Incidental changes in orthographic processing in the native language as a function of learning a new language late in life

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Abstract

Acquiring a second alphabetic language also entails learning a new set of orthographic rules and specific patterns of grapheme combinations (namely, the orthotactics). The present longitudinal study aims to investigate whether orthotactic sensitivity changes over the course of a second language learning program. To this end, a group of Spanish monolingual old adults completed a Basque language learning course. They were tested in different moments with a language decision task that included pseudowords that could be Basque-marked, Spanish-marked or neutral. Results showed that the markedness effect varied as a function of second language acquisition, showing that learning a second language changes the sensitivity not only to the orthographic patterns of the newly acquired language, but to those of the native language too. These results demonstrate that the orthographic representations of the native language are not static and that experience with a second language boosts markedness perception in the first language.

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Introduction

Learning a new language not only involves acquiring new vocabulary, grammar, phonology and syntactic rules, but also acquiring the implicit statistical probabilities regarding the new language's orthographic structure, such as orthotactics. Orthotactics are the patterns of grapheme combinations in written words (see Conway, Bauernschmidt, Huang, & Pisoni, 2010; Krogh, Vlach, & Johnson, 2013), and they are learned implicitly by extracting the sub-lexical regularities of words. People become sensitive to these regularities even after little exposure to printed words (Chetail & Content, 2017), developing a high sensitivity to letter sequences belonging to one's language (Miller, Bruner, & Postman, 1954; Owsowitz, 1963).

When readers are exposed to one or several languages, they pick up statistical orthotactic regularities in an unconscious manner, and these seemingly automatically extracted patterns guide ulterior language processing. For instance, a Spanish-English bilingual can easily detect that the word *txerri* (the Basque word for pig) is neither an English nor a Spanish word solely on the basis of the statistical orthotactic regularities of its constituents, since the bigram *tx* is not present in the English or Spanish vocabulary. Hence, native speakers of English or Spanish do not need to know the meaning of *txerri*, or have any knowledge of Basque, in order to decide that this word does not belong to their native language. When we learn a second language (L2) with an alphabet that maps onto our native one, a similar process of extracting statistical orthotactic regularities takes place (Bordag, Kirschenbaum, Rogahn, & Tschirner, 2017; Comesaña, Soares, Sánchez-Casas, & Lima, 2012). Thus, it seems plausible that as we become more proficient in a second language, the new statistical regularities would be better integrated within the preexisting set, leading to a change in our sensitivity to them. In other words, it seems reasonable to predict that the general sensitivity to the orthotactics of both first and second language would change once the new regularities have entered into the system. With this in mind, this study aims to investigate how learning a second language could change the sensitivity to statistical orthotactic regularities from both languages.

Previous research exploring language detection mechanisms by manipulating orthographic markedness (namely, the use of language-specific letter combinations) has demonstrated that young bilingual adults, as well as young monolingual adults, are highly sensitive to violations of the statistical orthotactic regularities of the native language (Casaponsa, Carreiras, & Duñabeitia, 2014; Vaid & Frenck-Mestre, 2002). In the study by Casaponsa et al. (2014), Spanish monolinguals and Spanish-Basque bilinguals performed a language decision task on Spanish and Basque words. Critically, some of the Basque words included highly distinctive marked bigrams, while others did not. All groups were faster at detecting letter strings that violated Spanish orthotactics as compared to other strings, showing a recognition advantage for Basque words with marked bigrams (e.g., *etxe*, the Basque word for house, which contains the bigram 'tx' that does not exist in Spanish). These results showed that even monolinguals can easily detect letter patterns that do not align with their previous implicit orthographic knowledge. Importantly, this suggests that people develop a certain degree of sensitivity to letter sequences that do not conform to their native orthotactic rules, regardless of whether they know the language of the words or not.

Results from monolingual and bilingual samples thus suggest that orthotactic processing occurs at an early, semantics-free stage of visual word recognition. Consequently, language attribution mechanisms triggered by orthotactic patterns appear to take place at a sub-lexical level, before access to lexical and semantic representations (see BIA+ extended model, Van Kesteren, Dijkstra, & de Smedt, 2012; see also BIA+ S model, Casaponsa, Thierry, & Duñabeitia, 2020). Studies exploring the influence of sub-lexical orthographic cues on event-related potential (ERP) patterns related to automatic and unconscious processing of language switches corroborate this idea (e.g., Casaponsa, Carreiras, & Duñabeitia, 2015; Casaponsa, Thierry, & Duñabeitia, 2020; Hoversten, Brothers, Swaab, & Traxler, 2017). Therefore, it seems plausible that sub-lexical factors such as orthotactic distinctiveness play a key role in determining the language of words during visual word recognition (see also Oganian, Conrad, Aryani, Heekeren, & Spalek, 2016; Vaid & Frenck-Mestre, 2002). And, in the absence of additional contextual cues, multilingual single word recognition is a process that initially requires a fast-acting language detection mechanism. Consequently, orthotactics should have a direct impact in second language learning through correct and efficient language categorization.

