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► To cite this version:

Audrey Bürki, Pauline Welby, Mélanie Clément, Elsa Spinelli. Orthography and second language word learning: Moving beyond “friend or foe?”. *Journal of the Acoustical Society of America*, 2019, 145 (4), pp.EL265-EL271. 10.1121/1.5094923 . hal-02106593

HAL Id: hal-02106593

<https://hal.science/hal-02106593>

Submitted on 23 Apr 2019

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1 Orthography and second language word learning: Moving beyond “friend or foe?”

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24 Running title: Orthography and second language word learning

25

26 **Abstract**

27 French participants learned English pseudowords either with the orthographic form displayed
28 under the corresponding picture (Audio-Ortho) or without (Audio). In a naming task,
29 pseudowords learned in the Audio-Ortho condition were produced faster and with fewer
30 errors, providing a first piece of evidence that orthographic information facilitates the
31 learning and on-line retrieval of productive vocabulary in a second language. Formant
32 analyses, however, showed that productions from the Audio-Ortho condition were more
33 French-like (i.e. less target-like), a result confirmed by a vowel categorization task performed
34 by native speakers of English. It is argued that novel word learning and pronunciation
35 accuracy should be considered together.

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37

38 **Keywords**

39 speech production, vowels, L2 pronunciation, word learning, orthography

40

41 1. Introduction

42 Adult learners of a second language (L2) rarely attain native-like pronunciation. One factor
43 that may lead to non-target-like productions is exposure to the orthographic form of words.
44 Unlike children, who learn to understand and speak their native language (L1) years before
45 they learn to read, adult learners of an L2 often learn the written and spoken forms of words
46 together. However, the extent to which orthography influences performance in the L2 among
47 adult learners and which aspects of performance it influences, are far from settled questions.
48 The aim of the current study is to examine the influence of orthographic information on two
49 aspects of language production in L2: pronunciation accuracy and novel word form learning
50 (i.e. the ability to encode, access, and produce novel words). We concentrate on the case of
51 L1-L2 pairs with a common alphabetic writing system, since the additional issues raised by
52 the processing of unfamiliar writing systems are beyond the scope of the study.

53 The results of earlier studies paint a picture of a pervasive influence of L1 orthography on
54 pronunciation accuracy in L2. Observations of spurious “spelling pronunciations” among
55 language learners are common, and unsurprising, many studies have found that exposure to
56 orthography may lead to productions that are less target-like. For L1 Italian learners of
57 English, Bassetti and Atkinson (2015) found orthography effects on the pronunciation of
58 words with silent letters, vowels with digraphs versus singleton letters, and homophonous
59 words with different spellings. Bassetti (2017) found differences in the pronunciation of
60 English words with double versus single consonants by Italian learners (see also Rafat,
61 2016). Hayes-Harb *et al.* (2018) found an effect of L1 English orthography on the
62 pronunciation of German devoiced obstruents, as did Young-Scholten and Langer (2015) in
63 a study of learners in a natural immersion setting. In some cases, however, exposure to
64 orthographic forms can lead to productions that are *more* target-like. For example, in a
65 study of the production of assibilated/fricative rhotics of Spanish (e.g. [ř] in *ahumar*) by L1

66 English speakers, Rafat (2015) found that participants who both heard novel words and saw
67 their written forms produced more rhotic sounds, while those who did not see the written
68 form produced non-target-like fricatives (see also Erdener and Burnham, 2005, and Nimz
69 and Khattab, 2019).

70 A number of models have formalized the influence of the L1 phonological system on
71 the perception and subsequent categorization of sounds in the L2 input (e.g. Flege 1995, Best
72 and Tyler, 2007; see Rafat, 2016 for an overview). The pronunciation of L2 words should
73 reflect this phonemic categorization. None of these models, however, has integrated a role of
74 L1 orthography-induced phonological transfer. Best and Tyler (2007) do, however, raise the
75 possibility that the use of a common grapheme in L1 and L2 may lead to L2 learners
76 “equating” phoneme categories, even when their phonetic realizations are phonetically quite
77 different, e.g. rhotics represented by <r> in French [ʁ] and English [ɹ].

