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Masked morphological priming and sensitivity to the statistical structure of form-to-meaning mapping in L2

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Abstract

In one's native language, visual word identification is based on early morphological analysis and is sensitive to the statistical structure of the mapping between form and meaning (Orthography-to-Semantic Consistency, OSC). How these mechanisms apply to a second language is much less clear. We recruited L1 Italian-L2 English speakers for a masked priming task where the relationship between prime and target was morphologically transparent, e.g., *employer-EMPLOY*, morphologically opaque, e.g., *corner-CORN*, or merely orthographic, e.g., *brothel-BROTH*. Critically, participants underwent thorough testing of their lexical, morphological, phonological, spelling, and semantic proficiency in their second language. By exploring a wide spectrum of L2 proficiency, we showed that this factor critically qualifies L2 priming. Genuine morphological facilitation only arises as proficiency grows, while orthographic priming shrinks as L2 competence increases. OSC was also found to modulate priming and interact with proficiency, providing an alternative way of describing the transparency continuum in derivational morphology. Overall, these data illustrate the trajectory towards a fully consolidated L2 lexicon and show that masked priming and sensitivity to OSC are key trackers of this process.

Keywords: Bilingualism, Morphology, Masked priming, Language proficiency.

1. Introduction

Visual word identification occurs effortlessly in skilled adult readers. This process has received a considerable amount of attention, and there is now wide consensus that the recognition of printed words involves an early morphological analysis – words that are made up of meaningful sub-parts, such as *kind-ness* or *clean-er*, are identified via their constituents (e.g., Amenta and Crepaldi, 2012). Masked priming experiments have further revealed that morpheme identification is primarily based on form, as indicated by the fact that even pseudoderived words, like *corner*, facilitate the identification of their pseudostems, *corn*, more than orthographic controls (e.g., *dialog-dial* Grainger et al., 1991; Kazanina, 2011; Longtin et al., 2003; Lavric et al., 2007; Marelli et al., 2013; Rastle et al., 2000, 2004)(but see Milin et al., 2017, for conflicting evidence). Some models of word identification interpret these effects as related to an early stage in morphological decomposition that is semantically blind (e.g., Crepaldi et al., 2010; Rastle et al., 2004; Taft

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14 and Nguyen-Hoan, 2010), although some masked priming studies reported that facilitation is greater in transparent than opaque pairs (e.g., Diependaele et al., 2011; Feldman et al., 2009, 2012; Marelli et al., 2013), suggesting the involvement of some early semantic processing that would stem from morpho-orthographic segmentation.

18
19 Whether the same mechanisms apply to visual word identification in a second language (L2) is far less clear. The few experiments which have investigated this diverge in both data and theoretical interpretations. Silva and Clahsen (2008) investigated masked morphological priming with derived words (e.g., *bitterness*) in a group of L1-English, and in different groups of advanced L2-English readers. They compared derivational with repetition priming (*rigidity-RIGID* vs. *rigid-RIGID*), and found that the two effects are equally strong in L1, but not in L2. Based on these results, the authors argue that L2 readers might only have partial access to the combinatorial processes that are necessary to appreciate morphology as in their L1, and they would therefore rely more on whole-word retrieval in visual word recognition.

29 Working with prefixed, (pseudo)derived primes (e.g., *disagree-AGREE*, *mischievous-CHIEF*, *stranger-ANGER*) and with Chinese-English bilinguals, Li and Taft (2019) similarly found a difference between morphological priming in L1 and L2. Although L1 readers experienced facilitation with transparent and opaque morphological primes (e.g., Rastle et al., 2004; Longtin et al., 2003; Marelli et al., 2013), these primes yielded no more facilitation than orthographic controls for L2 readers.

35 These reports of a different morphological priming profile in L2 were not confirmed in Diependaele et al. (2011). These authors tested two groups of Dutch and Spanish non-native speakers of English in a masked priming study, with the same conditions that were typically adopted in the vast L1 literature – transparent suffixed primes (e.g., *viewer-VIEW*) were contrasted with opaque (pseudo-)suffixed primes (e.g., *corner-CORN*) and orthographically-matched, non-morphological controls (e.g., *dialog-DIAL*). They reported no statistically significant difference between morphological priming in L1 and L2, contrary to Silva and Clahsen (2008). Across three experiments, they seem to observe a graded facilitation pattern where genuine morphological priming is larger than the morpho-orthographic effect, which in turn exceeds orthographic priming. However, individual experiment data were not clear cut. Opaque priming, for example, did not differ statistically from the orthographic baseline in any of the three individual studies, making the genuine contribution of morphology somewhat unclear.

48
49 One aspect in which the studies described above agree is, interestingly, outside of their main scope. Namely, they report more orthographic priming (e.g., *colonel-COLON*) in L2 than in L1, and no priming at all in this latter. This pattern is confirmed in Hoyer and Clahsen (2015), where transparent, derivational priming was only contrasted with the orthographic effect – opaque primes were not part of the design. In their masked condition, these authors report the standard pattern in L1, with significant morphological facilitation and no orthographic effect. In L2, instead, this latter was equal to morphological priming.

57 The interaction of L1-L2 with form priming did not receive much attention because in all these studies the orthographic condition was effectively a control baseline. Diependaele et al. (2011) explain it in terms of slower prime processing. Here we offer a more intriguing interpretation, which relates to the literature on novel word learning and form priming

61 in L1. It is well established that nonword primes (e.g., *contract-CONTRACT*) yield
62 larger orthographic facilitation than word primes (e.g., *contrast-CONTRACT*) in L1,
63 a phenomenon known as Prime Lexicality Effect (PLE; e.g., [Forster and Veres, 1998](#)).
64 PLE is typically interpreted in terms of lexical competition – with word primes, the gain
65 that one gets from shared letters is offset by the competition in the lexicon between
66 the prime and the target representations. Lexical competition, in turn, has been often
67 taken as a benchmark for the consolidation of new lexical memories ([Gaskell and Dumay,](#)
68 [2003](#); [Tamminen and Gaskell, 2008](#); [Davis and Lupker, 2006](#)). Therefore, orthographic
69 priming from real words in L2 could be attributed to a still-incomplete consolidation
70 process, whereby memories for novel words are perhaps present in the brain, but not
71 yet fully lexicalised. Essentially, they would work similarly to nonwords in L1; because
72 they do not participate in lexical competition, they yield priming based on sub-lexical
73 processing. This interpretation connects nicely with recent evidence in L1, showing that
74 prime lexicality modulates morphological facilitation in French native speakers [Grainger](#)
75 [and Beyersmann \(2020\)](#). Moreover, it connects to general theories of lexical and language
76 learning ([Ullman, 2001, 2005](#)).

77 In this paper we attempt to provide a fuller description of L2 morphological priming.
78 We do this by replicating this orthographic effect described above, qualifying it through
79 consideration of individual variability (see below), and developing its theoretical impli-
80 cations more fully.

81
82 Morphological priming in L2 has also been studied with inflected primes; however, the
83 picture remains difficult to interpret. [Kirkici and Clahsen \(2013\)](#) compared the processing
84 of inflected and derived words in non-native speakers of Turkish using a series of masked
85 priming experiments. The non-native speakers involved in this study had a variety of L1
86 backgrounds, but were all highly proficient. Priming in L1 turned out to be equivalent for
87 inflection (*sorar-SOR*, s/he asks-ask) and derivation (*yorgunluk-YORGUN*, tiredness-
88 tired). In L2 instead, derivational priming was larger than the inflectional effect, which
89 did not emerge at all.

90 In an experiment with regular (e.g., *billed-BILL*) and irregular (e.g., *fell-FALL*)
91 masked primes, [Feldman et al. \(2010\)](#) reported statistically different patterns of facil-
92 itation in L1 and L2 speakers of English. The critical interaction between regularity and
93 prime relatedness was not significant in L2, although some further post-hoc analyses re-
94 vealed that regular inflected primes, but not irregular inflections, did provide facilitation
95 as compared to an orthographic baseline (e.g., *billion-BILL*, *fill-FALL*). In line with the
96 data from derivational priming (e.g., [Diependaele et al., 2011](#)), form priming was signif-
97 icant in L2. [Coughlin and Tremblay \(2014\)](#) assessed verb inflectional priming in French
98 with a similar design: they compared morphological primes (e.g., *donnons-DONNE*, (*we*)
99 *give-(I) give*) to both an orthographic (e.g., *doute-DONNE*, (*I*) *doubt-(I) give*) and an
100 unrelated baseline (e.g., *parle-DONNE*, (*I*) *speak-(I) give*). In this study, the pattern
101 of facilitation did not differ statistically in native and non-native speakers, contrary to
102 [Feldman et al. \(2010\)](#). Similarly to [Feldman et al.](#)'s results, orthographic priming was
103 again significant in L2; however, contrary to a vast body of literature (e.g., [Forster and](#)
104 [Veres, 1998](#); [Davis and Lupker, 2006](#)), this was also the case for L1. Further data from a
105 phrase completion experiment suggests that noun inflection differs in L1 vs. L2 speakers
106 ([Foote, 2015](#)).

107 Why does morphological priming prove to be so difficult to characterize in L2? A

108 strong candidate to explain inconsistency in the previous data is surely individual vari-
109 ability. Evidence is accumulating that visual word identification is heavily influenced
110 by the individual profile of each reader (e.g., [Andrews and Hersch, 2010](#); [Andrews and](#)
111 [Lo, 2013](#); [Milin et al., 2017](#)). In a masked derivational priming experiment, [Andrews](#)
112 [and Lo \(2013\)](#) showed that the pattern of facilitation between transparent, opaque, and
113 orthographic primes changes as a function of readers' spelling skills (as compared to
114 their vocabulary). They report that priming is very similar in the opaque and transpar-
115 ent conditions when spelling skills are strong, but when spelling skills are weak, opaque
116 priming is less pronounced and may even be equivalent to the orthographic baseline.
117 [Milin et al. \(2017\)](#) also provided data suggesting that some readers may not show a
118 difference between opaque and form priming. Along similar lines, [Beyersmann et al.](#)
119 [\(2015a\)](#) reported that individuals with high vocabulary and spelling competence display
120 facilitation from non-suffixed nonword primes (e.g., bankord-BANK), while readers with
121 relatively weaker skills do this to a much lesser extent. They take these results to show
122 that morphological processing depends on more general lexical and orthographic skills:
123 people with relatively lower levels of language proficiency rely more heavily on morpho-
124 logical segmentation than individuals with relatively higher levels of language proficiency
125 (see also [Grainger and Beyersmann, 2017](#)). Similar conclusions have been drawn in stud-
126 ies using a combination of vocabulary and spelling abilities to index individual differences
127 in morphological priming among novice readers ([Beyersmann et al., 2015b](#); [Hasenäcker](#)
128 [et al., 2015](#)).

129 All these results relate to L1, and it is not obvious that they generalise to L2. Con-
130 versely, these effects may even be magnified in L2, where inter-subject variability is
131 likely enhanced by the diversity of the learning experience. Factors like Age of Acquisi-
132 tion (AoA) or proficiency may well mean different cognitive processes are in place when
133 L2 readers are exposed to printed words. Along these lines, [Dawson et al. \(2017\)](#) have
134 recently shown that morphologically structured nonwords (e.g., earist) are more likely to
135 be taken as words than control stimuli (e.g., earilt) in adults and adolescents, but not in
136 younger children. These data refer to L1, but do show that less experience with printed
137 words may determine a different morphological processing – this may apply to L2 speak-
138 ers as well as children learning L1 (see also [Beyersmann et al., 2015a,b](#); [Grainger and](#)
139 [Beyersmann, 2017](#)). Another recent study by [Verfissimo et al. \(2018\)](#) investigated masked
140 morphological priming in Turkish-German bilinguals, and found an effect of AoA on in-
141 flectional, but not derivational L2 priming, suggesting that sensitivity to morphological
142 features is constrained by the learning trajectory of a (second) language.