Preceding research on language categorization suggests differential development of sequential bilinguals' linguistic systems (Segalowitz, 1991; Van Kesteren et al., 2012); it assumes that the native language is stable through time while the second language is the one that changes the most throughout acquisition and consolidation. It is thus expected that the native language influences the second language, and not the other way around. Evidence in support of this assumption comes from studies showing that second language learners normally exhibit difficulties with L2 accent and prosody, with spillover or transfer effects from their L1. This evident L2 malleability has led some authors to characterize the native language as stable and resistant and the L2 weak as impressionable (Frenck-Mestre & Pynte, 1997; Hernandez, Bates, & Avila, 1994). However, and not surprisingly, recent evidence shows that not the L2 but also the L1 changes during learning (see, among many others, Baus, Costa, & Carreiras, 2013; Kroll, Dussias, Bice, & Perrotti, 2015).

While L2 language learning abilities can extend beyond young adulthood, the malleability of the native language as a function of the acquisition of a new language seems to diminish with increasing age (Macwhinney, 2007; Schmid & Köpke, 2017). In spite of the cognitive decline associated with ageing (Harris et al., 2009), language learning can effectively take place late in life (see Antoniou & Wright, 2017; Ramos, Fernández García, Antón, Casaponsa, & Duñabeitia, 2017; Ware et al., 2017). The question of interest here is whether L2 acquisition late in life impacts L1 orthotactic structure. Thus, the present study focuses on older adults as a critical test group. It is worth noting that the sensitivity to violations of the orthotactic rules of the first and second language has already been shown in younger bilingual adults to certain extent (Oganian, Conrad, Aryani, Spalek, & Heekeren, 2015), suggesting that L2 learning might have an impact in L1 orthotactics. However, it is unclear whether similar L1 changes can be observed in older populations, when presumably the resistance to change and stability of L1 is at its peak, and the malleability and plasticity of the language system is at its lowest.

Hence, the present longitudinal study aims to investigate whether older adults are sensitive to markedness before learning a second language, and how this learning process changes their sensitivity to orthographic regularities. Specifically, we tested whether language learning late in life and the progressive improvement in L2 skills modulated learners' sensitivity not only to L2 orthotactics, but also to the orthotactic structure of the L1. To this end, older native Spanish speaker adults immersed in a Basque language-learning course for two consecutive academic years were tested in three critical moments (before, during, and after language learning) on their sensitivity to orthotactics via a language discrimination task. We decided to use a two-alternative forced-choice language decision task on pseudowords to minimize the influence of pre-existing L1 lexical and semantic knowledge (see Oganian et al., 2016, for a similar procedure).

Methods

Participants

Thirty retired Spanish monolingual adults took part in this longitudinal experiment. However, only twenty participants remained through the two year sessions (8 females; mean age = 66.57; SD = 5.56). All participants were living in the Basque Country, a Spanish region with two coexisting co-official languages, Spanish and Basque. None of the participants had prior knowledge of Basque, neither could they understand or produce linguistic structures in any other language than Spanish (see below). All participants reported having normal or corrected-to-normal vision, and none of them had any history of chronic neuropsychological disorders.

Participants were recruited by advertisement at a Center of Continuing Education for Adults where free Basque lessons were offered to retired Spanish monolingual adults with no prior knowledge of Basque. This experiment was part of a larger project suported by the Basque Government to study the impact of second language acquisition in the elderly on other cognitive capacities, such as inhibitory control (Antón, Fernández García, Carreiras, & Duñabeitia, 2016) and switching ability (Ramos et al., 2017). Participants signed a written consent form approved by the Ethics and Research Committees of the Basque Center on Cognition, Brain, and Language (BCBL) before the start of the research and educational actions.

