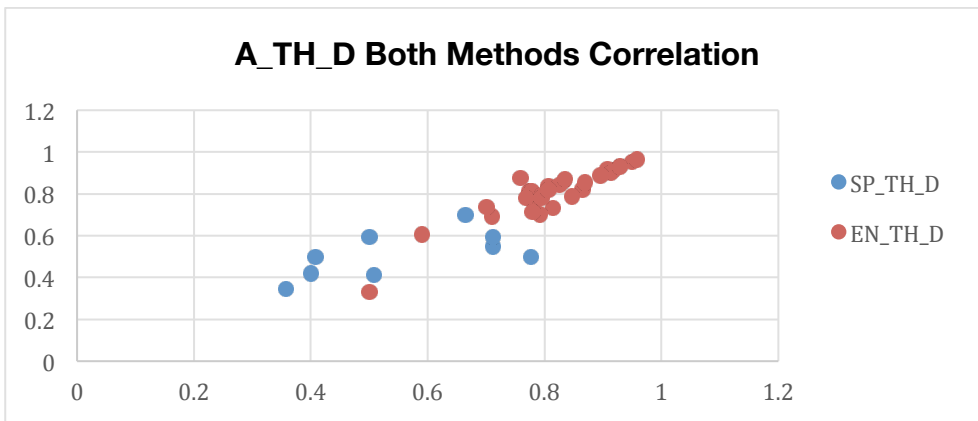
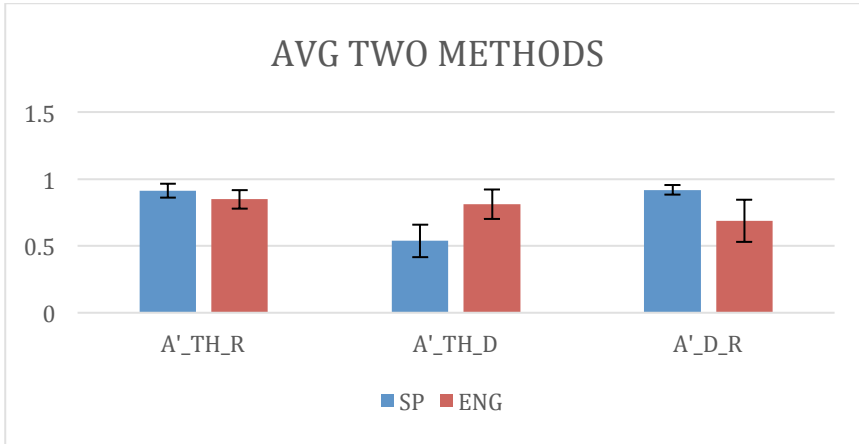
POSPRUEBA

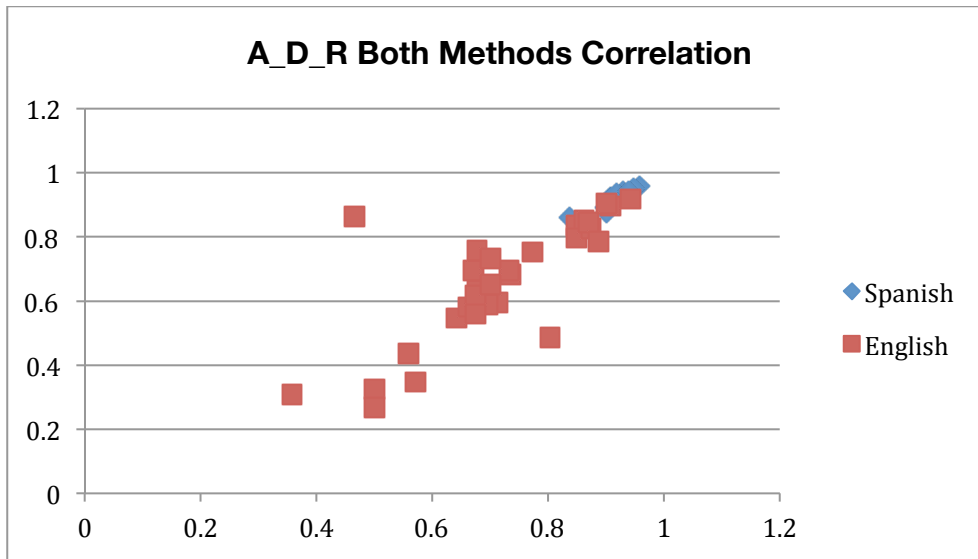
Escucharás una lista de 40 “palabras”, una a la vez, y tu objetivo es escoger la palabra equivalente que la corresponde con las teclas 1, 2, y 3 en el teclado (en el teclado de números en la parte derecha del teclado). La siguiente palabra se escuchará después de tu respuesta.

