

# 1            Incidental changes in orthographic processing in the native 2            language as a function of learning a new language late in life

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## 12        **Abstract**

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

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## 32        **Keywords**

33        Orthotactics; orthographic regularities; markedness; second language learning.  
34

## 36 Introduction

37 Learning a new language not only involves acquiring new vocabulary, grammar,  
38 phonology and syntactic rules, but also acquiring the implicit statistical probabilities regarding  
39 the new language's orthographic structure, such as orthotactics. Orthotactics are the patterns  
40 of grapheme combinations in written words (see Conway, Bauernschmidt, Huang, & Pisoni,  
41 2010; Krogh, Vlach, & Johnson, 2013), and they are learned implicitly by extracting the sub-  
42 lexical regularities of words. People become sensitive to these regularities even after little  
43 exposure to printed words (Chetail & Content, 2017), developing a high sensitivity to letter  
44 sequences belonging to one's language (Miller, Bruner, & Postman, 1954; Owsowitz, 1963).

45 When readers are exposed to one or several languages, they pick up statistical  
46 orthotactic regularities in an unconscious manner, and these seemingly automatically extracted  
47 patterns guide ulterior language processing. For instance, a Spanish-English bilingual **can easily**  
48 **detect** that the word *txerri* (the Basque word for pig) is neither an English **nor a** Spanish word  
49 solely on the basis of the statistical orthotactic regularities of its constituents, since the bigram  
50 *tx* is not present in **the English or Spanish vocabulary. Hence, native speakers of English or**  
51 **Spanish do not need to know the meaning of *txerri*, or have any knowledge of Basque, in order**  
52 **to decide that this word does not belong to their native languages.** When we learn a second  
53 language (L2) with an alphabet that maps onto our native one, a similar process of extracting  
54 statistical orthotactic regularities takes place (Bordag, Kirschenbaum, Rogahn, & Tschirner,  
55 2017; Comesaña, Soares, Sánchez-Casas, & Lima, 2012). Thus, it seems plausible that as we  
56 become more proficient in a second language, the new statistical regularities would be better  
57 integrated within the preexisting set, leading to a change in our sensitivity to them. In other  
58 words, it seems reasonable to predict that the general sensitivity to the orthotactics of both first  
59 and second language would change once the new regularities have entered into the system.  
60 With this in mind, this study aims to investigate how learning a second language could change  
61 the sensitivity to statistical orthotactic regularities from both languages.

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

77 Results from monolingual and bilingual samples thus suggest that orthotactic processing  
78 occurs at an early, semantics-free stage of visual word recognition. Consequently, language  
79 attribution mechanisms triggered by orthotactic patterns appear to take place at a sub-lexical  
80 level, before access to lexical and semantic representations (see BIA+ extended model, Van  
81 Kesteren, Dijkstra, & de Smedt, 2012; see also BIA+ S model, Casaponsa, Thierry, & Duñabeitia,  
82 2020). Studies exploring the influence of sub-lexical orthographic cues on event-related  
83 potential (ERP) patterns related to automatic and unconscious processing of language switches  
84 corroborate this idea (e.g., Casaponsa, Carreiras, & Duñabeitia, 2015; Casaponsa, Thierry, &  
85 Duñabeitia, 2020; Hoversten, Brothers, Swaab, & Traxler, 2017). Therefore, it seems plausible  
86 that sub-lexical factors such as orthotactic distinctiveness play a key role in determining the

87 language of words **during visual word recognition** (see also Oganian, Conrad, Aryani, Heekeren,  
88 & Spalek, 2016; Vaid & Frenck-Mestre, 2002). And, in the absence of additional contextual cues,  
89 multilingual single word recognition is a process that initially requires a fast-acting language  
90 detection mechanism. Consequently, orthotactics should have a direct **impact** in second  
91 language learning **through** correct **and efficient** language categorization.

