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How Do Speakers of a Language with a Transparent Orthographic System Perceive the L2 Vowels of a Language with an Opaque Orthographic System? An Analysis through a Battery of Behavioral Tests

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Abstract: Background: The present study aims to investigate the effect of the first language (L1) orthography on the perception of the second language (L2) vowel contrasts and whether orthographic effects occur at the sublexical level. Methods: Fourteen adult Greek learners of English participated in two AXB discrimination tests: one auditory and one orthography test. In the auditory test, participants listened to triads of auditory stimuli that targeted specific English vowel contrasts embedded in nonsense words and were asked to decide if the middle vowel was the same as the first or the third vowel by clicking on the corresponding labels. The orthography test followed the same procedure as the auditory test, but instead, the two labels contained grapheme representations of the target vowel contrasts. Results: All but one vowel contrast could be more accurately discriminated in the auditory than in the orthography test. The use of nonsense words in the elicitation task eradicated the possibility of a lexical effect of orthography on auditory processing, leaving space for the interpretation of this effect on a sublexical basis, primarily prelexical and secondarily postlexical. Conclusions: L2 auditory processing is subject to L1 orthography influence. Speakers of languages with transparent orthographies such as Greek may rely on the grapheme–phoneme correspondence to decode orthographic representations of sounds coming from languages with an opaque orthographic system such as English.

Keywords: orthography; speech perception; deep; shallow

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1. Introduction

Each known spoken word is represented in the lexical memory, and it is activated through the presentation of the corresponding acoustic signal (Taft et al. 2008). Upon the learning of reading and writing, existing spoken word recognition is used by orthographic processes that demand reading through a recodification of orthography into phonology (Rastle and Brysbaert 2006; Van Orden 1991). Evidence of the effect of orthographic information on spoken word processing can be found in several studies. For example, Seidenberg and Tanenhaus (1979) investigated the role of orthography on rhyme detection. Cue words were presented both aurally and visually to the listeners. The findings indicated that orthographically different rhymes (e.g., "rye-tie") had longer detection latencies than orthographically similar rhymes (e.g., "pie-tie"). Frauenfelder et al. (1990), in a series of phoneme-monitoring experiments, examined the influence of lexical knowledge on the identification of French phonemes. The results showed that phonemes that are represented with many different graphemes (e.g., /k/ is represented by <c> and <k>) demonstrated slower detection times than phonemes that have only one orthographic representation (e.g., a non-final /t/ is represented only by the grapheme <t> in French).

Apart from the effect of orthography on the perception of *native* segmental contrasts, other studies reveal the impact of orthography on the perception of *non-native* contrasts. In an eye-tracking study of Weber and Cutler (2004), Dutch listeners listened to English words and were instructed to click on the appropriate picture. It was found that when listeners were instructed to click on "panda", they looked at "pencil" during the first spoken syllable, whereas English speakers acted reversely. In contrast, once they were told to click on "pencil", Dutch listeners looked only at the labeling of pencil and not at the one of panda. The authors attributed this eye-tracking performance of Dutch listeners to the fact that both English vowels /æ/ [pæn.d@] and /ɛ/ [pɛn.s@l] are perceived by Dutch speakers as instances of the Dutch /ɛ/; English /ɛ/ was perceived as being phonetically closer to the Dutch /ɛ/ than the English /æ/ was. However, this could also be explained as an effect of the listeners' native orthographic system (Cutler et al. 2006). For Dutch speakers, the rendition of the grapheme <e> is similar in both Dutch and English, while the rendition of <a> is different in the two languages; in the first syllable of the Dutch word "panda", <a> represents a back vowel. The grapheme <e> is perceived as representing a front central vowel. This provides a sensible explanation for the Dutch listeners' attention to the first syllable of the label word "pencil", when they were instructed to click on the label "panda" since the grapheme <e> of the former word represents the vowel /æ/ for Dutch speakers, which corresponds to the first vowel of the word "panda".