143
144 Most previous studies on L2 derivational priming did not try to characterize their
145 participants' profile in terms of proficiency or AoA beyond self reports, nor to investi-
146 gate whether and how these individual features may modulate the priming pattern. An
147 exception is perhaps [Li et al. \(2017\)](#), which reports on a masked morphological priming
148 experiment with Chinese-English bilinguals. The separation of participants into high-
149 proficiency and low-proficiency groups was validated via a questionnaire on English usage
150 and a vocabulary test (although neither metric was then used directly to model prim-
151 ing). Proficiency was found to interact with morphological facilitation; lower-proficiency
152 L2 readers showed significant priming in the transparent and form conditions, but not
153 in the opaque condition, while more proficient participants showed the predominant L1
154 pattern, with significant transparent and opaque priming, but no form priming. Work-

155 ing with inflectional primes, [Feldman et al. \(2010\)](#) obtained somewhat different results.
156 Proficiency did not interact significantly with the priming pattern in the main statisti-
157 cal model. However, the authors carried out separate analyses for higher and lower-
158 proficiency readers. They found genuine sensitivity to morphology, similarly to L1, only
159 for the former group; in lower-proficiency participants, morphological primes did not
160 yield any additional advantage as compared to an orthographic baseline. In contrast,
161 [Coughlin and Tremblay \(2014\)](#) observed that the difference between morphological and
162 orthographic priming does not interact with readers' proficiency, nor does the comparison
163 between orthographic and unrelated primes, i.e., form priming *per se*¹. So, overall the
164 pattern is far from clear.

165 It is important to note that proficiency was defined somewhat coarsely in these stud-
166 ies, based on a questionnaire on language usage and a vocabulary test ([Li et al., 2017](#)),
167 on speed and accuracy in the priming task itself ([Feldman et al., 2010](#)), or on a single
168 sentence completion task ([Coughlin et al., 2019](#)). Although these are legitimate ap-
169 proximations, language competence is a highly multicomponent construct and can be
170 assessed more widely. In the present study, we probe our participants' L2 proficiency
171 with a battery of tests covering seven language domains (morphological awareness, flu-
172 ency, phonemic discrimination, vocabulary, spelling, oral and reading comprehension).
173 We also assess AoA (and, more generally, the participants' learning experience) through
174 a questionnaire. Most importantly, we explicitly tried to recruit readers with varying
175 learning experiences and proficiency, so that we could properly assess whether L2 mor-
176 phological priming is affected by these factors.

177
178 Another recent development in the literature is the discovery that readers' morpho-
179 logical processing is mediated by their sensitivity to graded, probabilistic relationships
180 between form and meaning. [Marelli et al. \(2015\)](#) quantified these relationships in terms of
181 what they called Orthography-to-Semantics Consistency (OSC) – a frequency-weighted
182 average of the semantic similarity between all members of a given morpho-orthographic
183 family and their stem. Consider, for example, the word *corn*. If we take all the words in
184 the lexicon that start with the string *corn* – that is, that might potentially have *corn* as
185 a stem – we obtain items like *corny*, *cornish* or *corner*. Because these words are fairly
186 unrelated in meaning with *corn*, OSC would be low. By contrast, a stem like *risk*, whose
187 morpho-orthographic neighbourhood would be populated by words like *risks*, *risked*, or
188 *risky*, would have higher OSC, given that all these words are genuine morphological re-
189 latives and are therefore strongly related in meaning. In a large scale regression analysis,
190 [Marelli et al. \(2015\)](#) showed that words with higher OSC (that is, words that are part of
191 semantically consistent morpho-orthographic families) are identified more quickly.

192 More recently, [Amenta et al. \(2020\)](#) showed that OSC modulates morphological prim-
193 ing specifically. This is particularly interesting because OSC is a property of the target
194 itself, independently of any specific prime: *cornfield-CORN* would have the same exact
195 OSC of *cornice-CORN*, while, for example, the former pair would be considered more
196 semantically transparent than the latter. So, [Amenta et al.](#)'s results highlight the im-

¹[Foote \(2015\)](#) also included proficiency in her experimental design. However, this study investigates speech production in the context of a phrase completion task, which taps into cognitive processes that are very different from those driving masked visual priming. Therefore, we do not describe these data in more detail.

197 portance of the lexical-semantic region target words of priming experiments live in –
198 more specifically, the consistency of the mapping between form and meaning there. In
199 a sense, this extends the scope of semantic transparency well beyond the specific rela-
200 tionship between a target and any given prime: this factor is surely important in itself,
201 but is also qualified by the entire set of the target’s morpho-orthographic neighbours,
202 independently of which of these neighbours was actually used as a prime on any given
203 instance. More generally, the pattern of results described in Amenta et al. (2020) might
204 be taken to downplay the role of discrete categories, which may have given rise to incon-
205 sistent results at times (e.g., Davis, 2010; Feldman et al., 2009, 2012) and have proven
206 difficult to define precisely in some instances (e.g., the word *fruitless* is not directly re-
207 lated to the literal meaning of *fruit*, but there is a metaphorical sense where the stem is
208 more transparent, and the suffix is quite transparent, too; Baayen et al., 2011). In this
209 novel view, priming would be modulated by a network of probabilistic ties between form
210 and meaning, which potentially extends beyond morphology *per se* (e.g., phonaestemes;
211 Baayen et al., 2011; Marelli et al., 2015). Classic concepts like segmentation or affix/stem
212 identification might also fade to the background, and the debate on the role of semantics
213 in early processing would take an important turn: an effect of OSC does require an early
214 access to semantic information, but also implies that any potential orthographic unit
215 (including pseudo-affixes in opaque words) is activated independently of whether it will
216 actually turn out to be semantically transparent (Amenta et al., 2015).

217 Of course, the appreciation of these fine-grained ties between form and meaning likely
218 requires a rather extensive experience with any lexicon. Thus, one can imagine that L2
219 speakers would show less sensitivity to OSC; or perhaps more intriguingly, that their
220 sensitivity grows with proficiency. Or perhaps again, one needs early exposure to a lan-
221 guage in order to see a probabilistic form-meaning relationship structure, so that only
222 early-AoA participants would show an effect of OSC. More generally, OSC offers an in-
223 teresting perspective on the learning of a second language, which may involve a growing
224 sensitivity to probabilistic ties between form and meaning. We will try to shed light
225 on this issue by checking whether morphological priming – and, more generally, word
226 identification time – is modulated by OSC in L2.

227
228 To summarise, the present experiment tries to clarify how bilingual readers process
229 word morphological structure in L2, primarily by characterizing their profile in terms of
230 proficiency and age of acquisition. Moreover, we will check how and whether fine-grained,
231 probabilistic relationships between form and meaning (as tracked by Orthography-to-
232 Semantics Consistency) inform L2 visual word identification, which speaks to the hy-
233 pothesis that learning a novel lexicon proceeds through an increased appreciation of the
234 statistical structure of the orthography-semantics mapping.

235 2. Methods

236 *Participants*

237 81 students at the University of Trieste participated in the study. They were 73
238 right-handed and 8 left-handed native speakers of Italian, who provided informed writ-
239 ten consent to take part into the experiment. Their mean age was 24.3 years (range:
240 18–34) and their mean education was 17 years (range: 13–22); 27 of them were male.

241 Participants had no history of neurological impairment or learning disabilities, and nor-
242 mal or corrected-to-normal vision. They were compensated for their time with 20 Euros.
243 All participants took part in both the Italian-L1 and the English-L2 masked priming
244 experiments.

245 *Materials*

246 The Italian set of stimuli is composed of 150 prime-target pairs, 50 in each of three
247 conditions. Primes and targets in the *transparent* condition entertain a genuine morpho-
248 logical relationship (e.g., *artista-ARTE*, artist-ART). Primes and targets in the *opaque*
249 condition are semantically independent, but entertain an apparent morphological rela-
250 tionship, i.e., primes are made of a pseudo-stem, which is shared with the targets, and a
251 pseudo-suffix (e.g., *retaggio-RETE*, legacy-net; an analogous example in English would
252 be corner-CORN). Primes and targets in the *form* condition have a purely orthographic
253 relationship, i.e., primes share a (pseudo-)stem with their targets, but end in a non-suffix
254 (e.g., *corallo-CORO*, coral-CHOIR; an analogous example in English would be dialog-
255 DIAL). Targets and primes were matched across condition for frequency (as indexed by
256 the SUBTLEX-IT database; Crepaldi et al., 2013), length, Coltheart’s N and prime-
257 target orthographic similarity (see Table 1).

258
259 For each related prime, we selected a control prime that is semantically, orthographi-
260 cally, and morphologically unrelated to the targets (e.g., *plunder-ACRE*). Control primes
261 were matched as closely as possible to related primes on frequency, length and Coltheart’s
262 N (see Table 1). In order to avoid multiple presentations of the same target word to the
263 same participant, we rotated related and control primes over two lists, in a Latin Square
264 design; thus, each participant saw each target, either paired with its related or control
265 prime.

266
267 150 nonword targets were also selected to serve as NO trials in the lexical decision
268 task. They were matched with word targets on length (mean= 5.06, SD= 0.95). Each
269 of these targets was paired with a word prime, mirroring the structure of the word tar-
270 get set: half of these primes were orthographically similar to their targets, and 2/3 of
271 the primes were complex words. This served the purpose of leaving the primes devoid
272 of any information about the lexicality of their targets. These prime words were also
273 roughly matched with the word-target primes for frequency (mean=3.18, SD=0.87),
274 length (mean=7.42, SD=1.32), and Coltheart’s N (mean=3.02, SD=3.5).

275
276 The English set of stimuli perfectly mirrors the Italian one. It is largely based on
277 Rastle et al. (2004), with only a few additions and replacements. The lexical statistics
278 of these stimuli are reported in Table 2. Frequency values are based on SUBTLEX-UK
279 (Van Heuven et al., 2014).

280
281 The complete list of Italian and English stimuli is offered in the Appendix.

282 *Measures of proficiency in English*

283 English L2 proficiency was assessed via a battery of tests that cover phonemic fluency,
284 phonemic discrimination, spelling, vocabulary, morphological awareness, and oral and
285 reading comprehension.

286 *Phonemic fluency.* Participants were asked to produce as many words as possible
287 starting with the phonemes /f/ or /p/, in two separate 60-second sessions. Answers
288 were recorded through a microphone for off-line scoring. Each participant's score is the
289 total number of words produced.

290 *Phonemic discrimination.* Participants were acoustically presented with a probe
291 pseudo-word (e.g., *kneef*), and then with three test pseudo-words (e.g., *yawk*, *zeep*,
292 *wid*). They were asked to pick up which of the test pseudo-words shared one phoneme
293 with the probe. The score is the number of correctly identified test pseudo-words, out
294 of the 13 trials that made up the task. The shared phoneme could be either a consonant
295 or a vowel.

296 *Spelling.* 20 words were recorded by a native speaker of English, and included in
297 example sentences to clarify any lexical ambiguity. These words were then presented
298 to the participants, who were required to write them. Words were selected from [Burt
299 and Tate \(2002\)](#), among those that were correctly spelled by between 30% and 90% of
300 a sample of Australian first-year university students. This test is taken from [Andrews
301 and Lo \(2013\)](#), with Latin derivations excluded because Italian speakers may be able to
302 reconstruct their spelling based on etymology. Participants' score for the test was the
303 number of correctly spelled words.

304 *Vocabulary.* This task comes from the Test of English as a Foreign Language (TOEFL),
305 and consists of 20 sentences presented in a written form that are completed by choosing
306 a proper word among three alternative choices. The score for this test is the number of
307 correct choices.

308 *Morphological awareness.* This test was presented in a written form, and consisted
309 of 9 sentences that participants were asked to fill with an appropriate plausible pseudo-
310 word, chosen among two options. Nonwords contained a suffix, which unambiguously
311 made only one option a plausible sentence completion (e.g., *The tiny coral snake is*
312 _____ *(valgeful/valgefully) but deadly*). The score for the test is the number of
313 correct picks.

314 *Oral comprehension.* This test also comes from the TOEFL. Participants listened to
315 two conversations between English native speakers, and were then asked 6 comprehension
316 questions about them. They marked the correct answer among 4 alternatives. The score
317 for the test is the number of correct answers.

318 *Reading comprehension.* Participants were required to read a text passage of approx-
319 imately one page, and answer some comprehension questions. This task was taken again
320 from the TOEFL, and consisted of seven questions, each with 4 alternative choices. The
321 score is again the number of correct answers.

322 *Measures of Age of Acquisition of English*

323 Age of Acquisition of English (henceforth, AoA) was assessed via a questionnaire,
324 which we expanded to include items on perceived proficiency and language experience in
325 general. The questionnaire was composed of the following questions:

- 326 1. Which age were you exposed to English for the first time? (AoA proper)
- 327 2. Indicate how much you use English in your daily life from one (never) to five
328 (always)
- 329 3. In which context were you exposed to English for the first time – home or school?
- 330 4. Did you grow up in a context where multiple languages were spoken?

331 5. How would you rate your proficiency in English, from 1 (very bad) to 5 (very good)?

332 6. Do you speak any other languages in addition to Italian and English?