- 1= “iri”
- 2= “idi”
- 3= “otra opción”

E. A’ measures per contrast (averaged by two methods) and correlations







F. Length of Residency and Proficiency versus A' in contrast [idi] - [iði],

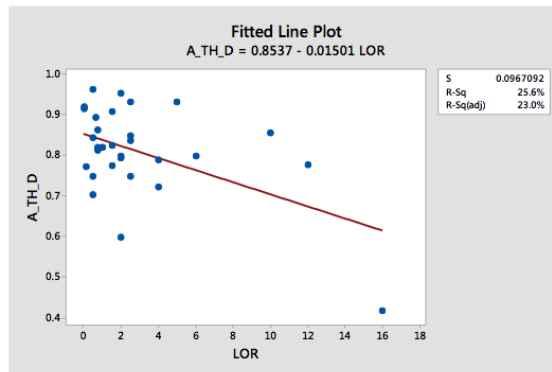
Regression Analysis: A_TH_D versus LOR, Skills

Analysis of Variance

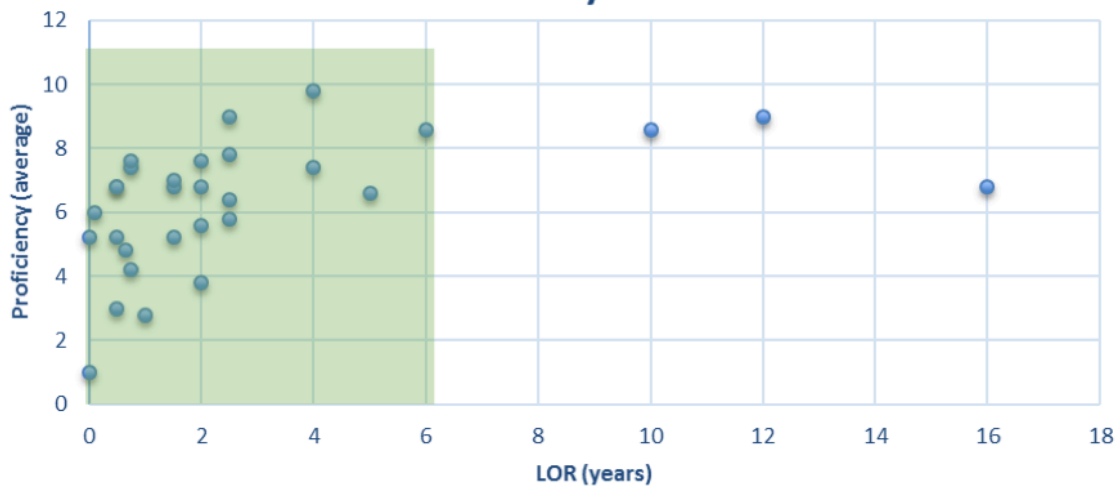
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	0.099484	0.049742	5.31	0.011
LOR	1	0.097950	0.097950	10.46	0.003
Skills	1	0.009148	0.009148	0.98	0.332
Error	27	0.252727	0.009360		
Lack-of-Fit	26	0.245765	0.009452	1.36	0.601
Pure Error	1	0.006962	0.006962		
Total	29	0.352211			

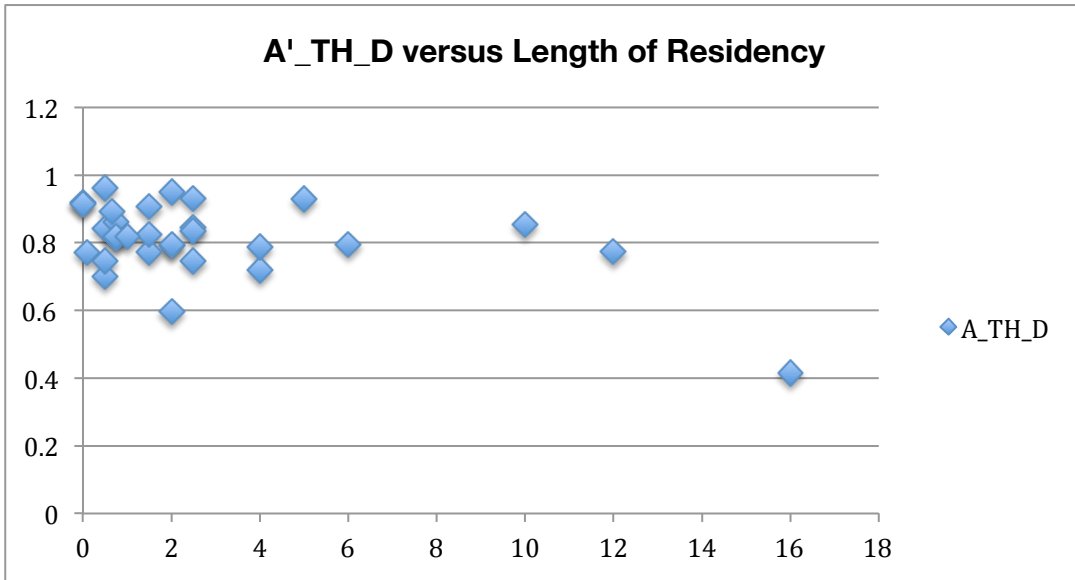
Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0967484	28.25%	22.93%	0.00%



Proficiency vs LOR





G. Chi-Square Results (Identification Task)

	IDI	ITHI	IRI	FILLER
chi-score	0.3798	120.0231	151.4784	2.2167
p value	0.827027	<0.00001*	<0.00001*	0.330109