Participants undertook Basque lessons for two whole academic years at the Center of Continuing Education for Adults. They attended Basque lessons for a period of eight months each year. Small groups of a maximum of 10 participants per class were arranged. In total, five hours and a half of training were set per week, distributed in three sessions held during working days. Participants were tested at the beginning of the academic year (T1), at the end of that same academic year (T2), and at the end of the second year of taking Basque lessons (T3). The linguistic project was coordinated by the Department of Education, Linguistic Policy and Culture of the Basque Government, and managed by native Basque-Spanish bilingual professional language trainers specialized in adult teaching.

At the beginning of the first academic year, all participants completed a general assessment consisting of a series of cognitive and language proficiency tasks. Age-related cognitive functioning was assessed using the Spanish version of the Mini-Mental State Examination (MMSE; see Lobo, Ezquerra, Gómez, Sala, & Seva, 1979). Participants' linguistic profile before learning Basque was characterized via self-report measures of proficiency, and all participants were asked to rate their knowledge of Spanish and Basque on a scale from 1 to 10 (see Table 1). Also, teachers evaluated participants' Basque proficiency based on their own perception before the lessons started, ensuring that they did not have previous knowledge of Basque . Self- and teacher-perceived Basque proficiency levels were also assessed at the end of the learning process, together with additional objective measures of Basque knowledge. As objective measures of language learning, participants completed a picture naming test (de Bruin, Carreiras, & Duñabeitia, 2017) in which participants had to name sixty-five common names in Basque (see Table 1), and the beginner language test (A1 level) of the Common European Framework for Reference (CEFR, Council of Europe, 2011), with a maximum score of 20.

Table 1. *Descriptive statistics of the assessment*

Before Basque lessons	
Age	65.2 (3.81)
Cognitive function (MMSE)	28.8 (1.24)
Self-perceived Spanish competence	8.1 (0.55)
Self-perceived Basque competence	0
Teacher-perceived Basque competence	0
After Basque lessons	
Self-perceived Basque competence	5.75 (1.45)
Teacher-perceived Basque competence	6.15 (1.09)
A1 level score	19.7 (4.28)
Picture naming	27.85 (10.26)

Note. Values reported correspond to the means (and standard deviations in parenthesis) of the age in years, result of the MMSE test, self-perceived Spanish and Basque skills (0-10 scale), teacher-perceived Basque competence (0-10 scale), score in the A1 level test (with a maximum score of 20), and number of correctly named pictures in a picture naming test.

Materials and procedure

First, a corpus of bigrams was constructed with the Spanish words from the B-PAL (Davis & Perea, 2005) and Basque words from the E-HITZ (Perea et al., 2006) databases, and filtered with the items contained in the SYLLABARIUM database (Duñabeitia, Cholin, Corral, Perea, & Carreiras, 2010). Words that contained letters that do not exist in the other language were removed (e.g., c, ñ, v). Bigrams that did not appear in any form in the other language were considered *illegal* and were selected for the construction of the marked pseudowords. Bigrams were considered *neutral* in both languages if they had a frequency of appearance of at least 10 times in different words of each database. One hundred and thirty-five pseudowords were generated with the help of Wuggy (Keuleers & Brysbaert, 2010), manipulating the presence or absence of distinctive bigrams of each language. Forty-five of these pseudowords were Spanish-marked items, forty-five were Basque-marked items, and forty-five were language-neutral pseudowords. Marked pseudowords were created making sure that at least one of the constituent bigrams violated the orthotactics of the other language. For instance, '*txamur'* is considered a Basque-marked pseudoword because the bigram 'tx' does not exist in Spanish (namely, the 'tx' bigram has a frequency of use of 0 in Spanish). On the other hand, neutral pseudowords were created using bigrams that were plausible in both languages, such as the bigram 'rd' that exists in words such as *cerdo* (the Spanish word for pig), or *ardi* (the Basque word for sheep). Those neutral bigrams were controlled to have equal mean frequency of use in Spanish and Basque, $t(44)=0.03$, $p=.976$, Cohen´s $d=.033$ (see Table 2). The position- and length-dependent mean bigram frequency of each pseudoword as provided by B-PAL and E-Hitz databases was calculated the sets of pseudowords were matched based on this measure. This way, neutral pseudowords had an overall mean bigram frequency similar to that of Spanish-marked pseudowords when measured according to the Spanish statistics, and similar to that of Basque-marked pseudowords when measured according to the Basque statistics. This ensured that neutral pseudowords were equally legal in both languages when position-dependent and length-dependent measures were taken into account. Furthermore, the number of orthographic neighbours in Spanish and Basque were controlled to be similar for neutral pseudowords and for marked pseudowords (see Table 2).