333 *Procedure*

334 Participants completed the AoA questionnaire online through the Department’s partic-
335 ipant recruitment system. The rest of the data collection happened in the lab, in
336 two sessions. During the first session, which lasted around an hour, participants carried
337 out the proficiency tests. During the second session, participants underwent the lexical
338 decision experiment, both in Italian (L1) and English (L2). This session lasted around
339 40 minutes. The testing order for the two languages was counterbalanced across partici-
340 pants.

341

342 For the lexical decision task, participants were tested in a soundproof, dimly lit
343 booth. Stimuli were presented in a randomized order using Psychopy (Peirce, 2007),
344 and responses were collected through a two-button, custom-made response box based
345 on Arduino microcontroller boards (<https://www.arduino.cc/>). The YES button was
346 always controlled by the dominant hand.

347 Each trial started with a string of hash marks, presented for 500ms, which was re-
348 placed by the prime, presented for 50ms in lowercase. The prime was immediately
349 followed by the target, presented in uppercase until response, or for 2000ms. All stimuli
350 were presented in the center of the screen. Participants were not informed of the presence
351 of the prime, and were asked to respond as quickly and as accurately as possible. Twelve
352 practice trials preceded the experiment proper, to allow familiarization with the task.
353 At the end of the session, participants were debriefed to check whether they noticed the
354 presence of a prime.

355 *Statistical Analysis*

356 Response time analyses were carried out on correct trials only. Exclusions were ap-
357 plied separately for the Italian (L1) and English (L2) datasets². For Italian, we excluded
358 one participant who was aware of the primes; two participants whose accuracy on non-
359 words was below 80%. We also excluded all trials concerning three target words, which
360 were responded to correctly less than 60% of the time over all participants, and indi-
361 vidual data points below 280ms or above 2500ms. This resulted in the exclusion of 526
362 datapoints, which amounts to 4.6% of all available data. We were then left with 11009
363 data points for the analysis.

364 In the English set, we excluded two participants who reported having seen the primes;
365 one additional participant whose mean overall response time was under 200ms; and indi-
366 vidual data points that were below 300ms or above 2000ms. This led to the exclusion of
367 281 datapoints, which is 3% of the total available data. The clean dataset was comprised
368 of 8938 data points. There were fewer English data points than Italian data points be-
369 cause participants made more mistakes on English trials than Italian trials.

370

²We checked that the pattern of results did not change when the exactly the same participants were included in the L1 and L2 datasets (see below in the Results section).

371 Generalized linear mixed models were used to fit reaction times within the R environ-
372 ment (R Development Core Team, 2008), using the package `lme4` (Bates et al., 2015). We
373 resorted to GLMMs in order to avoid RT transformations, which have been shown to po-
374 tentially distort the data pattern (for an extensive discussion about this topic, see Balota
375 et al., 2013; Lo and Andrews, 2015). Following Lo and Andrews (2015), we adopted a
376 Gamma distribution with an identity link function³. The effects of interest were *prime*
377 *relatedness* (related vs. unrelated), *morphological type* (transparent vs. opaque vs. or-
378 thographic), and their interaction. For the proficiency and AoA analyses, we added each
379 individual predictor tracking these variables (i.e., each test score and each questionnaire
380 item) to the main interaction, one at a time to avoid excessive collinearity. Trial position
381 in the randomised list, target frequency, target length, target orthographic neighborhood
382 size and rotation were also added as fixed effects, to control for spurious variance. In
383 general, only those variables that produced a significant increase in goodness of fit were
384 retained in the analyses, as determined via the `anova` function comparing hierarchical
385 models. The statistical significance of the effects of interest was assessed using Type
386 III sum-of-squares and χ^2 Wald tests as implemented in the `Anova` function from the
387 `car` package (Fox and Weisberg, 2019). When this test was significant, we explored the
388 model parameters via the `anova` function and computed model-based response time es-
389 timates through the package `effects` (Fox and Hong, 2009). All figures were created
390 using `ggplot2` (Wickham, 2016).

391 *Data availability and open science*

392 All data, stimuli and code that were used in the context of this experiment are openly
393 available at the [Open Science Framework](#).

394 **3. Results**

395 The overall mean RT and accuracy in the task were 594ms and 95% respectively, for
396 Italian; and 672ms and 76% for English (81% in the transparent condition, 75% in the
397 opaque condition and 70% in the orthographic condition).

398 The model for the Italian data reveals a significant interaction between *prime related-*
399 *ness* and *morphological type*, $\chi^2[2] = 228.8, p < .001$. The interaction is driven by signifi-
400 cantly more priming in the transparent, $\beta = -36.8, t = -14.5, p < .0001$, and opaque con-
401 ditions, $\beta = -14.2, t = -6.4, p < .0001$, as contrasted with the orthographic condition,
402 which does not seem to show any facilitation, $\beta = -1.3, t = -0.64, p = .52$. Transparent
403 priming is also significantly larger than opaque priming, $\beta = -22.5, t = -6.8, p < .0001$.
404 The estimated RTs for each condition are plotted in Figure 1, left panel.

405 The model for the English data also reveals a significant interaction between *prime*
406 *relatedness* and *morphological type*, $\chi^2[2] = 32.9, p < .0001$. Similarly to Italian, trans-
407 parent primes yield more facilitation than orthographic primes, $\beta = -17.1, t = -5.5, p <$
408 $.0001$, thus confirming that L2 speakers are fully sensitive to genuine, semantically trans-
409 parent morphology. The difference between opaque and orthographic priming is only
410 marginally significant, $\beta = -5.6, t = -1.9, p = .058$, probably due to the most glaring

³We also examined the Inverse Gaussian distribution, which had an equivalent quality of fit. However, we eventually opted for the Gamma distribution because models converged more easily.

411 difference between the English and the Italian data – orthographic primes yield signifi-
412 cant facilitation themselves, $\beta = -19, t = -5.34, p = .0002$. Finally, transparent primes
413 seem to provide larger priming than opaque primes, $\beta = -11.5, t = -3.7, p = .0002$.
414 Figure 1, right panel, reports the estimated response times per condition in the English
415 dataset.

416 A cross-language analysis confirms that the priming pattern across conditions is dif-
417 ferent in L1 and L2, as attested by the significant interaction between *prime relatedness*,
418 *morphological type*, and *language*, $\chi^2[2] = 61.7, p < .0001$ ⁴.

419 *Language proficiency and priming*

420 L2 proficiency scores are distributed as illustrated in Figure 2 – we were able to
421 sample a rather wide distribution of proficiency, across different linguistic domains. The
422 correlation between pairs of indices is reported in Table 3, and varies between .25 and .68
423 (lower quartile= .43, median= .46, upper quartile= .54). This attests the effectiveness
424 of the battery – individual scores correlate enough to be credible measure of individuals’
425 proficiency, but also vary enough to effectively track different aspects of L2 competence.
426 Note, however, that these observed correlations likely underestimate the true correlations
427 in the population, as long as the tests that we used do not have perfect test-retest
428 reliability (Spearman, 1904) – which is very likely to be the case, as for any psychometric
429 test. Spelling engages in particularly strong correlations ($r > .60$), with phonemic fluency,
430 morphological awareness, vocabulary and oral comprehension. Morphological awareness
431 and oral comprehension also correlate quite strongly ($r = .68$). To explore more in
432 depth the structure underlying these correlations, we ran a Principal Component Analysis
433 (PCA) using a Varimax rotation. The results are illustrated in Figure 3 and indicate
434 that (i) seven Principal Components are necessary to account for this set of correlations,
435 i.e., they all explain a similar and substantial amount of variance; and (ii) each of them
436 map clearly to one specific proficiency metric. This suggests that the seven variables we
437 considered here constitute a minimal set of interpretable predictors; we could obviously
438 drop some of these metrics, but we would lose independent (and potentially important)
439 information. The PCA thus provides strong validation to the battery of tests that we
440 adopted.

441 As illustrated above, we assessed the impact of each subtest on L2 priming in a
442 separate model to avoid excessive collinearity. In fact, the condition number K (Belsley,
443 1980) is 33.92, above the threshold of 30 that indicates harmful collinearity if we were to
444 use all predictors in one unique model (Baayen et al., 2008). Note that, because we did
445 not have strong predictions as to which specific proficiency metric might work best, we
446 did not focus on any specific measure and adopted a rather exploratory approach.

447 Every individual sub-test improves overall goodness of fit, $\chi^2[6] = 15.79 - 35.02$, all
448 p values $< .014$ – quite unsurprisingly, RTs are better accounted for when participants’
449 proficiency is taken into account. This improved goodness of fit does not necessarily
450 come from morphological priming modulation; proficiency might just explain overall
451 response speed, or general sensitivity to priming. We thus assessed which proficiency

⁴To check that the pattern of results did not change when exactly the same set of participants were considered in the L1 and L2 experiments, we refitted the models above excluding from the Italian dataset those participants who were excluded from the English dataset. Indeed, the pattern of results remains the same.

452 score, if any, interacted specifically with prime relatedness and morphological condition.
453 This happens for phonemic discrimination, $\chi^2[2] = 42.5, p < .0001$, vocabulary $\chi^2[2] =$
454 $39.3, p = .001$, and morphological awareness $\chi^2[2] = 16.3, p = .0002$. The remaining tests
455 – phonemic fluency, spelling, oral comprehension and reading comprehension – did not
456 reach significance (all χ^2 s < 4.78, all $ps > .09$)⁵.

457 For phonemic discrimination, the nature of the priming modulation is illustrated
458 through the model-based estimates in Figure 4. Transparent and opaque priming seem
459 to be solid and consistent across the whole phonemic discrimination spectrum, while ortho-
460 graphic priming appears to shrink with growing performance. This is supported by
461 the model parameters, where orthographic priming is significantly different from both
462 opaque, $\beta = -5.65, t = -6.45, p < .0001$, and transparent priming, $\beta = -2.94, t =$
463 $-3.45, p = .0006$, while the latter two conditions do not differ, $\beta = .55, t = -.75, p = .45$.
464 The priming modulation pattern is similar for vocabulary (Figure 5). Transparent facil-
465 itation is again consistent across different levels of vocabulary skills, while orthographic
466 priming shrinks significantly with growing proficiency, $\beta = -3.28, t = -6.21, p = .001$.
467 Again similarly to the phonemic discrimination results, opaque priming differs from
468 orthographic priming, $\beta = -1.75, t = -3.31, p = .0009$. Unlike the phonemic dis-
469 crimination results, however, opaque priming also differs from transparent facilitation,
470 $\beta = -2.32, t = -3.73, p = .0001$.

471 So, transparent priming is consistently strong and independent of L2 proficiency,
472 whereas form priming consistently shrinks towards zero with growing proficiency. Opaque
473 priming resembles the transparent condition in the phonemic discrimination analysis,
474 while it differs from transparent priming in the vocabulary results.

475 The pattern for morphological awareness (Figure 6) shows again that transparent
476 priming remains strong across the board. Contrary to the previous metrics, however, so
477 does form priming, which is not significantly different from the transparent condition,
478 $\beta = .084, t = 0.97, p = .32$. The odd one out is now opaque priming, which shrinks with
479 growing morphological awareness more than both the form, $\beta = -4.23, t = 4.03, p <$
480 $.0001$, and the transparent condition, $\beta = -5.58, t = -6.58, p < .001$.

481
482 Since error rates were relatively high in L2, which reduced the number of datapoints
483 available to the models, we further assessed the reliability of the proficiency results via a
484 *jackknife* procedure (Ang, 1998) – we repeatedly fitted the models described above to a
485 subsample of the original observation set and checked that the model estimates remained
486 fairly stable. These additional analyses fully confirm the pattern of results illustrated
487 above, as shown in Figure 7.

488 *AoA analysis*

489 The scores collected through the AoA questionnaire on L2 are distributed as illus-
490 trated in Figure 7. AoA proper, panel (a), is reasonably well distributed, with a peak
491 around the age of 6, which is the age children enter school in Italy. This coheres with

⁵ *Phonemic fluency* and *reading comprehension* were fairly close to the significance threshold ($p = .16$ and $p = .09$, respectively). We therefore explored these effects slightly more in depth in the analysis script, which the interested reader can find at the [Open Science Framework](#) repository for this project. While we do not consider these effects as statistically reliable and therefore do not discuss them further, the reader may explore the data and perhaps find interesting information for future research.

492 the fact that most of our participants learned English at school, panel (c). Interestingly,
493 we also happened to recruit few participants with $AoA < 6$, who learned English at
494 home. Quite notable are the nicely symmetrical distributions for daily use of English,
495 panel (b), and self-rated proficiency, panel (e). Finally, most of our participants did
496 not grow up in a multilingual environment, panel (d), but ended up speaking at least
497 another language in addition to Italian and English, panel (f). Importantly, AoA proper
498 correlates $-.15$ with daily usage, $.04$ with self rated proficiency, and never stronger than
499 $|.23|$ with the objective proficiency scores; this means that we can assess the effect of
500 AoA independently of other variables.