78 Importantly, however, pronunciation is only one component of word learning. In
79 order to produce words, speakers must first encode in long term memory novel labels (i.e.
80 phonological representations) and their associations with the corresponding concepts. To our
81 knowledge, the question of whether orthography influences the performance of L2 speakers
82 in production tasks has not yet been examined. According to the dominant view in
83 psycholinguistics, production and recognition/perception recruit distinct phonological
84 representations (see Kittredge and Dell, 2016, for recent evidence and a literature review).
85 Existing studies have all focused on receptive vocabulary¹ and thus their findings cannot be
86 taken to inform language production.

87 Ehri (2005) argues that knowledge of the alphabetical system allows readers to bond
88 spelling to pronunciation in memory when they encounter novel written words (see also Ehri
89 and McCormick, 1998). Research on L1 provides evidence that this orthographic information
90 benefits spoken-word learning in children. For example, Rosenthal and Ehri (2007) taught

91 second graders sets of novel English words. For half of these words, the orthographic form
92 was presented during learning, while for the other half, no orthographic information was
93 provided. In the test naming phase, words learned with the orthography were better recalled
94 than those learned without. The same results were obtained with fifth graders. In addition, for
95 this population, the contribution of orthographic information was greater for participants with
96 higher reading abilities. The dual-coding theory (Sadoski, 2005) also predicts better memory
97 for words learned with orthographic information: lexical representations become stronger
98 with each additional source of information. In the current study, we investigate whether the
99 benefit of orthographic information extends to adult learners of an L2.

100 We test the hypotheses that the presentation of the orthographic form along with the
101 auditory form 1. facilitates the learning of novel word forms and their retrieval from the
102 lexicon, and 2. leads to less nativelike pronunciation, if the critical grapheme-to-phoneme
103 correspondences (GTPCs) differ between L1 and L2. We focus on L1 speakers of French
104 learning novel L2 English pseudowords.

105 **2. Method**

106 *2.1 Participants*

107 Twenty-six undergraduate students (20 women; age: 18–26 years, mean: 20.6) from the
108 Université Grenoble Alpes (France) participated in the experiment for course credit.
109 Participants were native speakers of French who reported normal or corrected-to-normal
110 vision and no hearing impairment. All had English as an L2, with varying degrees of
111 proficiency, and all reported spending most of their time speaking and hearing French (88%,
112 $sd = 12%$, vs English, 11%, $SD = 8%$).

113

114 2.2 Materials

115 Stimuli were 20 monosyllabic English pseudowords C(C)VC(C), each of which was paired
116 with a color picture of a rare animal, plant or object. The pseudowords contained only
117 consonant phonemes present in both English and French, and there were no minimal pairs.
118 Half were spelled with <i> (e.g. *lisk*) and half with <o> (e.g. *mog*). Crucially, the French
119 GTPCs for these graphemes (<i> ~ /i/, e.g. *disque* [disk] ‘disk’ and <o> ~ /ɔ/ in closed
120 syllables, e.g. *bogue* [bɔg] ‘husk’) differ from the vowel produced in the spoken stimuli and
121 from the most common North American English GTPCs (<i> ~ /ɪ/, the “default rule” for this
122 grapheme (Carney, 1994: 337), e.g. *disk* [disk]) and <o> ~ /ɑ/ generally in monosyllabic
123 words, e.g. *log* [lag]). The graphemes <i> and <o> can also correspond to other phonemes in
124 English (e.g. <i> ~ /aɪ/, /, *file*, <o> ~ /oo/, *go*). Note, however, that the vowel /ɪ/ is not present
125 in the French inventory and that in French <o> never corresponds to /ɑ/. The pseudowords
126 were: <i> *biv, blit, disp, flid, glizz, lisk, mib, nij, vig, zick*; <o> *blöp, flob, gosk, lozp, mog,*
127 *skock, sloz, stot, vod, zox*. They were recorded by a 26-year-old female native speaker of
128 English from Winnipeg, Manitoba, Canada, using an AKG C520 head-worn microphone and
129 a Zoom H4nSP Handy recorder at a sampling rate of 48 kHz.

130

131 2.3 Procedures

132 Each participant was tested individually in a quiet room over two successive days. The first
133 day included the training session, and the following day the test session. This allowed for the
134 consolidation of the representations of the novel words, since newly learned words are more
135 likely to be lexicalized after a night of sleep (Gaskell and Dumay 2003).