Table 2. *Descriptive statistics of characteristics of the materials*

	Neutral pseudowords	Spanish-marked pseudowords	Basque-marked pseudowords
Length	5.88 (1,46)	6.11 (1,35)	6.11 (1,54)
Neighbors in Spanish	1.75 (2,49)	0.35 (1,19)	1.91 (2,19)
Neighbors in Basque	1.6 (2,15)	1.64 (2,67)	0.2 (0,69)
Mean bigram frequency in Basque	2.06 (0,35)	0.68 (0,29)	2.10 (0,29)
Mean bigram frequency in Spanish	2.24 (0,54)	2.25 (0,52)	0.91 (0,39)
Illegal bigram frequency in Basque	0 (0)	1.31 (0,51)	0 (0)
Illegal bigrams frequency in Spanish	0 (0)	0 (0)	1.37 (0,61)

Note. Values reported are means and standard deviation in parenthesis on word length (number of letters), orthographic neighbours (number of words that share all letters but one), mean bigram frequency (position- and length-dependent mean bigram frequency as extracted by B-PAL and E-HITZ), and illegal bigrams (extracted from total counts of the LEXESP and SILLABARIUM databases).

Participants were tested individually in a quiet room within the educational institution by a trained research assistant who accompanied them during the course of the whole language learning process. The same computer was used at all test moments in order to avoid any hardware-related differences across sessions. The experiment was programmed in Experiment Builder (SR Research, Ontario). The start of each trial was marked by a fixation cross appearing in the middle of the screen for 500 ms, immediately followed by the target word for 3000 ms or until participants' response. At the beginning of the task, participants performed some trials as practice. They were instructed to decide whether the string of letters appearing on the screen could belong to Spanish or Basque (i.e., forced-choice), and to do so as fast as possible. Participants were asked to press one out of two buttons in a handheld controller to indicate whether each string could belong to Spanish or Basque. Participants were informed that none of the strings appearing on the screen were real words. Participants were asked to perform this task before (T1) and after (T2) the first academic year, and one year later (T3).

Data analysis

Accuracy and reaction times were collected, and all statistical analyses were carried out in the statistical environment R (R core team, 2013). Before data analysis, responses below 200 ms (0.01 %) and timeouts (0.04%) were excluded. Also, responses that deviated 3.5 standard deviations above and below the mean from all within-subjects (1.05% of outliers) or within-items (0.43% of outliers) factors were excluded from the analyses, leading to a final rejection of 1.33% of the data.

Accuracy was analyzed with logistic mixed-effects models and reaction times with linear mixed-effects models (Baayen, Davidson, & Bates, 2008; Barr, 2013; Jaeger, 2008), using lme4 package for R (Bates, Mächler, Bolker, & Walker, 2015). We first fitted maximal random structure models. When the data did not support the execution of the maximal model random structure, we then reduced the model complexity in order to arrive at a parsimonious model. To do so, we computed principal component analyses (PCA) of the random structure (see Bates et al., 2015), and then kept the number of principal components that cumulatively accounted for 100% of the variance. Type-III Anova Wald-tests was obtained to assess the significance of fixed effects for binary data, and Type-III Anova F-tests with Satterwhite approximations to degrees of freedom were obtained for response latency analysis. Averaged reaction times and accuracy rates per condition are presented in Table 3. Considering that decisions made on neutral pseudowords cannot be characterized as correct or incorrect responses in the absence of language cues, response latencies for these items were modelled by the type of response. The response tendency was based on the given response of the participants, being dummy coded as '1' if participants responded Spanish and '0' if they responded Basque (see Table 3). In contrast, in the case of marked pseudowords, the percentage of correct responses was analyzed based on the presence of language cues, and reaction times were analysed using only correct answers (see Table 3).

First, we investigated whether Type of Markedness (Neutral, Spanish-marked, Basque-marked) and Test Moment (T1, T2, T3) had an overall impact on participants' language choice.

Then, we analysed marked and neutral pseudowords separately, given the low proportion of “other" language choices for marked conditions (i.e., Spanish-marked pseudowords and Basque-marked pseudowords were correctly categorised as Spanish and Basque, respectively, more than 90% of the cases; see Table 3). Note also that responses for neutral pseudowords cannot be categorized as correct or incorrect responses for obvious reasons. Thus, response latencies for neutral psuedowords were analysed including Test Moment (T1, T2, T3) and Response Type (Spanish, Basque) as predictors. Reaction times and accuracy data of marked pseudowords was analysed including Test Moment (T1, T2, T3) and Type of Markedness (Basque-marked, Spanish-marked) as predictors.