501 We followed the same modelling approach as for proficiency, that is, we first assessed
502 whether AoA proper allows an overall better account of RTs. This does not seem to
503 be the case, $\chi^2[6] = 10.61, p = .10$, which suggests that age of acquisition does not
504 contribute to explaining morphological priming data.

505 Among the other scores that we collected via the AoA questionnaire, only self-rated
506 proficiency improves the quality of the model predictions, $\chi^2[6] = 17.78, p = .006$. Self-
507 rated proficiency also modulates L2 priming, $\chi^2[2] = 68.08, p < .001$, thus nicely con-
508 firming the pattern revealed by the objective proficiency scores. Self-rated proficiency
509 perfectly mirrors the phonemic discrimination results illustrated above: orthographic
510 priming shrinks with growing proficiency significantly more than both opaque, $\beta =$
511 $-13.45, t = -6.46, p < .0001$, and transparent priming, $\beta = -13.77, t = -6.95, p < .0001$,
512 while there is no difference between the latter two $\beta = -.3, t = -0.16, p = .86$.

513 The remaining four variables (speaking a third language, learning L2 at school vs.
514 home, and learning L2 in a multilingual environment) do not affect RTs, all $\chi^2[6] < 5.87$,
515 all $p > .48$.

516 *OSC analysis*

517 As stated in the Introduction, we also wanted to assess the role of Orthography-to-
518 Semantics Consistency (OSC) in L2, and particularly whether this variable affects mor-
519 phological priming. Because OSC typically co-varies with morphological transparency
520 (Marelli et al., 2015), we first checked whether this was the case also in our set of stimuli,
521 as indeed it was (see figure 9; $F[2, 144] = 21.02, p < .0001$). We thus simply substituted
522 *morphological type* with OSC in the proficiency models that yielded significant priming
523 modulations with the former variable.

524 OSC modulates morphological priming in L2, via interactions with vocabulary, $\chi^2[1] =$
525 $181.84, p < .0001$ and morphological awareness, $\chi^2[1] = 111.53, p < .0001$. Phone-
526 mic discrimination does not seem to modulate priming significantly in the OSC model,
527 $\chi^2[1] = .27, p = .6$. Figures 10 and 11 illustrate these interactions, which both show the
528 same pattern: priming remains strong independent of the proficiency metrics when OSC
529 is high, but shrinks toward zero with growing vocabulary and morphological awareness
530 when OSC is low. Given that high OSC characterizes target words in the transparent
531 condition and low OSC marks target words in the opaque and orthographic conditions
532 (see Figure 9), these results essentially mirror those that emerged with vocabulary and
533 phonemic fluency above – transparent priming (i.e., priming at high OSC) is independent
534 of proficiency, while orthographic and, to some extent, opaque priming (i.e., priming at
535 low OSC) decreases with increasing proficiency.

536 In terms of how well OSC accounts for the priming pattern as compared to the
537 classic distinction between transparent, opaque, and orthographic primes, we computed

538 the Akaike Information Criterion (AIC; [Akaike, 1974](#)) for the category-based and OSC
539 models involving the proficiency metrics that were significant with both approaches,
540 that is, morphological awareness and vocabulary. In both cases, AIC is lower for the
541 OSC models (113613.5 vs. 111639.7, and 113623.8 vs. 111662.4, for morphological
542 awareness and vocabulary, respectively). These results suggest that OSC provides a
543 better account for the data than the categorical distinction between transparent, opaque,
544 and orthographic primes.

545 4. Discussion

546 In this study we show that orthographic and morphological priming differs in L1
547 and L2. In L1, we replicated the widely attested pattern whereby the recognition of a
548 target word is facilitated by the prior presentation of a semantically transparent (e.g.,
549 dealer-DEAL) or semantically opaque (e.g., corner-CORN) prime, but not by a non-
550 morphological, orthographic prime (e.g., public-PUB). In L2, genuine and opaque deriva-
551 tions provide facilitation, similarly to L1. However, form primes also provide facilitation,
552 contrary to the native language. We also found that transparent derivations yield more
553 priming than opaque primes, both in L1 and L2.

554 Critically, we discovered that this group-level pattern in L2 is modulated by read-
555 ers' proficiency, as tracked by phonemic discrimination, vocabulary, and morphological
556 awareness. While transparent priming remains consistently strong, facilitation in the
557 form condition decreases with increasing phonemic discrimination and vocabulary skills.
558 Opaque priming also shrinks with growing vocabulary, but less than form priming. Be-
559 cause both morphological conditions seem to behave differently from the orthographic
560 baseline, this confirms the genuine morphological nature of this effect. Morphological
561 awareness modulates opaque priming and we find no evidence that any other proficiency
562 metric is specifically related to morphological priming. Age of Acquisition also seems to
563 play little or no role, as attested also in [Veríssimo et al. \(2018\)](#).

564 Finally, we observed that Orthography-to-Semantic Consistency (OSC) affects lex-
565 ical decision in a second language, and extend the growing body of evidence for OSC
566 effects in L1 ([Marelli et al., 2015](#); [Amenta et al., 2017](#)). Interestingly, we found that
567 OSC also interacts with individual proficiency, and is able to account for morphological
568 priming as well as (or better than) the classic distinction between transparent, opaque,
569 and orthographic primes ([Amenta et al., 2020](#)).

570
571 At the group level, our results seem to confirm a pattern of facilitation often reported
572 in previous studies – transparent primes (e.g., *dealer-DEAL*) provide more facilitation
573 than orthographic controls (e.g., *dialog-DIAL*), while opaque primes (e.g., *corner-CORN*)
574 stand somewhere in between. Unsurprisingly, the statistical pattern is clearer for L1
575 than for L2. For L2, proficiency analyses (discussed below) provide crucial insight and
576 therefore the group-level pattern is not particularly important. More interesting is the
577 significant difference between transparent and opaque priming in L1-Italian. This repli-
578 cates the pattern reported by [Marelli et al. \(2013\)](#) for this language, and confirms that
579 at least some morpho-semantic processing happens early during the visual identification
580 of complex words, in line with other priming results (e.g., [Feldman et al., 2012](#); [Jared
581 et al., 2017](#)), a meta-analysis of masked priming data ([Davis and Rastle, 2010](#); [Feldman
582 et al., 2009](#)), and evidence from other paradigms (e.g., [Amenta et al., 2015](#); [Schmidtke](#)

583 et al., 2017). Amenta et al. (2020) recently showed that masked morphological priming
584 interacts with OSC in L1, which also suggests some early semantic processing triggered
585 by a morpho-orthographic analysis. Moreover, Amenta et al.’s results show that dynam-
586 ics in the lexical-semantic network qualify the broad distinction between transparent and
587 opaque words in important ways. We come back to this point below, when we discuss
588 the OSC analysis reported in this paper.

589 It is also important to note that we found opaque priming to be stronger than ortho-
590 graphic facilitation in L1-Italian, which again confirms the data by Marelli et al. (2013)
591 and shows that, even if some morpho-semantic processing is likely in place, morphological
592 segmentation happens independently of semantic transparency. This result is in keeping
593 with data from several other languages (e.g., Diependaele et al., 2011; Kazanina, 2011;
594 Longtin et al., 2003; Marslen-Wilson et al., 2008; Rastle et al., 2000), although it must
595 be noted that Milin et al. (2017) recently reported a weak priming effect for pairs with
596 substantial orthographic overlap, independent of the presence of a suffix.

597
598 Again at the group level, our results seem to support the idea that morphological
599 processing during visual word identification differs in L1 and L2. This is in line with
600 Clahsen and Felser (2006), Li et al. (2017), Li and Taft (2019) and, for inflectional prim-
601 ing, Feldman et al. (2010). This finding also seems to contradict Diependaele et al.
602 (2011). However, if one looks closely at the priming pattern observed in the individual
603 morphological conditions, the inconsistency is less than it would seem. Genuine deriva-
604 tions provide solid facilitation in both L1 and L2, which is consistent across studies. In
605 our experiment, opaque primes tend to yield less facilitation than transparent deriva-
606 tions in L2 (as they also do in L1) – again, this is comparable to the observations in
607 Diependaele et al. (2011). L1 and L2 differ most in form priming, with a clear null effect
608 in L1, in line with a large body of literature (e.g., Rastle et al., 2004; Longtin et al.,
609 2003; Forster et al., 1987), and clear orthographic similarity facilitation in L2. Again,
610 this pattern of results mirrors the findings of Diependaele et al. (2011).

611 The main difference between Diependaele et al. (2011) and our observations here is in
612 the comparison between form and opaque priming in L2 – opaque priming is somewhat
613 smaller in our experiment (19ms vs 26ms), which makes it harder to differentiate from
614 form priming, while these two conditions were statistically distinguishable in Diepen-
615 daele et al. (2011) (albeit only when the two groups of L2 learners that they considered
616 were analysed together, showing that this effect was not very strong even in their data).
617 Overall, then, despite a different outcome in the three-way interaction between *prime*
618 *relatedness*, *morphological type* and *language*, the difference between our data and Diepen-
619 daele et al. (2011) only consists in a somewhat weaker L2 opaque priming in the current
620 experiment.

621
622 L2 form priming is clearly solid here, as it was in previous experiments: orthographi-
623 cally similar words facilitate each other during lexical identification in a second language.
624 In line with previous reports, this contrasts with a very clear null effect in L1. This pat-
625 tern nicely mirrors the Prime Lexicality Effect (PLE) observed in native speakers (e.g.,
626 Forster and Veres, 1998) – nonwords provide strong facilitation to orthographically re-
627 lated targets in masked priming (e.g. *contrapt*–*CONTRAST*), but this facilitation is
628 reduced, and sometimes even turns into inhibition (Davis and Lupker, 2006), when the
629 prime is a real word (e.g., *contract*–*CONTRAST*). This phenomenon is classically inter-

630 preted in terms of lexical competition – both *contrapt* and *contract* would provide the
631 same amount of facilitation at the letter coding level, but the established lexical repre-
632 sentation for *contract* would then compete with that of the target word, thus generating
633 lexical inhibition that would offset the sub-lexical priming.

634 From this perspective, our data suggest that L2 words behave similarly to nonwords
635 in L1, mimicking the results obtained in native speakers by Grainger and Beyersmann
636 (2020). L2 lexical representations might not be very well established (or even present).
637 Therefore, lexical competition would be reduced (or absent), thus providing no offset to
638 the sub-lexical facilitation brought about by a form-related prime. This nicely connects
639 with the growing literature on novel word learning (e.g., Gaskell and Dumay, 2003;
640 Sobczak and Gaskell, 2019; Tamminen and Gaskell, 2008; Tamminen et al., 2010; Walker
641 et al., 2019), where lexical competition is often taken as the primary diagnostic for a
642 fully consolidated lexical memory.

643 This hypothesis also fits neatly with the proficiency analysis, particularly concerning
644 phonemic discrimination and vocabulary: L2 form priming shrinks with growing compe-
645 tence on these two skills. This may suggest that L2 lexical memories become more fully
646 established with growing proficiency, such that lexical competition is progressively more
647 obvious as readers gain command over a second language.

648 More generally, this interpretation is also consistent with recent explanations of non-
649 word morphological priming in L1. Grainger and Beyersmann (2017) suggest that the
650 reason why non-suffixed nonwords (e.g., *farmald*) prime their stems (*FARM*) while anal-
651 ogous word primes fail to do so (e.g., *dialog-DIAL*) is exactly that the former lack lexical
652 representations, and therefore provide no inhibition to their targets. Here we connect
653 this interpretation to the construct of lexicalization/consolidation of novel word mem-
654 ories, therefore providing a general framework to account for both nonword processing
655 and word learning in L1, and lexical processing along a proficiency continuum in L2.
656 Grainger and Beyersmann (2017) also center their model around activation of embed-
657 ded word units. This mechanism provides an alternative account for L2 orthographic
658 priming; in addition to form similarity due to shared letters, *freeze* might facilitate the
659 processing of *free* because the visual word identification system has recognized the target
660 as an embedded word within the prime. Note, however, that this alternative interpreta-
661 tion does not affect the core idea that words fail to provide strong inhibition in L2: if
662 form priming is to surface, *freeze* must not compete strongly with *free*, no matter where
663 the facilitatory side of the effect comes from.