136 *Training session: word learning (Day 1)* Participants were told that they were going
137 to learn new English words to be used in an American mobile phone app under development

138 and that they would be tested on how well they had learned the words. Each of the 20
139 pseudowords was presented in a randomized order 20 times in 20 blocks. For all
140 pseudowords, a sound file was played over Sennheiser HD 212Pro headphones and its
141 associated picture was simultaneously displayed at the center of a computer screen for four
142 seconds. Immediately after the offset of the image, the next sound file/picture pair was
143 presented. For each participant, half (10) of the pseudowords were presented with the
144 orthographic form displayed under the picture (Audio-Ortho condition) and half (10) were
145 presented without it (Audio only condition). The two conditions were counterbalanced across
146 two experimental lists. The learning session lasted approximately 40 minutes. No responses
147 were collected and so no feedback was given, and there was no practice session.

148 *Test session: picture naming (Day 2).* Participants were asked to name each picture as
149 quickly and as accurately as possible and their responses were recorded. Each picture was
150 named four times (in separate blocks) by each participant. Within each block, presentation
151 order was random. The experiment was controlled by E-Prime 2.0 software (Psychology
152 Software Tools, 2016). Participants then completed a language background questionnaire.

153 **3. Results**

154 To assess learning of the novel L2 word forms, naming accuracy and response times were
155 measured, and to assess pronunciation accuracy, formant analyses and a vowel categorization
156 task were used.

157

158 *3.1 Naming accuracy*

159 Responses were coded as correct if all phones of the target pseudoword were produced in the
160 correct order with no additional phones, and the vowel produced was in the same region of
161 the vowel space as the target (e.g. for *mog*: [mɑg], [mæg] or [mɔg]). Other responses were

162 coded as incorrect (e.g. for *mog*: [mig]). Coding was performed independently by two coders,
163 and inter-coder agreement was high ($\kappa = 0.99$).

164 The data of one participant who produced only one correct response were excluded
165 from the analyses. The remaining 25 participants gave a total of 906 correct responses
166 (45.3%, $n=2000$). Data analyses were conducted in R (R Core Team, 2018). A generalized
167 mixed-effects model with a logit function was fitted to these data, with learning modality (i.e.
168 spoken form only (Audio) versus spoken and written form (Audio-Ortho)) and repetition
169 (sum-coded) as fixed effects, Participant and Item as random intercepts, and by Participant
170 and by Item random slopes for the factor learning modality. Correct responses were more
171 frequent in the Audio-Ortho than in the Audio modality (51% vs. 39%, $b = 0.67$, $SE = 0.33$,
172 $z = 2.02$, $p = 0.04$). The probability of producing an error was higher for the first repetition
173 than for other repetitions ($b = 0.31$, $SE = 0.095$, $z = 3.25$, $p = 0.0012$).

174

175 3.2 Response times

176 The data set was restricted to the correct responses to the first presentation of the picture (201
177 responses). Three data points were removed because the participant initially produced an
178 incorrect response. For each correct response, naming latency was defined as the time
179 between the onset of presentation of the image and the onset of the vocal response. Visual
180 inspection of the distribution led us to remove one data point below 600 ms and one above
181 3200 ms, leaving 196 data points for the statistical analyses. A linear mixed-effects model
182 was fitted to the log transformed naming times (transformation indicated by the Box-Cox
183 test), with learning modality as fixed effect, Participant and Item as random intercepts, and by
184 Participant and by Item random slopes for the factor modality. The latencies were
185 significantly shorter (1417 ms, $SD = 608$) in the Audio-Ortho than in the Audio condition
186 (1609 ms, $SD = 707$, $b = 0.13$, $SE = 0.053$, $t = 2.41$, $p = 0.023$).