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

104           **While L2 language learning abilities can extend beyond young adulthood**, the malleability of  
105 the native language as a function of the acquisition of a new language seems to diminish with  
106 increasing age (Macwhinney, 2007; Schmid & Köpke, 2017). In spite of the cognitive decline  
107 associated with ageing (Harris et al., 2009), language learning can effectively take place late in  
108 life ( see Antoniou & Wright, 2017; Ramos, Fernández García, Antón, Casaponsa, & Duñabeitia,  
109 2017; Ware et al., 2017). The question of interest **here** is whether L2 acquisition late in life  
110 impacts L1 orthotactic structure. Thus, the present study **focuses** on older adults as a critical test  
111 group. **It is worth noting that the sensitivity to violations of the orthotactic rules of the first and**

112 second language has already been shown in younger bilingual adults to certain extent (Oganian,  
113 Conrad, Aryani, Spalek, & Heekeren, 2015), suggesting that L2 learning might have an impact in  
114 L1 orthotactics. However, it is unclear whether similar L1 changes can be observed in older  
115 populations, when presumably the resistance to change and stability of L1 is at its peak, and the  
116 malleability and plasticity of the language system is at its lowest.

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

128

## 129 **Methods**

### 130 *Participants*

131 Thirty retired Spanish monolingual adults took part in this longitudinal experiment.  
132 However, only twenty participants remained through the two year sessions (8 females; mean  
133 age = 66.57; SD = 5.56). All participants were living in the Basque Country, a Spanish region with  
134 two coexisting co-official languages, Spanish and Basque. None of the participants had prior  
135 knowledge of Basque, neither could they understand or produce linguistic structures in any

136 other language than Spanish (see below). All participants reported having normal or corrected-  
137 to-normal vision, and none of them had any history of chronic neuropsychological disorders.

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

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

155  
156 At the beginning of the first academic year, all participants completed a general  
157 assessment consisting of a series of cognitive and language proficiency tasks. Age-related  
158 cognitive functioning was assessed using the Spanish version of the Mini-Mental State  
159 Examination (MMSE; see Lobo, Ezquerra, Gómez, Sala, & Seva, 1979). Participants' linguistic  
160 profile before learning Basque was characterized via self-report measures of proficiency, and all  
161 participants were asked to rate their knowledge of Spanish and Basque on a scale from 1 to 10

162 (see Table 1). Also, teachers evaluated participants' Basque proficiency based on their own  
 163 perception before the lessons started, ensuring that they did not have previous knowledge of  
 164 Basque . Self- and teacher-perceived Basque proficiency levels were also assessed at the end of  
 165 the learning process, together with additional objective measures of Basque knowledge. As  
 166 **objective measures of language learning**, participants completed a picture naming test (de Bruin,  
 167 Carreiras, & Duñabeitia, 2017) in which participants had to name sixty-five common names in  
 168 Basque (see Table 1), and **the** beginner language test (A1 level) of the Common European  
 169 Framework for Reference (CEFR, Council of Europe, 2011), with a maximum score of 20.

170

171 Table 1. *Descriptive statistics of the assessment*

<b><i>Before Basque lessons</i></b>	
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
<b><i>After Basque lessons</i></b>	
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)

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

175

176

177 *Materials and procedure*

178 First, a corpus of bigrams was constructed with the Spanish words from the B-PAL (Davis  
 179 & Perea, 2005) and Basque words from the E-HITZ (Perea et al., 2006) databases, and filtered  
 180 with the items contained in the SYLLABARIUM database (Duñabeitia, Cholin, Corral, Perea, &  
 181 Carreiras, 2010). Words that contained letters that do not exist in the other language were  
 182 removed (e.g., c, ñ, v). **Bigrams that did not appear in any form in the other language were**  
 183 **considered *illegal* and were selected for the construction of the marked pseudowords. Bigrams**