Simon et al. (2010) examined the effect of orthographic representation during a training study on the ability of listeners to learn a non-native phonological contrast. In particular, they investigated whether the French phonological contrast /u/ - /y/ could be facilitated if learners were exposed to grapheme-to-phoneme correspondences. The study employed native speakers of American English who did not have any knowledge of French. The participants were divided into two groups: one sound-only group, which was provided with the pronunciation of nonword pairs, and one sound-spelling group, which was provided with the spelling of the aforementioned nonword pairs. All of them completed AXB discrimination tests. The findings indicated that there were no significant differences in the contrast discrimination scores between the two groups, and there was variation in the participants' scores. Although access to orthographic information did not facilitate the perception of novel phonological contrasts, the authors offer several potential explanations for the lack of support for their initial hypothesis.

The present study aims to examine the effect of L1 orthography on the discrimination of L2 vowel contrasts. Moreover, it aims to find evidence that supports a particular locus or loci with respect to the orthographic effects since previous studies suggested different levels of auditory processing, which depended on the orthographic transparencies of languages. First, it is important to define the terms *sublexical*, *prelexical*, and *postlexical*, which will be extensively used to describe the locus or loci of orthographic effects. Escudero and Wanrooij (2010) pointed out that the term *sublexical* refers to detailed processing units (i.e., phonemes and graphemes) without taking into consideration the chronological order of processing; therefore, such representations can be activated before, during, or after lexical access. By contrast, the terms *prelexical* and *postlexical* imply a specific chronological order for the activation of representations that can be before and after lexical access, respectively.

There is no convergence with respect to the *locus* or *loci* for orthographic effects in the literature (Escudero and Wanrooij 2010). That is, it is still unknown if *prelexical*, *lexical*, or *postlexical* levels are activated in the phonological decoding process. Hallé et al. (2000) investigated the effect of orthography at the phoneme level, concluding that a lexical access mechanism was activated for word recognition. More specifically, English listeners detected the phoneme /b/ in English "bs/bt" words (e.g., "absurde") rather than /p/ that depicts the words' actual pronunciation (e.g., /apsyrd/). Moreover, in a word-guessing gating task, the /b/ responses overcame the /p/ responses for "bs/bt" words before the presentation of sufficient acoustic information for the word guessing. Ziegler and Ferrand (1998) concluded that orthography affects the perception of words at the lexical level. The researchers found that the lexical decision of words that could be inconsistently spelled was longer and more difficult in comparison to the lexical decision of words that had consistent spelling and that this consistency effect was absent from nonwords. The authors also observed effects at the prelexical level. Ventura et al. (2004) argued that lexical influence emerging from orthographic knowledge damages spoken word recognition. In a shadowing task, which triggers lower processing levels, the previous orthographic consistency effect was not confirmed and, thus, such an effect could only be lexical and not sublexical. Effects on the postlexical level were found by some studies (e.g., Ganong 1980; Seidenberg et al. 1984). However, it is difficult to determine whether the processing takes place either on the prelexical or the postlexical level through a behavioral task (Escudero and Wanrooij 2010).

In contrast, some studies show the effects of orthography on auditory processing at the *sublexical* level. For example, Taft et al. (2008) investigated auditory primes that had the same English orthography as their spoken target words (e.g., the pseudohomograph /dri:d/, which has the same spelling as the target word "dread"), concluding that they were easier than primes which were phonologically equal to their target words but differed in spelling (e.g., the word /šri:d/ followed by the spoken word "shred"). The authors carried out two auditory lexical decision tasks, which were created in a way that they did not allow participants to be aware of the relationship between phonology and orthography. The orthographic facilitation relied on sublexical information enabled for the prime. The authors added that their findings contradict the findings of Ventura et al. (2004) and Ziegler and Ferrand (1998) since the latter authors employed real words in their studies, implying that the orthographic effect occurred at a lexical rather than a sublexical level. Escudero and Wanrooij (2010) examined the effect of L1 orthography on the perception of Dutch vowels by Peruvian-Spanish listeners by employing a categorization task and two directly comparable tasks: an auditory XAB task and an orthography XAB task. The results showed that orthography affected the discrimination accuracy of the Dutch contrasts since there were significant differences in accuracy between the auditory and the orthography task. For instance, the Dutch /a/-/ɑ/ contrasts could be discriminated better in the orthography task than in the auditory task since the orthographic representation of the Dutch /a/, namely <aa>, helped listeners to understand that the Dutch /a/ has a longer duration than the Dutch /ɑ/. Another important conclusion that emerged from the study is that orthographic effects on speech perception might have occurred at a sublexical level.