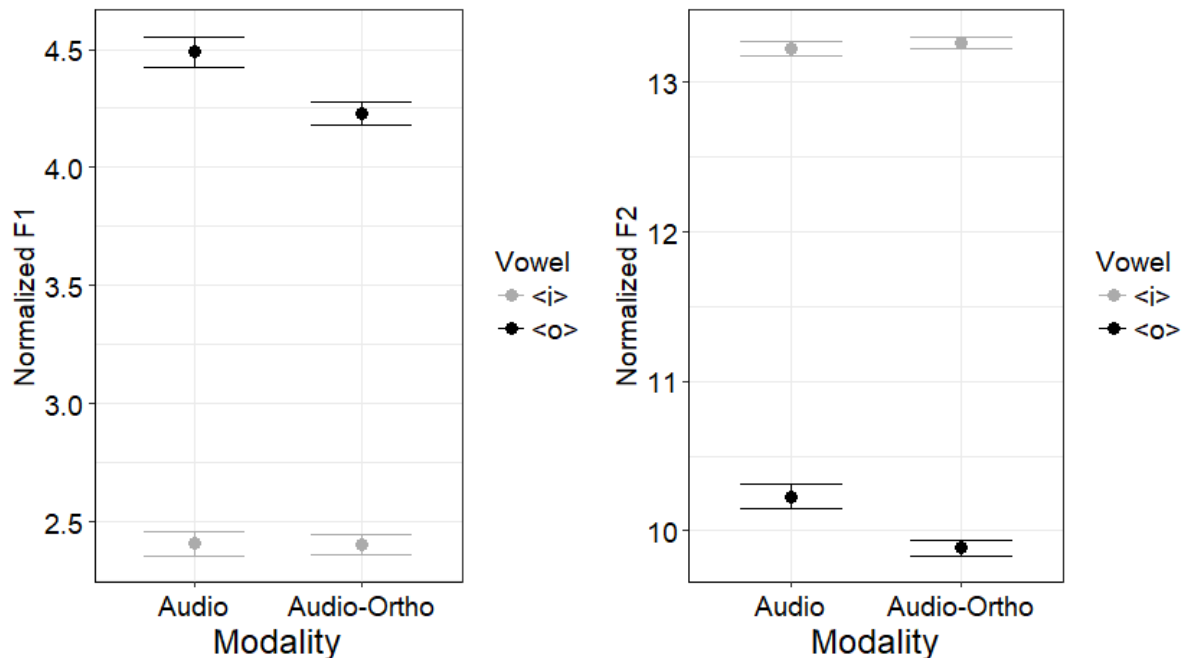
187 3.3 Formant analyses.

188 We conducted formant analyses to examine whether seeing the orthographic form of the
189 word led to pronunciations compatible with French orthography. The data from all four
190 repetitions were considered. For each correct response, the beginning and end of the
191 pseudoword and of the vowel were labelled. All labelling and acoustic analyses were
192 performed in Praat (Boersma and Weenink, 2017), using scripts to semi-automate the
193 process. The first and second formants (F1, F2) were extracted from the vowel mid-point and
194 hand corrected (for 21 items). Thirty items with unclear formants were excluded, leaving 876
195 data points. The formant values were then normalized using the Bladon procedure,
196 appropriate for data sets with very few vowel categories represented (and evaluated in Flynn
197 and Foulkes, 2011).

198 In line with the French (L1) GTPCs, for <i>, we expected vowels to be more /i/-like
199 (French-like) in the Audio-Ortho than in the Audio modality, that is, higher and fronter, thus
200 with lower F1 and higher F2. For <o>, we expected vowels to be more /ɔ/-like (French-like)
201 in the Audio-Ortho modality, that is, higher and backer and possibly rounded, thus with both
202 lower F1 and lower F2. These predictions were borne out by the analyses (see Figure 1).

203 A linear mixed-effects model was fitted to the log transformed F1 value (following
204 the Box-Cox test). Vowel and learning modality were entered as fixed effects, together with
205 their interaction. We included random intercepts for Participant and Item, by Participant and
206 by Item random slopes for the factor modality, and a by Participant random slope for the
207 factor vowel. The interaction was not significant ($F(1,15.85) = 1.16, p = 0.30$). The model
208 without the interaction revealed main effects of vowel, with lower F1 value for <i> than for
209 <o> ($b = 0.58, SE = 0.047, t = 12.31, p < 0.0001$), and of modality, with lower F1 values in
210 the Audio-Orthography modality ($b = 0.052, SE = 0.021, t = 2.51, p = 0.022$). The same
211 analysis was performed for F2, using the untransformed values (following the Box-Cox test).

212 The model revealed a significant interaction between vowel and modality ($F(1,16.95) = 4.56$,
213 $p = 0.048$, suggesting that seeing the orthographic form led to an increase in F2 value for <i>
214 and a decrease in F2 for <o>.