184 were considered *neutral* in both languages if they had a frequency of appearance of at least 10  
185 times in different words of each database. One hundred and thirty-five pseudowords were  
186 generated with the help of Wuggy (Keuleers & Brysbaert, 2010), manipulating the presence or  
187 absence of distinctive bigrams of each language. Forty-five of these pseudowords were Spanish-  
188 marked items, forty-five were Basque-marked items, and forty-five were language-neutral  
189 pseudowords. Marked pseudowords were created making sure that at least one of the  
190 constituent bigrams violated the orthotactics of the other language. For instance, *'txamur'* is  
191 considered a Basque-marked pseudoword because the bigram 'tx' does not exist in Spanish  
192 (namely, the 'tx' bigram has a frequency of use of 0 in Spanish). On the other hand, *neutral*  
193 pseudowords were created using bigrams that were plausible in both languages, such as the  
194 bigram 'rd' that exists in words such as *cerdo* (the Spanish word for pig), or *ardi* (the Basque  
195 word for sheep). Those neutral bigrams were controlled to have equal mean frequency of use in  
196 Spanish and Basque,  $t(44)=0.03$ ,  $p = .976$ , Cohen's  $d=.033$  (see Table 2). *The position- and length-*  
197 *dependent mean bigram frequency of each pseudoword as provided by B-PAL and E-Hitz*  
198 *databases was calculated the sets of pseudowords were matched based on this measure. This*  
199 *way, neutral pseudowords had an overall mean bigram frequency similar to that of Spanish-*  
200 *marked pseudowords when measured according to the Spanish statistics, and similar to that of*  
201 *Basque-marked pseudowords when measured according to the Basque statistics. This ensured*  
202 *that neutral pseudowords were equally legal in both languages when position-dependent and*  
203 *length-dependent measures were taken into account.* Furthermore, the number of orthographic  
204 neighbours in Spanish and Basque were controlled to be similar for neutral pseudowords and  
205 for marked pseudowords (see Table 2).

206

207

208



209

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

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

211 *Note.* Values reported are means and standard deviation in parenthesis on word length (number of letters), orthographic  
 212 neighbours (number of words that share all letters but one), mean bigram frequency (position- and length-dependent mean  
 213 bigram frequency as extracted by B-PAL and E-HITZ), and illegal bigrams (extracted from total counts of the LEXESP and  
 214 SILLABARIUM databases).  
 215

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

229

230 *Data analysis*

231 Accuracy and reaction times were collected, and all statistical analyses were carried out  
232 in the statistical environment R (R core team, 2013). Before data analysis, responses below 200  
233 ms (0.01 %) and timeouts (0.04%) were excluded. Also, responses that deviated 3.5 standard  
234 deviations above and below the mean from all within-subjects (1.05% of outliers) or within-  
235 items (0.43% of outliers) factors were excluded from the analyses, leading to a final rejection of  
236 1.33% of the data.

237 Accuracy was analyzed with logistic mixed-effects models and reaction times with linear  
238 mixed-effects models (Baayen, Davidson, & Bates, 2008; Barr, 2013; Jaeger, 2008), using lme4  
239 package for R (Bates, Mächler, Bolker, & Walker, 2015). We first fitted maximal random  
240 structure models. When the data did not support the execution of the maximal model random  
241 structure, we then reduced the model complexity in order to arrive at a parsimonious model. To  
242 do so, we computed principal component analyses (PCA) of the random structure (see Bates et  
243 al., 2015), and then kept the number of principal components that cumulatively accounted for  
244 100% of the variance. Type-III Anova Wald-tests was obtained to assess the significance of fixed  
245 effects for binary data, and Type-III Anova F-tests with Satterwhite approximations to degrees  
246 of freedom were obtained for response latency analysis. Averaged reaction times and accuracy  
247 rates per condition are presented in Table 3. Considering that decisions made on neutral  
248 pseudowords cannot be characterized as correct or incorrect responses in the absence of  
249 language cues, response latencies for these items were modelled by the type of response. The  
250 response tendency was based on the given response of the participants, being dummy coded as  
251 '1' if participants responded Spanish and '0' if they responded Basque (see Table 3). In contrast,  
252 in the case of marked pseudowords, the percentage of correct responses was analyzed based  
253 on the presence of language cues, and reaction times were analysed using only correct answers  
254 (see Table 3).