Table 3. *Descriptive statistics for the language decision task in the three different test moments (T1, T2 and T3). The values reported correspond to the means and standard deviations (in parenthesis) of the accuracy rates (% of hits) and of the reaction times (in milliseconds).*

	Marked		**Neutral**	
ACCURACY	Basque	Spanish	Basque tendency	Spanish tendency
T1	92.44 (26.45)	91.12 (28.46)	32.36 (20.56)	67.64 (46.81)
T2	94.33 (23.14)	94.72 (22.38)	28.03 (18.79)	71.97 (44.94)
T3	93.2 (25.18)	91.74 (27.54)	28.04 (21.38)	71.96 (44.95)
REACTION TIMES	Basque	Spanish	Basque tendency	Spanish tendency
T1	873 (296)	1003 (446)	1295 (559)	1050 (454)
T2	897 (306)	953 (380)	1269 (526)	1029 (467)
T3	883 (283)	898 (297)	1276(519)	1014 (441)

Results

Overall response choices

First, we analyzed the tendency of Spanish responses based on Type of Markedness (Spanish-marked, Basque-marked, and Neutral) across Test Moments (T1, T2, and T3). Analyses revealed a main effect of language markedness [$\chi^2(2)= 199.72$, $p<.001$], such that the tendency of Spanish responses was higher for Spanish-marked pseudowords as compared to neutral pseudowords [b=2.32, SE=0.44, z=5.23, p<.001], and for neutral pseudowords as compared to

Basque-marked pseudowords [b=5.25, SE=0.42, z=12.55, p<.001]. We did not find a significant main effect of the Test Moment [$\chi^2(2)=2.63$, p=.275]. The interaction between Type of Markedness and Test Moment was significant [$\chi^2(4)=13.03$, p=.01]. However, post-hoc analyses revealed no significant differences across Test Moment for neutral (all ps>.26), Basque-marked (all ps>.40), or Spanish-marked pseudowords (all ps>.21).

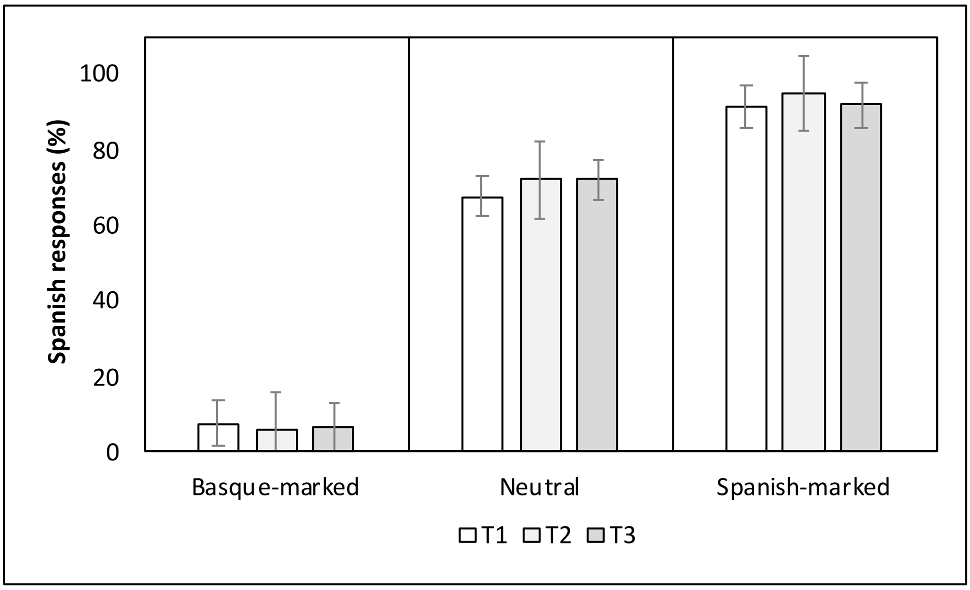

Figure 1. Percentage of Spanish responses to Basque-marked, neutral, and Spanish-marked pseudowords before language learning (T1), after one year of language learning (T2), and after two years (T3). Error bars represent ±1 standard error (SE) of the mean.