215

216 Fig. 1. Mean normalized F1 (left) and F2 (right) values and standard errors
217 (values are adjusted for within-Participant designs following Morey, 2008)
218 as a function of the Modality and Vowel statistical model.

219 3.4 Vowel categorization task

220 We designed a follow-up experiment to determine whether the observed formant differences
221 between conditions correspond to the perception of different vowel categories by native
222 speakers of English. The stimuli included all correct response tokens from the word-learning
223 task that were produced without hesitations or dysfluencies (465 <i>, 423 <o>), as well as the
224 20 model pseudowords produced by the model speaker of English and an additional 20
225 tokens produced by a naive native speaker of French. The experiment was run in two blocks
226 (one for each vowel grapheme) using Praat ExperimentMFC. Listeners were 24 native

227 speakers of North American English recruited in Aix-en-Provence, France (19 women; age:
228 19–70 years, mean: 30.1), with no reported speech or language disorders. Participants
229 listened to the pseudoword tokens presented over headphones in a randomized order and
230 performed a forced choice identification task, using keywords to indicate the vowel heard
231 (for <i>: *beet*, *bit* or *bet*, corresponding to /i/, /ɪ/ or /ɛ/; for <o>: *huck*, *hoke*, *hock*, *hack*,
232 corresponding to /ʌ/, /o/, /ɑ/, /æ/). The order of presentation of the blocks and of the
233 keywords was counterbalanced. Responses were coded according to whether they were
234 compatible with French GTPCs (<i>: *beet* /i/; <o>: *huck* /ʌ/, *hoke* /o/) or incompatible (<i>:
235 *bit* /ɪ/, *bet* /ɛ/; <o>: *hock* /ɑ/, *hack* /æ/). In line with our predictions, participants produced
236 more French-orthography-compatible vowels in the Audio-Ortho condition (78%) than in the
237 Audio only condition (65%, $b = 0.72$, $SE = 0.22$, $z = 3.2$, $p = 0.0014$). As expected, the
238 vowels of the model native speaker of Canadian English were almost never (2%) categorized
239 as French-orthography-compatible. Note also that the probability of categorizing an
240 occurrence as French-orthography-compatible was predicted for <i> by both F1 ($b = 1.65$, SE
241 $= 0.18$, $z = 9.2$, $p < 0.0001$) and F2 (normalized) values ($b = 1.38$, $SE = 0.13$, $z = 10.9$,
242 $p < 0.0001$) and for <o> by F1 ($b = 1.15$, $SE = 0.14$, $z = 8.5$, $p < 0.0001$), though not by F2
243 (normalized) values ($b = 0.16$, $SE = 0.24$, $z = 0.67$, $p = 0.50$).

244

245 **4. Discussion**

246 We investigated whether the presentation of the orthographic as well as the auditory form
247 influenced two aspects of L2 learning: pronunciation accuracy and novel word form learning.
248 Results showed a clear effect of orthographic information on pronunciation accuracy.
249 Presentation of the orthographic form along with the auditory form led to less native-like
250 productions of the novel words, whose vowel graphemes have different GTPCs in the

251 participants' L1 and L2. This effect was found for a language pair in which both the L1 and
252 the L2 have relatively opaque orthographies (i.e. lack one-to-one grapheme-to-phoneme and
253 phoneme-to-grapheme correspondences), *contra* the original predictions of Erdener and
254 Burnham (2005). These and other recent results (Rafat, 2016) highlight the importance of
255 expanding models of the influence of the L1 phonological system on that of L2 to integrate
256 the potential role of L1 orthography. We note that the orthography-induced phonological
257 transfer observed here for L2 is in line with the hypothesis that orthography can modify the
258 nature of the phonological representations in the L1. Perre *et al.* (2009), for example, showed
259 with EEG recordings that a typical effect of orthography in the processing of spoken (L1)
260 words (the phono-graphemic consistency effect) was localized in an area traditionally
261 dedicated to phonological processing (the supramarginal gyrus) whereas no activation was
262 observed in the area that codes orthographic information (the visual word form area) (see also
263 Racine *et al.*, 2014).