664
665 Before moving to the individual proficiency effects, a word of caution is in order for
666 the group-level comparison between L1 and L2 priming. Our within-participant design
667 did not allow for an L1-L2 comparison within the same language. Of course, this leaves
668 the possibility open that the difference we observed here is related to the specific features
669 of Italian and English, rather than to their L1/L2 status, or to the different sets of items
670 that we used. Although we took great care in making the L1-Italian and the L2-English
671 stimulus sets as similar as possible, it will be important to see our findings replicated
672 with a different design, or with other languages.

673
674 The impact of individual readers' proficiency – as tracked by phonemic discrimina-
675 tion, vocabulary, and morphological awareness – extends well beyond the orthographic
676 condition, and critically qualifies the entire pattern of form and morphological priming.

677 Consistently across the three different metrics, the effect of transparent primes ap-
678 pears to be rather insensitive to proficiency. Also consistent across metrics, visual word
679 identification is dominated by mere form similarity when readers do not have great com-
680 mand over their L2. As the leftmost panels of Figure 4, Figure 5 and Figure 6 clearly
681 show, transparent, opaque and orthographic primes have barely-distinguishable effects
682 on their (pseudo-)stems at low levels of proficiency. This pattern resembles the re-
683 sults reported for the inflectional domain by Feldman et al. (2010), where lower profi-
684 ciency readers failed to show any different facilitation for morphological and orthographic
685 primes⁶. As with our suggestion above, this points to a rather weak lexical network in
686 low-proficiency L2 readers. At this stage, the lexicon may perhaps be characterized
687 more as a collection of unconsolidated word memories than as a network that supports
688 the lexical dynamics typical of L1.

689 These results suggest that morphological priming is a convenient metric to track the
690 emergence of a fully-fledged (i.e., L1-like) morpho-lexical system in a second language.
691 Early on, form similarity would be the only driving force, with no morpho-lexical distinc-
692 tion between orthographic, opaque, and transparent priming. As word representations
693 become more and more consolidated, lexical competition arises, driving down purely or-
694 thographic priming. Genuine morphological detectors would also start to develop, so
695 that complex words progressively differentiate from an orthographic baseline, eventually
696 yielding a pattern of facilitation that closely resembles L1.

697
698 Where do opaque primes stand in this framework? Interestingly, different proficiency
699 metrics seem to provide somewhat different answers here. For example, opaque priming
700 fits neatly with transparent priming in the interaction with phonemic awareness. This
701 resonates with group-level accounts of morphological priming that show no difference at
702 all between genuine and pseudo-derivations (e.g., Kazanina, 2011; Longtin et al., 2003;
703 Marslen-Wilson et al., 2008; Rastle et al., 2004). On the contrary, the interaction be-
704 tween masked priming and phonemic discrimination shows that, while opaque priming
705 is still significantly different from the orthographic baseline (thus confirming the genuine
706 morphological nature of these effects), it also differs from the transparent condition: the
707 facilitation from *corner* to *corn* shrinks more with growing proficiency than the facilita-
708 tion from *dealer* to *deal*. This pattern resonates with accounts of group-level effects in
709 early morphological processing that grant some role to semantics (e.g., Feldman et al.,
710 2009, 2012; Jared et al., 2017).

711 The pattern revealed by morphological awareness is also intriguing: the higher the
712 score on this metric, the smaller the opaque facilitation (whereas form and transparent
713 priming are largely unaffected). Thus, it seems that this skill helps the reader distin-
714 guish between genuine derivations and words that only have an orthographic appearance
715 of complexity. Since morphological awareness taps into one's capacity to manipulate
716 word parts in a meaningful way (and therefore is strongly based on semantics), this
717 connection may not be surprising. However, morphological awareness is also related to
718 production more than to comprehension, and requires explicit judgments, so that partic-
719 ipants have to deliberately access their morphological knowledge. This stands in stark

⁶Interestingly, it is not entirely clear whether morphological and orthographic primes were different from an unrelated baseline in Feldman et al. (2010), while these primes clearly yield quicker responses than unrelated controls in the present work.

720 contrast with masked priming, which taps into early perception and implicit/unaware
721 processing. Nevertheless, the data illustrated here suggest some connection between the
722 two tasks that surely calls for more investigation.

723

724 The critical importance of each reader’s proficiency profile in these data also relates
725 to: (i) the mounting evidence on the effect of individual variability in L1 (e.g., [Andrews](#)
726 [and Hersch, 2010](#); [Burt and Tate, 2002](#); [Andrews and Lo, 2013](#); [Beyersmann et al., 2015a](#));
727 (ii) proficiency studies in developing readers which show different morphological priming
728 profiles according to vocabulary and spelling skills ([Beyersmann et al., 2015b](#)); and (iii)
729 developmental data that point to some changes over the course of adolescence in the way
730 letter strings are processed ([Dawson et al., 2017](#)). Evidence is growing that experience
731 with the written language (and, possibly as a consequence, better and more refined
732 orthographic representations/processing) produces substantial change in the dynamics
733 behind visual word identification. A precise characterization of the cognitive profile of
734 each individual reader and a careful consideration of their experience with visual words
735 is increasingly fundamental to the field, because it seems to critically qualify most of the
736 phenomena previously believed to emerge in undistinguished groups of participants.

737 Particularly relevant here is the recent suggestion that readers with relatively lower
738 lexical and orthographic representations/processing may rely more on morphological
739 structure (e.g., [Beyersmann et al., 2015a](#); [Grainger and Beyersmann, 2017](#)). This is
740 very consistent with the general idea, fully supported by the present data, that morpho-
741 logical processing is modulated by language proficiency. [Beyersmann’s](#) and [Grainger’s](#)
742 work focused on L1; here we extend the idea to L2.

743 Other recent evidence shows that developing readers rely more on morphological
744 processing when their language is less consistent in its spelling-to-sound relationships
745 ([Mousikou et al., 2020](#); [Beyersmann et al., 2020](#)). Although these data focus more on the
746 sub-lexical stages of reading and visual word identification, they reinforce the idea that
747 morphological processing is modulated by the availability and/or quality of other levels
748 of representation that readers might use.

749

750 Among the many proficiency indices we considered here, vocabulary, phonemic dis-
751 crimination and morphological awareness turned out to be the best metrics to account for
752 L2 morphological priming. We would not want to draw bold conclusions based on these
753 data. There was not much evidence in the L2 literature on individual proficiency scores
754 and morphological priming, and therefore it was difficult to make specific predictions;
755 our approach was largely an exploratory one. Furthermore, the proficiency metrics were
756 somewhat correlated with each other. This is probably unavoidable given the complexity
757 underlying one’s knowledge of a language (e.g., [Leclercq et al., 2014](#)). We took great
758 care to ensure that this set of predictors was indeed mapping independent constructs
759 (see the results of the PCA illustrated above, in [Figure 3](#)). However, we cannot entirely
760 rule out the possibility that at least part of the priming modulation that we observed
761 here emerged spuriously as a consequence of this dense network of correlations. A few
762 considerations would suggest otherwise, though. For example, the three significant pre-
763 dictors do not seem to correlate particularly strongly as compared to other proficiency
764 metrics; the correlation coefficients between phonemic discrimination and morphological
765 awareness (.43) and between phonemic discrimination and vocabulary (.44) sit around
766 the lower quartile of the distribution. Also, morphological awareness is most strongly

767 tight to oral comprehension and spelling, neither of which modulates priming.

768 An obvious comparison for these data is the L1 results obtained on the issue by
769 [Andrews and Lo \(2013\)](#), [Andrews and Hersch \(2010\)](#) and [Beyersmann et al. \(2015a\)](#).
770 These findings focus particularly on vocabulary and spelling skills, and on their relative
771 strength. Using a more bottom-up, exploratory approach, our analyses highlight that
772 vocabulary modulates priming in L2, in line with some L1 reports ([Beyersmann et al.](#),
773 [2015a](#)), although not all ([Andrews and Lo, 2013](#)). We found no evidence for a specific
774 role of spelling in the modulation of masked morphological priming in L2; again, this is
775 in line with [Beyersmann et al. \(2015a\)](#), but not with [Andrews and Lo \(2013\)](#). Generally
776 speaking, it is perhaps not surprising that L1 and L2 results do not entirely match. There
777 is evidence, in fact, that native and non-native language processing recruit at least partly
778 different neural systems and cognitive mechanisms ([Sulpizio et al., 2020](#); [Liu and Cao,](#)
779 [2016](#)). Therefore, any comparison should be interpreted with some caution. However,
780 we note that, in this specific case, there seems to be more inconsistency in the L1 data
781 themselves than in the comparison between L1 and L2.

782 Why should these particular proficiency metrics affect morphological and form prim-
783 ing specifically? While the role of morphological awareness in the modulation of opaque
784 priming is fairly obvious (see above), it is less easy to understand why vocabulary and
785 phonemic discrimination should be big players here. We can only speculate at this stage,
786 but for what concerns vocabulary, one possibility relates to the proposal by [Beyersmann](#)
787 [et al. \(2015a\)](#) and [Grainger and Beyersmann \(2017\)](#); readers with a weak and relatively
788 small lexical network might rely more heavily on other sources of information, such as
789 morphology. This account, however, would be hard to extend to phonemic discrimina-
790 tion, which should not be particularly important in the quick and automatic identifica-
791 tion of visual words entailed by masked priming. More research is clearly needed here, to
792 complement our exploratory approach with some more specific confirmatory experiments.

793
794 Finally, we demonstrated for the first time an effect of Orthography-to-Semantic
795 Consistency (OSC; [Marelli et al., 2015](#)) in L2, showing that readers capture fine-grain,
796 probabilistic ties in form-to-meaning mapping outside of their native language. This
797 result invites an intriguing new perspective on the learning of a second language, which
798 may be related (among other things, of course) to an appreciation of the statistical
799 structure behind the relationship between form and meaning in the novel lexicon ([Forster](#)
800 [and Veres, 1998](#); [Castles et al., 2007](#); [Perfetti and Hart, 2002](#); [Perfetti, 2007](#); [Andrews and](#)
801 [Hersch, 2010](#); [Andrews and Lo, 2013](#); [Hersch and Andrews, 2012](#)). Further reinforcing
802 this suggestion, we found that sensitivity to OSC interacts with proficiency – the more
803 one gains command over L2, the more sensitive it becomes to probabilistic relationships
804 between orthography and semantics.

805 This, in turns, affects the priming pattern. When proficiency is low, priming is
806 strong across the board, that is, independent of OSC. When proficiency is high, instead,
807 priming is critically qualified by OSC, so that facilitation disappears for targets with
808 lower values on this metric. One possible account for this result is that, when the
809 target word comes from a lexical region where the correspondence between form and
810 meaning is largely arbitrary (i.e., OSC is low), participants discount form as a source of
811 information to meaning. Thus, they are left with purely lexical-orthographic processing,
812 where facilitation coming from the shared letters is offset by the lexical competition
813 between the prime and target representations. When OSC is high, the participants'

814 visual identification system knows that form does indeed point to meaning, and therefore
815 the (consistent) semantic information coming from the prime provides a headstart in
816 processing the target. This sensitivity to the structural characteristics of the lexical
817 space, however, only emerges when L2 proficiency is high.

818 The data described here also suggest that OSC provides a nice account of the priming
819 pattern independent of the classic categorical distinction between transparent, opaque,
820 and orthographic primes (see [Amenta et al., 2020](#), for similar evidence in L1). OSC
821 correlates with these categories, and it proved able to account for priming in the statistical
822 model even when these other predictors were removed. The AIC analysis also suggests
823 that OSC provides a better fit for the data than the classic categorical approach. This
824 may necessitate a different interpretation of morphological priming, which would depend
825 not only (or at all?) on the relationship between primes and targets themselves, but
826 on transparency in form-to-meaning mapping in the lexical region from whence the
827 target and the prime come ([Amenta et al., 2020](#)). This item-level, rather than category-
828 level account of priming resonates with [Milin et al. \(2017\)](#), who found that, overall,
829 most variability in priming was accounted for by between-prime variation, rather than a
830 systematic distinction between classes of prime-target relationships.