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

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

266

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

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

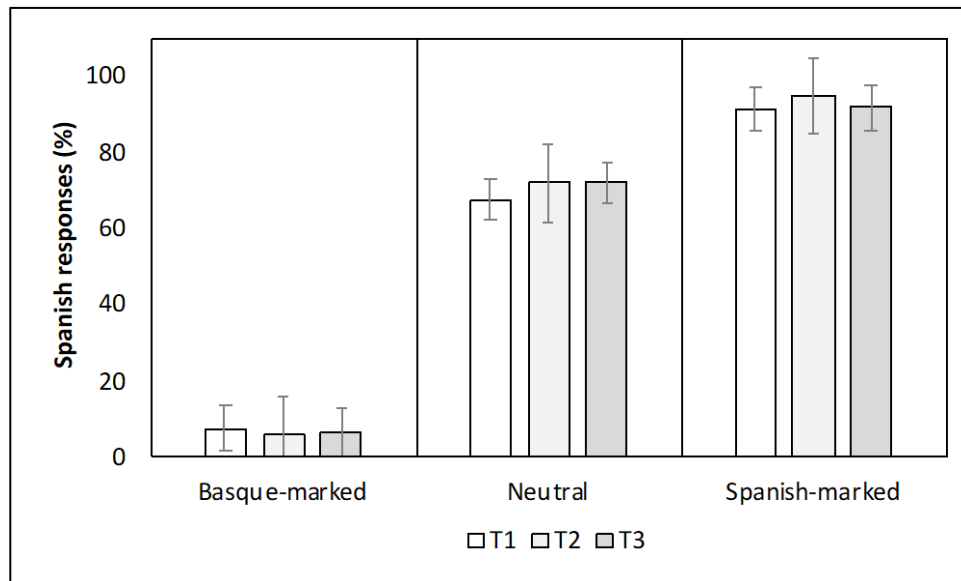
270

## 271 Results

### 272 Overall response choices

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

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



283

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

287

288 *Neutral pseudowords*

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

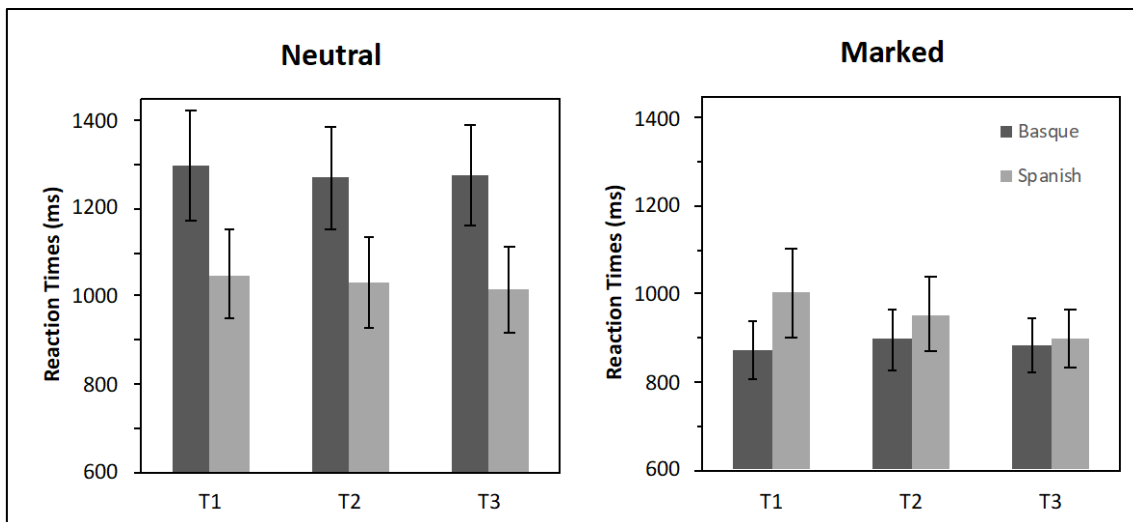
295

296 *Marked pseudowords*

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

301           Analyses of reaction times on marked pseudowords revealed a main effect of Type of  
302 Markedness [ $F(1,36.3)=6.46, p=0.02$ ], indicating that participants were overall slower at  
303 detecting Spanish-marked than Basque-marked pseudowords [ $b=90.25, SE=35.51$ ; see Figure 2].  
304 The main effect of Test Moment was not significant [ $F(2,19)=.83, p=.45$ ]. Importantly, a  
305 significant interaction was found between Type of Markedness and Test Moment  
306 [ $F(2,4778)=20.89, p<.001$ ]. Planned comparisons revealed that whilst in T1 participants were  
307 significantly slower at responding to Spanish-marked pseudowords as compared to Basque-  
308 marked pseudowords [i.e., markedness effect;  $b=155.73, SE=36.97, t(42.6)=4.21, p<.001$ ], this  
309 difference diminished after language learning [T2:  $b=67.81, SE= 436.90, t(42.3)=1.84, p=.07$ ; T3:  
310  $47.21, SE=36.995, t(42.7)=1.28, p=.21$ ]. This reduction of the markedness effect over the  
311 different test moments was due to an overall reduction in response latencies to Spanish-marked  
312 pseudowords [ $b=96.31, SE=41.19, t(20.9)=2.34, p=.03$ ], whilst Basque-marked pseudoword  
313 response latencies remained constant [ $b=-12.21, SE=41.13, t(20.7)=-.30, p=.77$ ].