This study aims (a) to investigate the effect of L1 orthography on the discrimination of English vowel contrasts by Greek learners of L2 English, and (b) to assess whether there are L1 orthography effects on L2 auditory processing at the sublexical level. It employs a similar behavioral protocol to the one used by Escudero and Wanrooij (2010). However, it differs from this study in that it examines a new set of languages, namely, Greek and English. To our knowledge, no other studies have investigated the effect of L1 Greek orthography on the perception of L2 English vowel contrasts. Moreover, the methodological protocol is quite different as the stimuli of this study consist of nonsense words. Finally, the speakers of this study were not involved in any categorization test (i.e., involving the mapping of non-native sounds onto native sounds), but they completed two AXB discrimination tests, an auditory test and an orthography test to determine whether there are differences in the discrimination of particular English contrasts between the two tests (i.e., the interaction of contrast and test). The effect of contrast on the discrimination scores in each test will also be investigated to reveal how different types of L2 contrasts are affected by L1 orthography. Further predictions about the discrimination of English vowel pairs in the two tests will follow in the next section after describing the phonological and orthographic system of both Greek and English.

Greek and English Phonological and Orthographical Systems

The Greek vowel system consists of five pure vowels /i e a o u/, and there are no vowel duration distinctions; however, vowel duration is affected by stress (Georgiou and Themistocleous 2021). The vowel system of English (Received Pronunciation) is more complex than the Greek system consisting of 11 main vowel monophthongs that can be lax /ɪ ʊ e æ ʌ ɒ/ or tense /iː uː ɜː ɔː ɑː/ (Roach 2004). This study will focus on specific English vowel pairs that are predicted to be difficult to discriminate by Greek speakers since both members of the contrasts are not present in the Greek phonological system. Specifically, the English vowel contrasts are the following: /ɪ/ - /iː/, /ɑː/ - /ʌ/, /ɑː/ - /æ/, and /ɔː/ - /ɒ/.

The *Perceptual Assimilation Model* (Best 1995; Best and Tyler 2007) predicts the discrimination of non-native sound contrasts on the basis of the assimilation of each contrast member to the phonological categories of the listeners' L1. In particular, it proposes six assimilation types that determine the discrimination of non-native sound contrasts. According to the model, much discrimination difficulty is predicted in the *Single Category* assimilation where both members of a sound contrast are assimilated to the same L1 phonological category, with both members constituting equally good or bad exemplars of that category. Better discrimination accuracy is expected in the *Category Goodness* difference assimilation in which two non-native sound contrasts are assimilated to a single L1 phonological category with one member constituting a good exemplar of that category while the other constitutes a deviant one. Moreover, the newly introduced *Universal Perceptual Model* (UPM; Georgiou 2021b) predicts that completely overlapping contrasts (those sharing the same above-chance responses; i.e., L1 responses for given L2 categories that significantly differ from a predetermined chance score) might receive poor discrimination unless listeners perceive some phonetic distance between the L2 sounds; in the latter scenario, the goodness-of-fit ratings of the above-chance responses significantly differ with each other. Considering the phonetic distance between the Greek and English vowels (see Figure 1) and the categorization of English vowels by Greek speakers in previous studies (Georgiou 2019), it is predicted that in the auditory discrimination test, learners will assimilate both members of the English vowel contrasts /ɔː/ - /ɒ/, /ɑː/ - /æ/, and /ɑː/ - /ʌ/ to a single Greek phonological category, struggling to perceive much phonetic distance between the two contrast members. Alternatively, according to UPM, these contrasts will receive poor discrimination since they will be classified as above chance responses in the same set of L1 phonetic categories. In contrast, the discrimination accuracy of the English /ɪ/ - /iː/ vowel contrast will range from moderate to good since Greek learners may be able to perceive within category acoustic differences between the members of the contrast (see Georgiou 2019); therefore, this contrast will be more accurately discriminated than the previous contrasts.