831 These considerations are relevant for the debate around the role of semantics in the
832 early stages of visual word identification (e.g., [Amenta and Crepaldi, 2012](#); [Davis and
833 Rastle, 2010](#); [Feldman et al., 2012](#)). First of all, it might justify the different results that
834 have sometimes been reported across experiments, particularly in different languages
835 where form-to-meaning mapping might easily be more or less consistent (e.g., [Kazanina,
836 2011](#); [Longtin et al., 2003](#); [Feldman et al., 2012](#)). Most importantly, an effect of OSC
837 in masked priming unequivocally requires *both* early access to semantic information, as
838 form-and-meaning accounts would suggest (e.g., [Feldman et al., 2012](#); [Milin et al., 2017](#)),
839 *and* the activation of all the input's possible orthographic units, independent of whether
840 these units will turn out to be meaningful in any given word, which is the fundamental
841 tenet of form-then-meaning theories ([Rastle et al., 2004](#); [Crepaldi et al., 2010](#); [Taft and
842 Nguyen-Hoan, 2010](#)). The focus of the theoretical debate would move beyond the issue
843 of whether semantics play an early role in complex word identification; the answer to this
844 question would be double-edged, as meaning does play a role, in the sense that semantic
845 information is accessed, but at the same time it doesn't, because orthographic units are
846 identified and activated independently of their transparency (e.g., [Amenta et al., 2015](#)).
847 A more important issue would be *how* form and meaning play their double act; OSC
848 provides an initial cue, but there are many questions that will need to be addressed,
849 such as determining the relevant orthographic neighbourhood that defines consistency
850 (e.g., [Marelli and Amenta, 2018](#)), and evaluating how much this is based on morphology
851 itself versus being a more general mechanism that identifies any possible form-meaning
852 regularity. As [Amenta et al. \(2020\)](#) suggest, the data currently available might not
853 yet be sufficient to justify a comprehensive reorientation towards the OSC approach;
854 after all, this variable correlates strongly with the classic categorical distinction between
855 transparent, opaque, and orthographic items, and it remains difficult to tease the two
856 sides apart. Nevertheless, the present data, and the growing body of OSC effects that
857 is accumulating (e.g., [Amenta et al., 2017](#); [Marelli and Amenta, 2018](#)), surely points in
858 this direction.

859 More generally, OSC highlights the role of the structural characteristics of the lexical-
860 semantic space whence words come, and particularly the probabilistic, associative cues

861 that tie representations together in this space. This marries well with some recent data in
862 L1. For example, [Grainger and Beyersmann \(2020\)](#) showed that morphological priming
863 is modulated by the conditional affix probability of the embedded word, i.e., how likely
864 it is in the language to find an affix after a given stem/embedded word. These data
865 demonstrate that priming is sensitive to lexical/morphological regularities, which, as the
866 present L2 data suggest, might be acquired through experience with a given language,
867 either native or non-native. From this perspective, priming would seem to depend on
868 the generation of predictions in visual word recognition, guided by prior linguistic input
869 and, again, the appreciation of probabilistic associative cues.

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874 **Supplementary material**

875 All the materials related to this paper (the stimulus list, the data sets, the analysis
876 scripts, and the tools that we used during the analysis) are publicly available at the Open
877 Science Framework (<https://osf.io/jnrvy/>).

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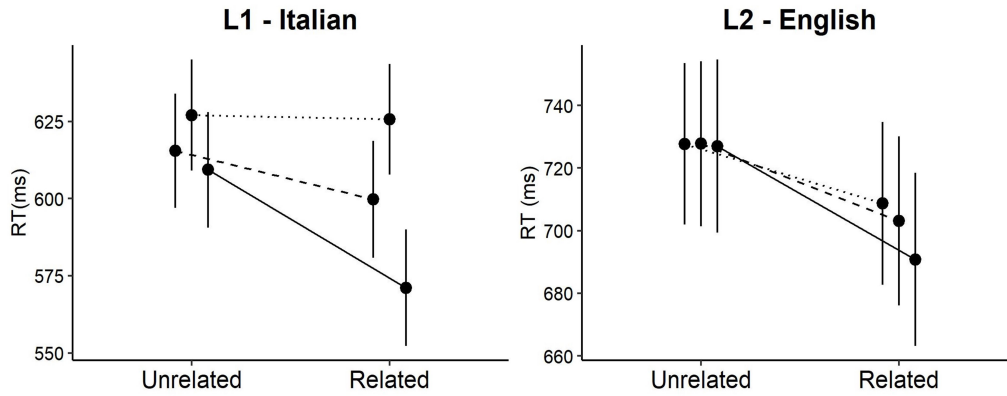


Figure 1: Model-based estimates of response times per condition, in L1 (left panel) and L2 (right panel). The solid, dashed and dotted lines represent the transparent, opaque and orthographic conditions, respectively. Error bars are 95% confidence intervals.

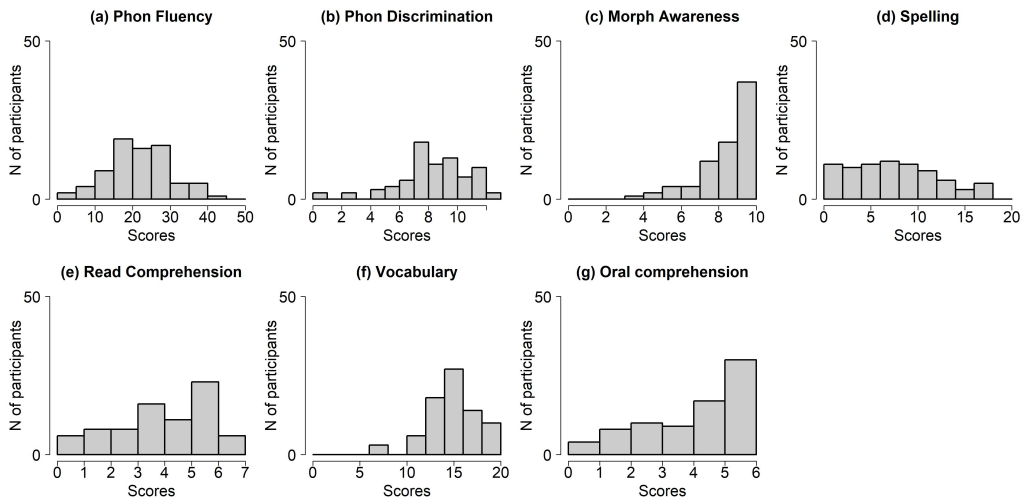


Figure 2: Participants' score distributions for each English proficiency subtest.

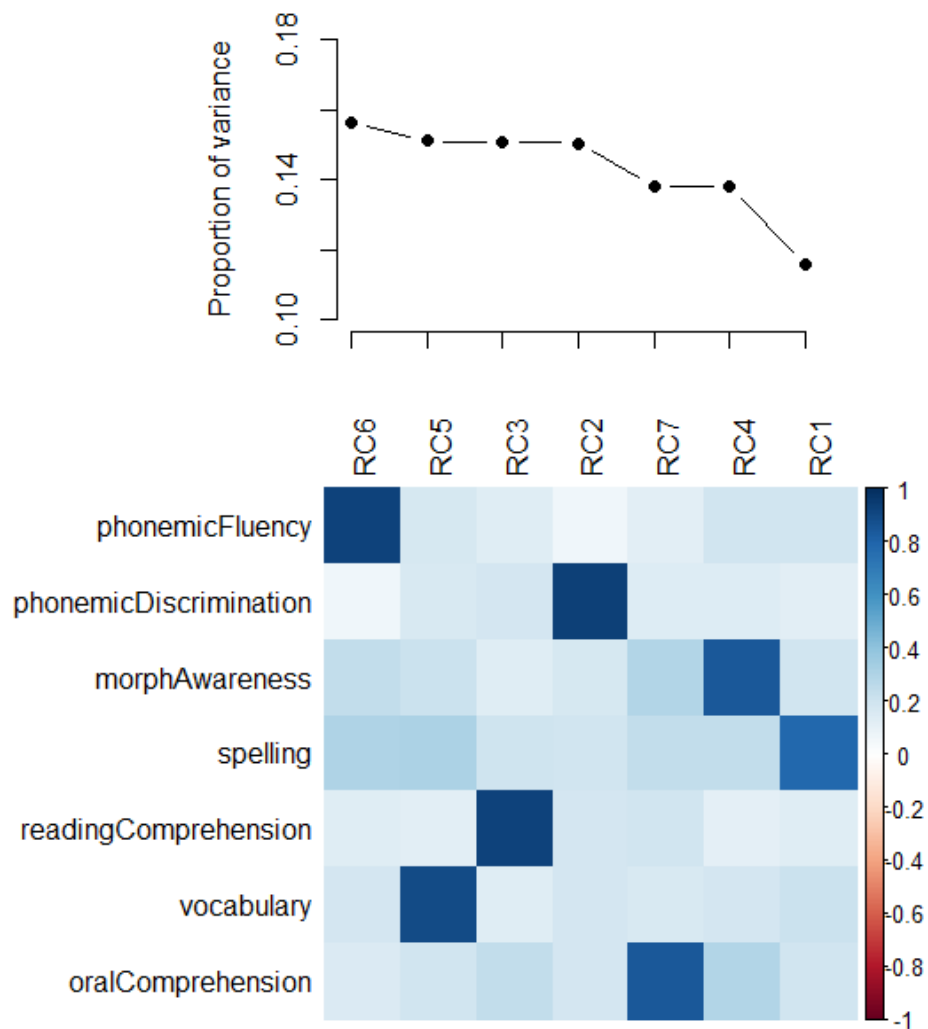


Figure 3: Illustration of the Varimax Principal Component Analysis on the seven proficiency metrics. The upper panel reports on the amount of variance accounted for by each Principal Component (RC). The lower panel describes the correlation between each Principal Component and the seven proficiency metrics; color codes for the strength of the correlation, as illustrated by the colorbar on the right.

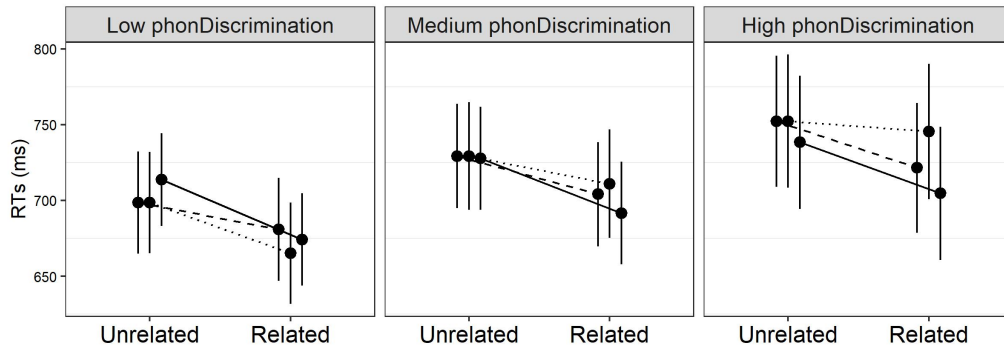


Figure 4: Model-based estimates of response times (RTs) relative to the interaction between prime relatedness, morphological type, and phonemic discrimination in L2. The solid, dashed and dotted lines represent the transparent, opaque and orthographic conditions, respectively. Effects are estimated at the 5th, 50th (median) and 95th percentile of the phonemic discrimination distribution. Error bars are 95% confidence intervals.

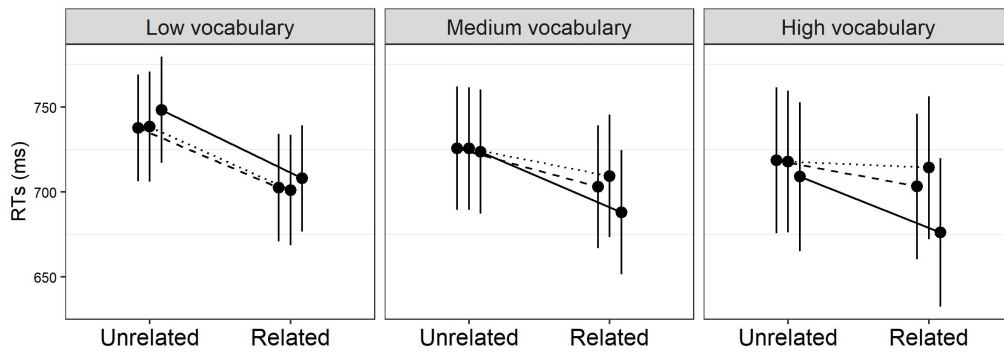


Figure 5: Model-based estimates of response times (RTs) relative to the interaction between prime relatedness, morphological type, and vocabulary in L2. The solid, dashed and dotted lines represent the transparent, opaque and orthographic conditions, respectively. Effects are estimated at the 5th, 50th (median) and 95th percentile of the vocabulary distribution. Error bars are 95% confidence intervals.