314



315 **Figure 2.** Bar plots depicting participants' response latencies in the language decision task for  
 316 neutral (left) and marked (right) pseudowords in T1, T2, and T3. For neutral pseudowords, all  
 317 Basque (dark grey) and Spanish (light grey) responses are included. For marked pseudowords,  
 318 only responses congruent with the marked type are included. Error bars represent  $\pm 1$  standard  
 319 error (SE) of the mean.  
 320  
 321

## 322 Discussion

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

334 As shown in the current study, before and after learning a second language, the  
 335 presence of language-specific orthotactic cues guides and aids language classification. Our

336 participants were able to **easily** classify Basque-marked and Spanish-marked pseudowords as  
337 Basque and Spanish, respectively, despite their complete lack of Basque knowledge. However,  
338 when participants classified seemingly neutral pseudowords without language-specific  
339 orthotactic cues, they showed a strong preference to classify them as belonging to their native  
340 language, Spanish. This effect was also accompanied by faster reaction times for the neutral  
341 pseudowords which they deemed to be Spanish. One possible explanation for this finding is that  
342 readers consider familiar orthotactic patterns to be part of their previous knowledge. In line with  
343 this assumption, previous research (Ellis & Beaton, 1993) has shown that people prefer to learn  
344 letter sequences that follow sequences found in their native language, suggesting they have a  
345 preference for patterns that follow or align with the L1 orthotactic rules.

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

357 While the finding of an inherent sensitivity of monolinguals to detect strings that deviate  
358 from the orthotactic standards set by the orthographic distributional properties of the native  
359 language is not a trivial one, other findings provide additional insights regarding the dynamic  
360 nature of the orthographic system. Interestingly, results from the two other test moments (T2

361 and T3) suggest that the probabilistic distribution of regularities in the native language changes.  
362 While accuracy in detecting the language of marked pseudowords remained very high and  
363 relatively constant across the three test moments, the analysis of reaction times showed  
364 significant variations depending on the type of pseudowords. Basque-marked pseudowords  
365 were detected equally fast across the three test moments, but reaction times to Spanish-marked  
366 pseudowords decreased significantly as a function of increased exposure to the new language.  
367 It could be tentatively argued that this reduction in reaction times associated with Spanish-  
368 marked pseudowords could be associated with a change in the response strategy. In a first test  
369 moment, participants could have had carefully evaluated if the pseudowords belonged to  
370 Spanish by assessing their degree of similarities with known Spanish words, and then stop using  
371 this strategy once they became familiar with the task, resulting in faster reaction times across  
372 sessions. However, this may not seem to be a valid explanation that fits all the data, since if this  
373 were the case, participants would have shown faster responses over time for all types of  
374 pseudowords. We believe that similar automatic sub-lexical and lexical competition and  
375 selection mechanisms guided participants' responses in the three test sessions, as predicted by  
376 current bilingual interactive activation models.

377 Hence, the current pattern could be readily accounted for by bilingual word  
378 identification models that predict different processing mechanisms as a function of the sub-  
379 lexical characteristics of the items (i.e., see BIA+ extended, Van Kesteren et al., 2015; see also  
380 BIA+ S, Casaponsa et al., 2020). In the case of neutral words, responses were mainly influenced  
381 by the formal similarity with existing lexical entries from the native language lexicon,  
382 consequently leading to faster Spanish choices compared to Basque choices (see Figure 2). Not  
383 surprisingly, responses to neutral pseudowords were heavily influenced by the native language  
384 even after learning Basque, leading to similar choices and responses latencies across sessions. It  
385 should be noted in this regard that the general level of L2 achieved was admittedly low (namely,