Neutral pseudowords

Analysis of the reaction times on neutral pseudowords based on the Response (Spanish, Basque) and Test Moment (T1, T2, T3) showed that participants were faster at classifying neutral pseudowords as Spanish (see Figure 2) than Basque [F(1,22.02)=10.14, p=.004; b=125.84, SE=39.53]. The main effect of Test Moment [F(2,19.99)=0.05, p=.95] and the interaction between Test Moment and Response [F(2,2202.14)=2.07, p=.13] were not significant.

Marked pseudowords

The analysis of congruent language selection responses based on the presence of Type of Markedness (Spanish-marked, Basque-marked) across Test Moments did not reveal any significant main effect or interaction (all ps > .12). Overall accuracy ratings were already close to ceiling at T1 for both the Spanish-marked and Basque-marked items (see Table 3).

Analyses of reaction times on marked pseudowords revealed a main effect of Type of Markedness [$F(1,36.3)=6.46$, $p=0.02$], indicating that participants were overall slower at detecting Spanish-marked than Basque-marked pseudowords [b=90.25, SE=35.51; see Figure 2]. The main effect of Test Moment was not significant [$F(2,19)=.83$, $p=.45$]. Importantly, a significant interaction was found between Type of Markedness and Test Moment [$F(2,4778)=20.89$, $p<.001$]. Planned comparisons revealed that whilst in T1 participants were significantly slower at responding to Spanish-marked pseudowords as compared to Basque-marked pseudowords [i.e., markedness effect; b=155.73, SE=36.97, $t(42.6)=4.21$, $p<.001$], this difference diminished after language learning [T2: b=67.81, SE= 436.90, $t(42.3)=1.84$, $p=.07$; T3: 47.21, SE=36.995, $t(42.7)=1.28$, $p=.21$]. This reduction of the markedness effect over the different test moments was due to an overall reduction in response latencies to Spanish-marked pseudowords [b=96.31, SE=41.19, $t(20.9)=2.34$, $p=.03$], whilst Basque-marked pseudoword response latencies remained constant [b=-12.21, SE=41.13, $t(20.7)=-.30$, $p=.77$].

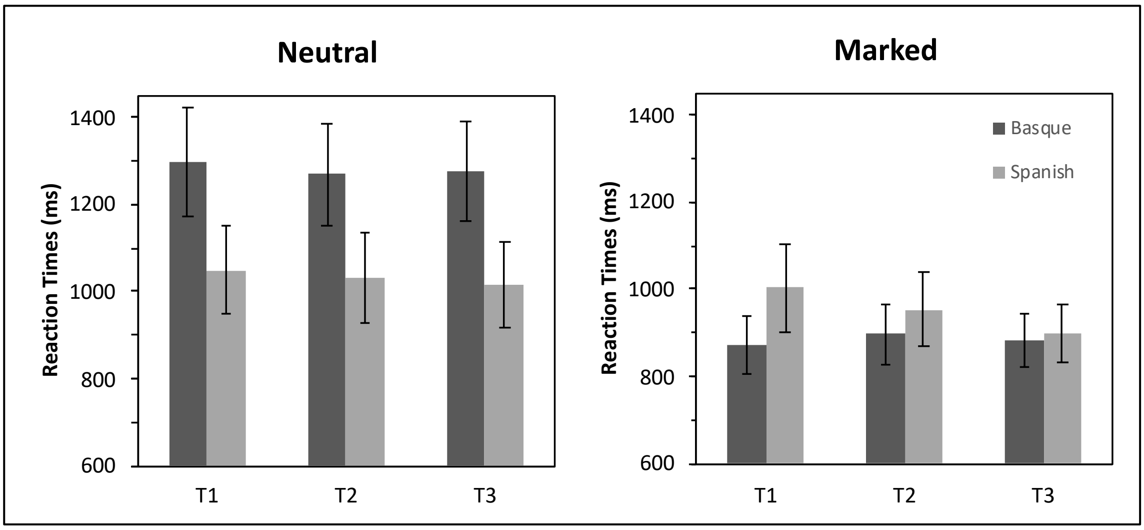

Figure 2. Bar plots depicting participants' response latencies in the language decision task for neutral (left) and marked (right) pseudowords in T1, T2, and T3. For neutral pseudowords, all Basque (dark grey) and Spanish (light grey) responses are included. For marked pseudowords, only responses congruent with the marked type are included. Error bars represent ±1 standard error (SE) of the mean.