264 In addition, the results showed that the presentation of the orthographic form helped
265 learners to successfully encode new items in the lexicon (fewer errors) and facilitated their
266 retrieval (faster naming times). To our knowledge, the current study is the first to provide
267 evidence that orthographic information facilitates the learning and on-line retrieval of new
268 productive vocabulary in an L2. Several studies have examined the role of orthography on
269 receptive vocabulary, with mixed results reported. In the paradigms typically used,
270 participants are asked to learn novel (pseudo)words associated with pictures representing
271 their meanings. In the training phase, pseudowords are presented either with auditory forms
272 only or with both auditory and orthographic forms. In the test phase, a recognition task
273 measures whether the new words have been memorized. In Escudero *et al.* (2008), L1 Dutch
274 speakers of L2 English learned English pseudowords containing a highly confusable non-
275 native vowel contrast (/ɛ/-/æ/, e.g. *tenzer-tandik*). Their results show that the participants who

276 were presented with both the spoken and written form during training were better able to
277 discriminate between target words and their competitors in subsequent tasks. In contrast,
278 Simon *et al.* (2010) found no evidence that orthography helped listeners to learn new words
279 or a new phonemic contrast. In a study of native speakers of Spanish learning Dutch
280 pseudowords, Escudero *et al.* (2014) examined whether the influence of orthography on word
281 learning depended on whether or not pairs of vowel graphemes signal a phonemic contrast in
282 both languages. For minimal pairs, access to orthographic forms in training facilitated word
283 recognition when grapheme-to-phoneme correspondences (GTPCs) correspondences
284 signaled a phonemic contrast in both languages (e.g. *pig-pug*), while it hindered word
285 recognition when they did not (e.g. *pig-pieg*) (see also Escudero, 2015). Some studies report
286 null results from which we cannot draw conclusions, and the failure to find effects may well
287 be due to methodological issues. In the word recognition/picture mapping tasks commonly
288 used in previous studies, for example, a correct response required participants to have
289 retained only minimal phonological information (e.g. onset or offset consonant). In some
290 studies, responses are close to ceiling, making any effect undetectable. Future studies could
291 examine the contribution of orthographic knowledge with a direct comparison of
292 performance in production and in recognition tasks.

293 Of course, we must bear in mind that while the availability of orthographic
294 information clearly facilitated word form learning in our study, it may do so only in cases
295 where there is at least partial overlap in the L1 and L2 GTPCs. For example, in our
296 pseudowords, while the vowels have inconsistent GTPCs between L1 and L2, the consonants
297 generally have *consistent* GTPCs (e.g. *nif* ~ *French* /nif/, *English* /nif/), which may facilitate
298 L2 word learning. In cases where there is little or no overlap, for example, for native speakers
299 of French or English learning L2 Irish words like *aghaidh* /aɪ/, ‘face’ or *Aodh* /i:/ (a boy’s
300 name), the orthography may not be helpful. We also note that our participants had different

301 degrees of proficiency in L2 English, and that further research is needed to establish how (or
302 if) L2 proficiency modulates the influence of orthography on the learning of new productive
303 vocabulary and on pronunciation accuracy.

304 Our results show that a nuanced view of the influence of orthographic information on
305 L2 learning is needed, that the effects cannot be simply characterized as “positive” or
306 “negative”, “friend” or “foe”. In a single experimental task with the same materials, we found
307 that the presentation of orthographic information led both to *more successful* novel word
308 learning and to *less accurate* L1-like vowel pronunciation. The effect on pronunciation may
309 not be simply a question of *if* orthographic forms are presented but of *when* they are
310 presented. In our study, participants in the Audio only condition were never presented with
311 the orthographic form of the word. In many L2 learning contexts, however, even if a word is
312 first learned from being heard, learners will eventually encounter the written form of the
313 word. The potential influence of the timing of the presentation of orthographic information
314 both on pronunciation accuracy and on novel word form learning, both in the short and long
315 term, is worth exploring.

316 The datasets and scripts to reproduce the analyses reported in this paper are stored on
317 the Open Science Framework website and can be accessed via the following link:
318 <https://osf.io/rfjh6/>

319 **Acknowledgments**

320 This work was partly supported by the University of Potsdam KoUP Cooperation Funding
321 scheme. This paper is partly based on a master's thesis submitted by Mélanie Clément to
322 Université Grenoble Alpes.

Textual footnote

¹ The speech production tasks of studies such as Erdener and Burnham (2005) and Rafat (2016, 2015) demonstrate the automaticity of the influence of L1 orthography. However, they required participants to retain (pseudo)words of an unfamiliar language for no more than approximately 16 seconds.

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