386 A1 level of CEFR), and accordingly the degree of L2 lexical consolidation was low too. In this line,  
387 Casaponsa, Antón, Pérez and Duñabeitia (2015) showed that at A1 levels, the speed of response  
388 to L2 words is indeed heavily influenced by L1 knowledge, coinciding with the findings of the  
389 current study. In the case of marked pseudowords, the mechanisms that underlie language  
390 identification differ for Spanish-like and Basque-like strings. On the one hand, responses to  
391 Basque-marked pseudowords were mainly driven by the earliest stages of orthographic  
392 processing, leading to faster reaction times as compared to Spanish-marked pseudowords.  
393 Importantly, these decisions were not affected by L2 proficiency, leading to similar reaction  
394 times across sessions (see Casaponsa et al., 2014, for similar results; see also BIA+S, Casaponsa  
395 et al., 2020). On the other hand, responses to Spanish-marked pseudowords appeared to be less  
396 mediated by sub-lexical stages of processing and more mediated by lexical search routines at  
397 initial stages of language learning, resulting in significantly slower reaction times at T1. We  
398 suggest that the reliance on specific L1 and L2 orthotactic information progressively increased  
399 as participants learned Basque, and that the response criteria for Spanish-marked pseudowords  
400 shifted from a lexical search at T1 to a sub-lexical strategy at T2 and T3, allowing participants to  
401 speed up their language decision process for strings that violated L2 orthotactics.

402 This account fits well with current bilingual interactive activations models that include  
403 sub-lexical language nodes (see BIA+ extended, Van Kesteren et al., 2015; see also BIA+S,  
404 Casaponsa et al., 2019). These accounts predict that the activation of the sub-lexical language  
405 nodes due to the presence of language-specific sub-lexical cues will speed up language decision  
406 processes once the orthotactic rules of the first and the second language are integrated in the  
407 system. In the absence of sub-lexical language cues, the language decision process would be  
408 guided by lexical language nodes, and hence influenced by lexical competition and selection  
409 mechanisms. Thus, the current results fit well with these accounts, and they suggest that  
410 participants developed increased sensitivity to orthotactic regularities specific to their native

411 language as a function of second language learning. This finding is particularly interesting as it  
412 suggests that learning a second language changes the sensitivity to the orthotactics of the native  
413 language (see also Casaponsa et al., 2014, suggesting that bilinguals' sensitivity to markedness  
414 changes as a function of proficiency).

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

428         The idea that **the** native language may be permeable challenges the assumption that the  
429 L1 remains static over time. Whilst the second language can be influenced by native language  
430 processing (Frenck-Mestre & Pynte, 1997; Hernandez et al., 1994; Segalowitz, 1991), the native  
431 language itself has been typically considered as relatively impermeable and immutable.  
432 However, results in this study suggest that L1 orthotactic sensitivity changes while learning a  
433 second language. The idea that bilinguals' whole linguistic system displays adaptive changes was  
434 already proposed by Kroll, Dussias, Bice, and Perrotti (2015; see also Dussias and Sagarra, 2007).  
435 They hypothesized that the linguistic system is permeable in both languages, especially when

436 high proficiency in L1 is achieved. The idea of native language changes pursuant to language  
437 learning fits well with preceding studies suggesting that learning new words and grammar  
438 interacts with the existing language in a dynamic way, changing the linguistic system as a whole  
439 (Baus et al., 2013; Chang, 2013; Kartushina, Frauenfelder, & Golestani, 2016; Linck, Kroll, &  
440 Sunderman, 2009). Following these premises, our results demonstrate that changes in the  
441 linguistic system due to L2 learning can emerge even when the malleability of the native  
442 language is presumably at its lowest. By means of testing older samples over a period of two  
443 years of language learning, we were able to show that lifelong exposure to a unique language  
444 system (namely, the native language), does not eliminate permeability to the properties of a  
445 new language. Furthermore, our results suggest that the sub-lexical mechanisms underpinning  
446 second language learning across the lifespan are relatively stable and qualitatively similar for old  
447 and young learners. Similar to young adults (see Oganian et al., 2016), older learners successfully  
448 rely on the acquisition of implicit knowledge when learning a second language, focusing on the  
449 statistical regularities of the sub-lexical units of their languages.

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

458

459

460 **Acknowledgements**

461           This study was partially supported by grants RED2018-102615-T and PGC2018-097145-  
462 B-I00 from the Spanish Government, H2019/HUM-5705 from the Comunidad de Madrid, and  
463 by a fellowship from La Caixa foundation (ID 100010434, code LCF/BQ/ES16/11570003).

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