Discussion

The present longitudinal study investigated changes in orthotactic sensitivity in a group of older Spanish monolingual adults before and after they learned Basque. Our results confirmed previous findings showing that older adults were highly sensitive to orthotactic markedness in Basque, as shown by their faster reaction times when responding to Basque-marked words (Casaponsa et al., 2014; Duñabeitia, Ivaz, & Casaponsa, 2016; Oganian, Conrad, Aryani, Heekeren, & Spalek, 2016). This sensitivity to L2 markedness was shown even before participants learned Basque, and it persisted during the learning process. However, and more importantly, we also found that participants demonstrated increased sensitivity to orthotactic markedness in their native language after learning a second language, evidenced by faster reaction times. This strongly suggests that sensitivity to native orthotactics changes due to the accommodation of newly acquired regularities from a second language.

As shown in the current study, before and after learning a second language, the presence of language-specific orthotactic cues guides and aids language classification. Our participants were able to easily classify Basque-marked and Spanish-marked pseudowords as Basque and Spanish, respectively, despite their complete lack of Basque knowledge. However, when participants classified seemingly neutral pseudowords without language-specific orthotactic cues, they showed a strong preference to classify them as belonging to their native language, Spanish. This effect was also accompanied by faster reaction times for the neutral pseudowords which they deemed to be Spanish. One possible explanation for this finding is that readers consider familiar orthotatic patterns to be part of their previous knowledge. In line with this assumption, previous research (Ellis & Beaton, 1993) has shown that people prefer to learn letter sequences that follow sequences found in their native language, suggesting they have a preference for patterns that follow or align with the L1 orthotactic rules.

In general terms, participants showed high sensitivity levels to orthographic markedness, responding significantly faster to marked than to neutral pseudowords in both languages, both before and during second language learning. Even though older adults were equally accurate at detecting Spanish-marked as they were at detecting Basque-marked pseudowords, they responsed more quickly to Basque-marked pseudowords. However, this was only true in the T1, when they had not yet learned Basque. This suggests that before learning the second language, participants could easily realize that Basque-marked pseudowords did not conform to the L1 orthotactic regularities. These results are in line with previous findings showing that even monolinguals are very sensitive to letter sequences that violate the orthotactic rules of their native language (Casaponsa et al., 2014; Casaponsa & Duñabeitia, 2016; Oganian, Conrad, Aryani, Heekeren, & Spalek, 2016).

While the finding of an inherent sensitivity of monolinguals to detect strings that deviate from the orthotactic standards set by the orthographic distributional properties of the native language is not a trivial one, other findings provide additional insights regarding the dynamic nature of the orthographic system. Interestingly, results from the two other test moments (T2 and T3) suggest that the probabilistic distribution of regularities in the native language changes. While accuracy in detecting the language of marked pseudowords remained very high and relatively constant across the three test moments, the analysis of reaction times showed significant variations depending on the type of pseudowords. Basque-marked pseudowords were detected equally fast across the three test moments, but reaction times to Spanish-marked pseudowords decreased significantly as a function of increased exposure to the new language. It could be tentatively argued that this reduction in reaction times associated with Spanish-marked pseudowords could be associated with a change in the response strategy. In a first test moment, participants could have had carefully evaluated if the pseudowords belonged to Spanish by assessing their degree of similarity with known Spanish words, and then stop using this strategy once they became familiar with the task, resulting in faster reaction times across sessions. However, this may not seem to be a valid explanation that fits all the data, since if this were the case, participants would have shown faster responses over time for all types of pseudowords. We believe that similar automatic sub-lexical and lexical competition and selection mechanisms guided participants' responses in the three test sessions, as predicted by current bilingual interactive activation models.

Hence, the current pattern could be readily accounted for by bilingual word identification models that predict different processing mechanisms as a function of the sub-lexical characteristics of the items (i.e., see BIA+ extended, Van Kesteren et al., 2015; see also BIA+ S, Casaponsa et al., 2020). In the case of neutral words, responses were mainly influenced by the formal similarity with existing lexical entries from the native language lexicon, consequently leading to faster Spanish choices compared to Basque choices (see Figure 2). Not surprisingly, responses to neutral pseudowords were heavily influenced by the native language even after learning Basque, leading to similar choices and response latencies across sessions. It should be noted in this regard that the general level of L2 achieved was admittedly low (namely, A1 level of CEFR), and accordingly the degree of L2 lexical consolidation was low too. In this line, Casaponsa, Antón, Pérez and Duñabeitia (2015) showed that at A1 levels, the speed of response to L2 words is indeed heavily influenced by L1 knowledge, coinciding with the findings of the current study. In the case of marked pseudowords, the mechanisms that underlie language identification differ for Spanish-like and Basque-like strings. On the one hand, responses to Basque-marked pseudowords were mainly driven by the earliest stages of orthographic processing, leading to faster reaction times as compared to Spanish-marked pseudowords. Importantly, these decisions were not affected by L2 proficiency, leading to similar reaction times across sessions (see Casaponsa et al., 2014, for similar results; see also BIA+S, Casaponsa et al., 2020). On the other hand, responses to Spanish-marked pseudowords appeared to be less mediated by sub-lexical stages of processing and more mediated by lexical search routines at initial stages of language learning, resulting in significantly slower reaction times at T1. We suggest that the reliance on specific L1 and L2 orthotactic information progressively increased as participants learned Basque, and that the response criteria for Spanish-marked pseudowords shifted from a lexical search at T1 to a sub-lexical strategy at T2 and T3, allowing participants to speed up their language decision process for strings that violated L2 orthotactics.