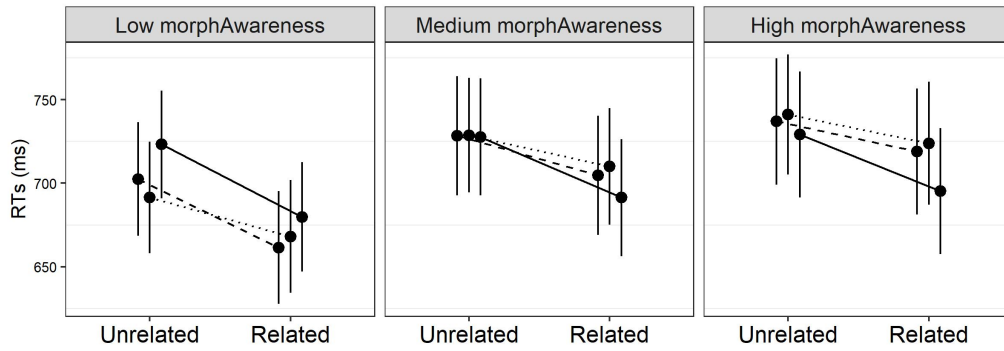


Figure 6: Model-based estimates of response times (RTs) relative to the interaction between prime relatedness, morphological type, and morphological awareness in L2. The solid, dashed and dotted lines represent the transparent, opaque and orthographic conditions, respectively. Effects are estimated at the 5th, 50th (median) and 95th percentile of the morphological awareness distribution. Error bars are 95% confidence intervals.

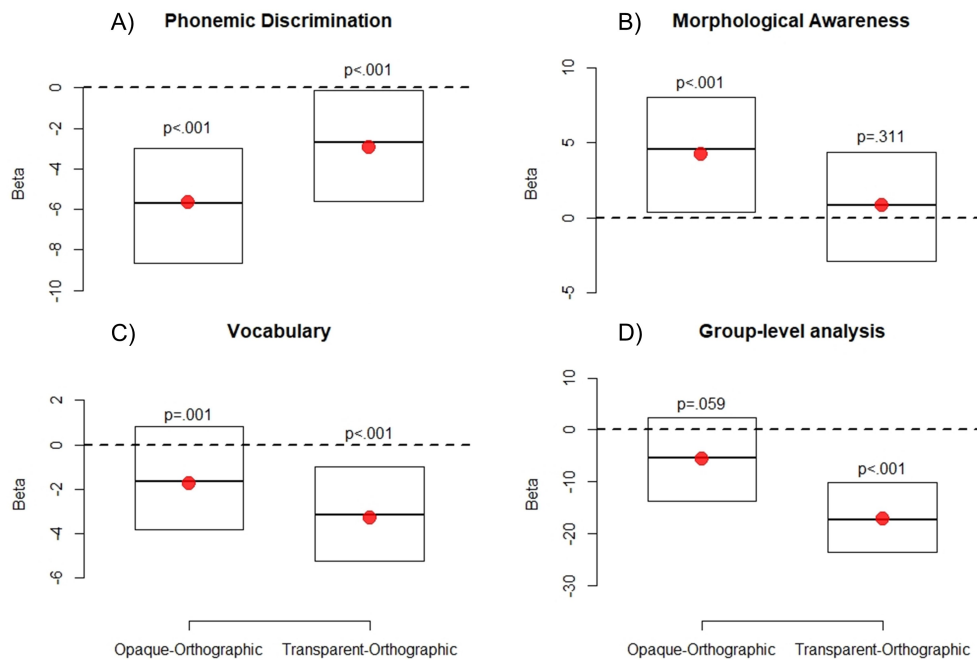


Figure 7: Jackknife results on the proficiency analysis. We used 200 replicates and, on each replicate, selected 40 out of 50 targets per condition, per participant. Each median estimate (the bold lines in the graphs) matches perfectly the full model estimates (the red dots). Also, the 5th and 95th percentiles (which define the boxes in the graphs) reflect nicely the significance of the estimated parameters in the full model (which is reported just above the boxes as a p value). Panel (a), (b) and (c) refer to the proficiency metrics that turned out to modulate priming in L2, while panel (d) refers to the L2 group-level analysis, for comparison.

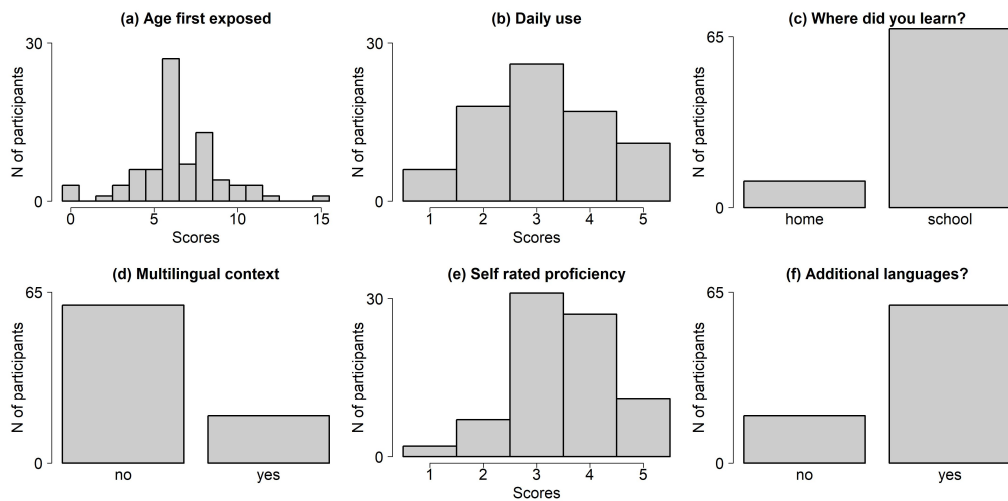


Figure 8: Scores distributions in the AoA questionnaire. All participants were Italian native speakers, the questions refer to English as a second language.

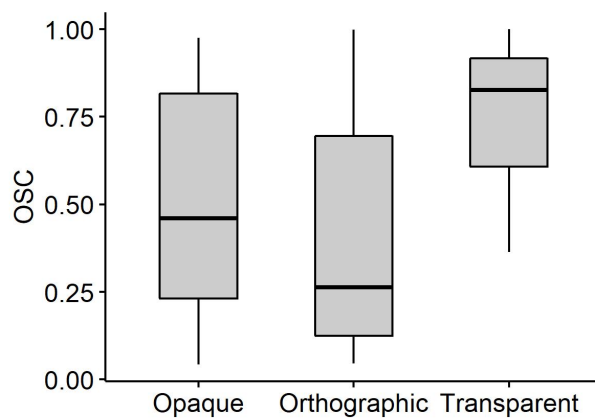


Figure 9: OSC distribution for the transparent, opaque and orthographic English target stems.

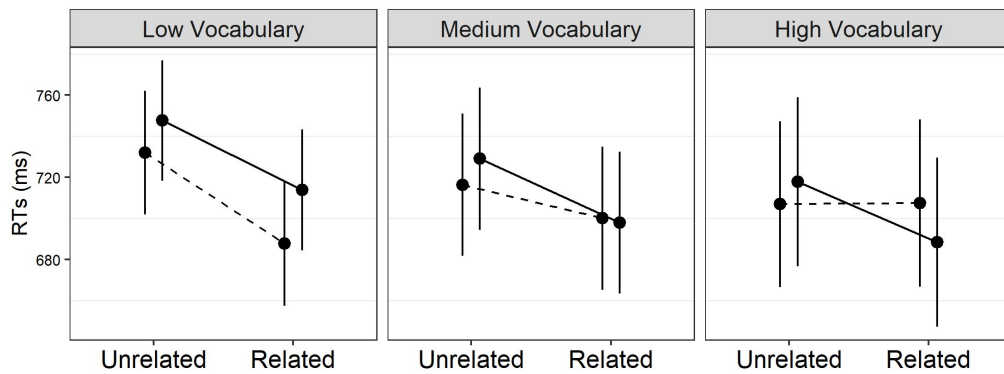


Figure 10: Model-based estimates of response times (RTs) relative to the interaction between prime relatedness, OSC, and vocabulary in L2. Effects are estimated at the 5th, 50th (median) and 95th percentile of the vocabulary distribution, and at the 20th (dashed line) and 80th percentile (solid line) of the OSC distribution. Error bars are 95% confidence intervals.

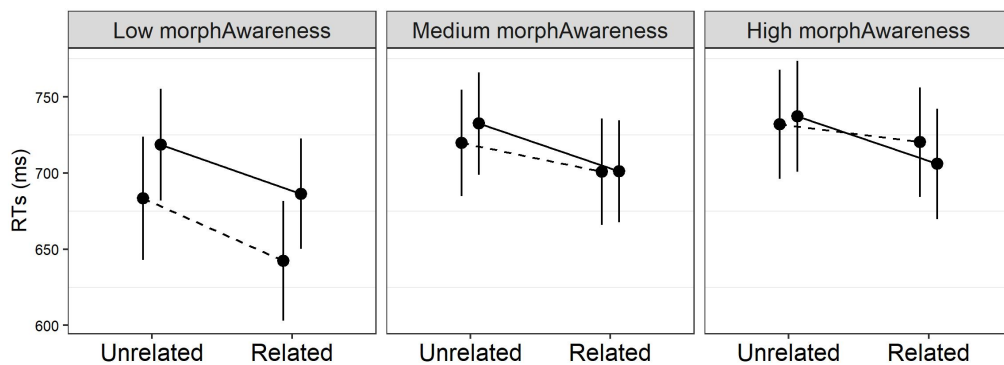


Figure 11: Model-based estimates of response times (RTs) relative to the interaction between prime relatedness, OSC, and morphological awareness in L2. Effects are estimated at the 5th, 50th (median) and 95th percentile of the morphological awareness distribution, and at the 20th (dashed line) and 80th percentile (solid line) of the OSC distribution. Error bars are 95% confidence intervals.

| | Transparent | Opaque | Orthographic |
|-----------------------------|--------------------|---------------|---------------------|
| Target frequency | 3.96 (0.67) | 3.63 (0.87) | 3.94 (0.84) |
| Target length | 5.16 (1.07) | 5.08 (0.84) | 4.94 (0.88) |
| Target Coltheart's N | 18.1 (11.3) | 20.1 (11.9) | 21.5 (13.4) |
| Related prime frequency | 2.92 (0.84) | 3.15 (0.78) | 3.22 (0.69) |
| Control prime frequency | 2.91 (0.68) | 3.09 (0.85) | 3.19 (0.67) |
| Related prime length | 7.70 (1.24) | 7.96 (1.21) | 7.52 (1.18) |
| Control prime length | 7.70 (1.24) | 7.96 (1.21) | 7.52 (1.18) |
| Related prime Coltheart's N | 3.6 (2.9) | 3.5 (2.6) | 4.2 (6.1) |
| Control prime Coltheart's N | 3.8 (2.9) | 3.8 (2.9) | 3.5 (2.5) |

Table 1: Stimulus statistics for the Italian L1 set; we report means and standard deviations. Frequency is reported in Zipf ([Brysbaert et al., 2018](#)).

| | Transparent | Opaque | Orthographic |
|-----------------------------|--------------------|---------------|---------------------|
| Target frequency | 4.09 (0.72) | 3.88 (0.74) | 3.72 (0.82) |
| Target length | 4.92 (0.65) | 4.80 (0.69) | 4.62 (0.68) |
| Target Coltheart's N | 6.66 (5.73) | 9.08 (7.78) | 11.72 (8.2) |
| Related prime frequency | 3.32 (0.93) | 3.43 (0.96) | 3.50 (0.93) |
| Control prime frequency | 3.30 (0.83) | 3.46 (1.03) | 3.47 (0.87) |
| Related prime length | 7.12 (1.15) | 7.09 (1.19) | 7.15 (1.68) |
| Control prime length | 7.12 (1.11) | 7.09 (1.16) | 7.15 (1.67) |
| Related prime Coltheart's N | 1.98 (2.5) | 2.50 (2.9) | 2.06 (3.2) |
| Control prime Coltheart's N | 3.4 (4.6) | 2.64 (4.7) | 3.04 (4.2) |

Table 2: Stimulus statistics for the English L2 set; we report means and standard deviations. Frequency is reported in Zipf ([Brysbaert et al., 2018](#)).

| | phonFluency | phonDiscrimination | morphAwareness | spelling |
|----------------------|--------------------------|---------------------------|--------------------------|-----------------|
| phonFluency | 1 | 0.25 | 0.54 | 0.61 |
| phonDiscrimination | 0.25 | 1 | 0.43 | 0.46 |
| morphAwareness | 0.54 | 0.43 | 1 | 0.64 |
| spelling | 0.61 | 0.46 | 0.64 | 1 |
| readComprehension | 0.35 | 0.44 | 0.4 | 0.49 |
| vocabulary | 0.45 | 0.44 | 0.54 | 0.65 |
| oralComprehension | 0.43 | 0.45 | 0.68 | 0.62 |
| | readComprehension | vocabulary | oralComprehension | |
| phonFluency | 0.35 | 0.45 | 0.43 | |
| phonDiscrimination | 0.44 | 0.44 | 0.45 | |
| morphAwareness | 0.4 | 0.54 | 0.68 | |
| spelling | 0.49 | 0.65 | 0.62 | |
| readingComprehension | 1 | 0.37 | 0.53 | |
| vocabulary | 0.37 | 1 | 0.51 | |
| oralComprehension | 0.53 | 0.51 | 1 | |

Table 3: Correlation among the English proficiency subtests.