This account fits well with current bilingual interactive activations models that include sub-lexical language nodes (see BIA+ extended, Van Kesteren et al., 2015; see also BIA+S, Casaponsa et al., 2019). These accounts predict that the activation of the sub-lexical language nodes due to the presence of language-specific sub-lexical cues will speed up language decision processes once the orthotactic rules of the first and the second language are integrated in the system. In the absence of sub-lexical language cues, the language decision process would be guided by lexical language nodes, and hence influenced by lexical competition and selection mechanisms. Thus, the current results fit well with these accounts, and they suggest that participants developed increased sensitivity to orthotactic regularities specific to their native language as a function of second language learning. This finding is particulary interesting as it suggests that learning a second language changes the sensitivity to the orthotactics of the native language (see also Casaponsa et al., 2014, suggesting that bilinguals' sensitivity to markedness changes as a function of proficiency).

Learning a language implies, among many other things, integrating new words within the set of existent representations of the native language. Therefore, while learning a second language, people also learn the similarities and differences between the to-be-incorporated words and the already known ones. The construction of the orthotactic repertoire is thus an automatic and spontaneous parallel process that takes place as a result of visual word processing. Learners need to implicitly acquire new orthotactic regularities and compare these with already known (native) patterns in order to make links between the new and the existing pieces of information. Thus, it seems plausible that as readers compare the new patterns with the old ones, they become more sensitive to the specificities of the old ones, consequently perceiving native orthotatic regularities differently. In other words, we propose that after learning a second language, readers may be better able to detect strings with native language-specific cues due to increased saliency as pieces of orthotactic information that contrast with the newly acquired language.

The idea that the native language may be permeable challenges the assumption that the L1 remains static over time. Whilst the second language can be influenced by native language processing (Frenck-Mestre & Pynte, 1997; Hernandez et al., 1994; Segalowitz, 1991), the native language itself has been typically considered as relatively impermeable and immutable. However, results in this study suggest that L1 orthotactic sensitivity changes while learning a second language. The idea that bilinguals' whole linguistic system displays adaptive changes was already proposed by Kroll, Dussias, Bice, and Perrotti (2015; see also Dussias and Sagarra, 2007). They hypothesized that the linguistic system is permeable in both languages, especially when high proficiency in L1 is achieved. The idea of native language changes pursuant to language learning fits well with preceding studies suggesting that learning new words and grammar interacts with the existing language in a dynamic way, changing the linguistic system as a whole (Baus et al., 2013; Chang, 2013; Kartushina, Frauenfelder, & Golestani, 2016; Linck, Kroll, & Sunderman, 2009). Following these premises, our results demonstrate that changes in the linguistic system due to L2 learning can emerge even when the malleability of the native language is presumably at its lowest. By means of testing older samples over a period of two years of language learning, we were able to show that lifelong exposure to a unique language system (namely, the native language), does not eliminate permeability to the properties of a new language. Furthermore, our results suggest that the sub-lexical mechanisms underpinning second language learning across the lifespan are relatively stable and qualitatively similar for old and young learners. Similar to young adults (see Oganian et al., 2016), older learners successfully rely on the acquisition of implicit knowledge when learning a second language, focusing on the statistical regularities of the sub-lexical units of their languages.

Taken together, the present results support the view that the native language is permeable and changes during second language learning. Specifically, learning a new language that does not share native language orthotactics can change the perception of orthotactics in the native language already at early stages of L2 acquisition. Future research should explore what other aspects of the native language may change as consequence of second language learning, and correctly characterize the stages and rythms at which these changes take place. This research will lead to a better understanding of the relationship between the native language and the multiligual linguistic system.

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