1087 Appendix

1088 L1 – Italian

| Transparent condition | | |
|-----------------------|---------------|---------------|
| Target | Related prime | Control prime |
| ARCO | arcata | melone |
| ARTE | artista | sottile |
| ASMA | asmatico | fogliame |
| ASTRO | astrologo | signorile |
| ATTO | attore | morale |
| BANCA | bancario | minerale |
| BENDA | bendaggio | minerario |
| CALCIO | calciatore | ventricolo |
| CAMPANA | campanile | variabile |
| CANTO | cantore | mammola |
| CREMA | cremoso | fertile |
| CUBO | cubista | tessile |
| DELFINO | delfinario | carotaggio |
| DITO | ditata | idrico |
| DOSE | dosaggio | camerata |
| ERBA | erboso | areola |
| FAMA | famoso | ideale |
| FANGO | fangoso | porcile |
| FARINA | farinoso | adrenale |
| FATO | fatale | fidata |
| FIENO | fienile | vettore |
| FORNO | fornaio | frenata |
| FRUSTA | frustata | ciarpame |
| GETTONE | gettonato | scambista |
| GHIACCIO | ghiacciolo | campagnolo |
| LEGNO | legname | puerile |
| MAZZA | mazzata | bombola |
| MITO | mitico | botola |
| NERVO | nervoso | turista |
| NOIA | noioso | sadico |
| OCCHIO | occhiata | naturale |
| ORIGINE | originario | linguaggio |
| ORTO | ortaggio | litorale |
| PAROLA | paroliere | necrotico |
| PENSIONE | pensionato | petroliera |
| POLLO | pollame | nudista |
| REGIA | regista | pittore |
| SABBIA | sabbiatura | soporifero |
| SANO | sanitario | alcolista |
| SASSO | sassata | fazione |

| | | |
|-------------------------|---------------|---------------|
| SCHIFO | schifoso | monetario |
| SERVO | servile | sudista |
| STILE | stilista | liberale |
| STRADA | stradale | eleganza |
| TASTO | tastiera | frittata |
| TAVOLO | tavolata | plateale |
| TAXI | taxista | pontile |
| UGGIA | uggioso | spumame |
| VELLO | veliero | bravata |
| VETRO | vetrata | fondale |
| Opaque condition | | |
| Target | Related prime | Control prime |
| ABITO | abitudine | documento |
| ARTIGLIO | artigliere | locandiere |
| BALLO | ballatoio | sedimento |
| BILE | bilico | barile |
| BRIGA | brigante | revisore |
| CALVO | calvario | lebbroso |
| CARRO | carriera | fiorentino |
| CAVIA | caviale | lunario |
| CERNIA | cerniera | sciabola |
| COLLE | collezione | parcheggio |
| CONO | conato | senile |
| COSCIA | coscienza | comunista |
| COSTA | costanza | pigmento |
| COSTO | costume | normale |
| DOGA | dogana | urbana |
| FALCO | falcata | corroso |
| FIRMA | firmamento | bilanciere |
| FORMA | formaggio | simpatico |
| FORZA | forziere | pompieri |
| FOSSO | fossile | calcolo |
| GARA | garante | padrone |
| GELO | geloso | dorato |
| GENERO | generoso | pazienza |
| GESTA | gestazione | sventurato |
| GOMITO | gomitolo | capienza |
| GRANO | granito | radioso |
| INDOLE | indolenza | discepolo |
| MAESTRA | maestranze | vivandiere |
| MASSO | massaggio | artistico |
| MATTO | mattanza | plenario |
| MIMO | mimosa | tisana |
| ORMA | ormeggio | timoroso |
| OSTE | ostaggio | acquario |

| | | |
|-------------------------------|---------------|---------------|
| PIETA' | pietanza | stellata |
| PIGNA | pignolo | festivo |
| QUIETE | quietanza | vituperio |
| RETE | retaggio | lampante |
| RETTA | rettile | violino |
| SALE | salario | formale |
| SERENA | serenata | volubile |
| SOSTA | sostanza | alleanza |
| STIVA | stivale | europeo |
| TATTO | tattico | caldaia |
| TEMPERA | temperanze | plafoniera |
| TESTA | testamento | cioccolato |
| TRATTO | trattore | scuderia |
| VANTO | vantaggio | piacevole |
| VENTO | ventola | pelvico |
| VINO | vinile | embolo |
| VIOLA | violenza | opinione |
| Orthographic condition | | |
| Target | Related prime | Control prime |
| ALBERO | albergo | istinto |
| AVO | avorio | patria |
| BANDA | bandiera | convento |
| BARRA | barracuda | cespuglio |
| BOCCA | boccia | sobria |
| CAMBIO | cambusa | ridosso |
| CAVO | cavallo | codardo |
| CELLA | cellula | relitto |
| CLAVA | clavicola | prematureo |
| CONGRUO | congrega | obsoleta |
| CORDA | cordoglio | travaglio |
| CORO | corallo | baruffa |
| CORTE | corteccia | scongiuro |
| FARO | faringe | omicida |
| GUADO | guadagno | ridicola |
| GUANO | quanto | stalla |
| LAMA | lamento | monello |
| LANA | lancia | radice |
| LENZA | lenzuola | cardiaco |
| LUCE | lucertola | dinosauro |
| LUPO | lupara | frolla |
| MALE | malta | riffa |
| MANDRIA | mandrillo | demoniaco |
| MANO | manto | spola |
| MASSA | massacro | collasso |

| | | |
|---------|------------|------------|
| MERCE | mercurio | castagno |
| META | metallo | dipinto |
| MUSEO | museruola | idilliaco |
| OBLIO | obliquo | cruento |
| ORDINE | ordigno | ristoro |
| PALLA | pallido | storico |
| PASSERO | passerella | salmonella |
| PELLE | pellicola | pagamento |
| PIANO | pianeta | salotto |
| PRODE | prodigio | prefisso |
| RAGGIO | raggiro | colosso |
| RESTO | restauro | vergogna |
| RISO | riserbo | ghianda |
| SALA | salasso | frangia |
| SALAME | salamandra | malaugurio |
| SCALO | scalogno | sonaglio |
| SCAMPO | scampolo | ossequio |
| SCIA | sciame | staffa |
| SOFFIO | soffitto | clausola |
| SPIA | spiaggia | orologio |
| SPINA | spinaci | litigio |
| SQUALO | squallido | trapianto |
| TRAMA | tramonto | sostegno |
| TRIBU' | tribuna | lattice |
| VELA | velcro | olezzo |

1089 L2 – English

| Transparent condition | | |
|------------------------------|---------------|---------------|
| Target | Related prime | Control prime |
| ACID | acidic | yearly |
| ACRE | acreage | plunder |
| ADOPT | adopted | kingdom |
| AGREE | agreement | equipment |
| ALARM | alarming | composer |
| ANGEL | angelic | watcher |
| ARTIST | artistry | calmness |
| BARON | baronet | voucher |
| BEARD | bearded | thinker |
| BLOOD | bloody | active |
| BOMB | bomber | lessen |
| BULB | bulbous | leftist |
| CHILL | chilly | finely |
| CLOUD | cloudless | enactment |
| CREAM | creamy | watery |

| | | |
|-------------------------|---------------|---------------|
| CRITIC | critical | tendency |
| DIET | dietary | wearily |
| DREAM | dreamer | masonry |
| DRUNK | drunkard | feathery |
| EMPLOY | employer | addition |
| ERUPT | eruption | vicarage |
| FILTH | filthy | harden |
| FIZZ | fizzle | touchy |
| FLESH | fleshy | lovers |
| FLOAT | floater | missive |
| GLOOM | gloomy | millar |
| GOLF | golfer | thinly |
| GOVERN | government | situation |
| GREEN | greenery | snobbish |
| GUILT | guilty | formal |
| INHIBIT | inhibitory | amateurish |
| LEGEND | legendary | anxiously |
| MARSH | marshy | thorny |
| MOURN | mourner | tripper |
| NORTH | northern | friendly |
| NYMPH | nymphet | acutely |
| OXYGEN | oxygenate | fossilise |
| POET | poetry | dealer |
| QUIET | quieten | mimicry |
| REACT | reaction | physical |
| RENEW | renewable | exemption |
| RISK | risky | downs |
| SCALD | scalding | jauntily |
| SOFT | soften | heroic |
| TEACH | teacher | finally |
| TOAST | toaster | wishful |
| TRAIN | trainee | cookery |
| TUFT | tufted | silken |
| VIEW | viewer | ranger |
| WIDOW | widowed | beastly |
| Opaque condition | | |
| Target | Related prime | Control prime |
| AMEN | amenable | palpably |
| AMP | ample | widen |
| ARCH | archer | feudal |
| AUDIT | audition | selfless |
| BOARD | boarder | factual |
| BRAND | brandy | safely |
| BRISK | brisket | foundry |
| BUZZ | buzzard | loyally |

| | | |
|-------------------------------|---------------|---------------|
| COAST | coaster | muffler |
| COUNT | country | service |
| COURT | courteous | developer |
| CRAFT | crafty | vainly |
| CROOK | crooked | pottery |
| CRYPT | cryptic | dweller |
| DEPART | department | production |
| DISC | discern | starter |
| EARL | early | within |
| FACET | facetious | distantly |
| FLEET | fleeting | simplify |
| FLICK | flicker | adviser |
| FRUIT | fruitless | alcoholic |
| GLOSS | glossary | sufferer |
| GLUT | gluten | bridal |
| GRUEL | grueling | existent |
| HEART | hearty | folder |
| HELM | helmet | brutal |
| INFANT | infantry | validity |
| INVENT | inventory | murderous |
| IRON | irony | sandy |
| LIQUID | liquidate | extremism |
| NUMB | number | really |
| ORGAN | organic | leaflet |
| PLAN | planet | editor |
| PLUCK | plucky | winger |
| PLUM | plumage | broiler |
| PUTT | putty | fishy |
| QUEST | question | actually |
| RATION | rational | steadily |
| SCULL | scullery | narrowly |
| SECRET | secretary | obviously |
| SIGN | signet | frosty |
| SNIP | sniper | hourly |
| SPLINT | splinter | idealism |
| STILT | stilted | gaseous |
| THICK | thicket | scruffy |
| TREAT | treaty | angler |
| TROLL | trolley | naughty |
| TRUMP | trumpet | chatter |
| UNIT | united | others |
| WHISK | whisker | coyness |
| Orthographic condition | | |
| Target | Related prime | Control prime |
| AGAIN | against | perhaps |

APPEND
ARSE
BASIL
BROTH
BUTT
CANDID
COLON
COMMA
DEMON
DIAL
ELECT
ETHER
EXTRA
FORCE
FREE
FUSE
GALA
GLAD
HEAVE
INTERN
INVEST
JERK
NEIGH
PARENT
PHONE
PLAIN
PLUS
PUB
PULP
QUART
RABBI
SCRAP
SHOVE
SHUN
SIGH
SMUG
SQUAW
STAMP
STIR
STUB
STUN
SURF
SURGE
TACT
TEXT
TWIN
TWIT

appendix
arsenal
basilisk
brothel
button
candidacy
colonel
command
demonstrate
dialog
electron
ethereal
extract
forceps
freeze
fuselage
galaxy
glade
heaven
internation
investigate
jerkin
neighbour
parenthesis
phonetic
plaintiff
plush
public
pulpit
quartz
rabbit
scrape
shovel
shunt
sight
smuggle
squawk
stampede
stirrup
stubborn
stunt
surface
surgeon
tactile
textile
twinkle
twitch

believer
timidly
benignly
warfare
prayer
epileptic
ability
equally
instruction
lately
suburban
rumbling
justify
prudish
golden
citation
keeper
cuffs
firmly
revolutionary
anaesthetic
twisty
struggled
lectureship
dreadful
absurdity
filmy
gently
gifted
roller
weekly
ninety
tricky
itchy
happy
twelfth
oddity
defector
buoyant
moisture
misty
medical
novelty
spindly
booklet
cheaply
lesser

VILLA
WEIR

villain
weird

grossly
manly