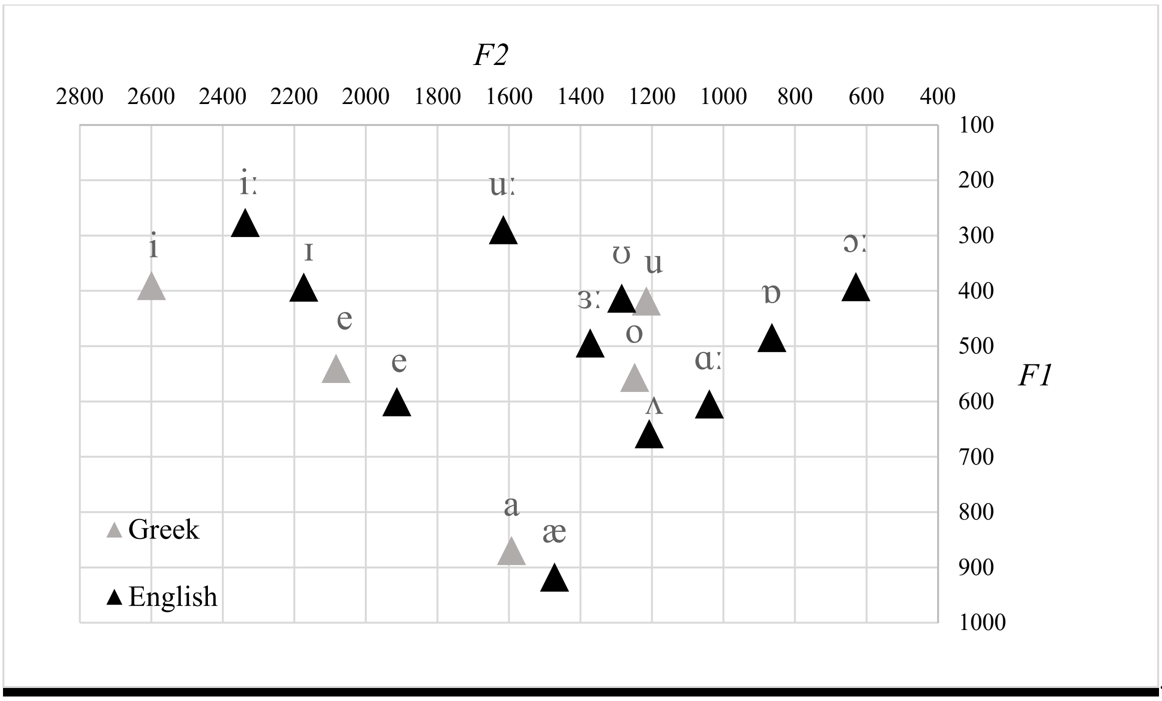

Figure 1. *F1* × *F2* of the (Cypriot) Greek and English (Timberlake 2004) vowels as produced by their respective adult native speakers.

Greek and English have two fundamentally different orthographic systems. Although the correspondence of grapheme–phoneme is often violated in Greek with a plethora of letters/digraphs for every single vowel (e.g., the Greek phoneme /i/ can be written as <ι>, <η>, <υ>, <οι>, <ει>, or <υι>), each orthographic grapheme (i.e., letter) is only read in one manner (Coutsougera 2007). Therefore, the Greek orthographic system can be described as *shallow* (or transparent). In contrast, the English orthographic system allows a grapheme to represent more than one phoneme; e.g., grapheme <a> can stand for either phoneme /æ/ such as in <cat> or phoneme /ɑː/ such as in <hard>. Thus, the English orthographic system can be described as *deep* (or opaque). According to the *Orthographic Depth Hypothesis* (ODH), shallow orthographies allow new readers (i.e., children) to decode the written words easier, being able to read them with fewer problems since these words are recognized with respect to the phonology of the language. On the contrary, deep orthographies create difficulties for new readers by decreasing their reading tempo since the word recognition process relies on the words' morphology via the printed visual orthographic structure of the word (Frost et al. 1987; Katz and Frost 1992). Therefore, ODH supports that shallow orthographic systems might force speakers to lean on *prelexical* decoding by identifying at first glance one by one the phonemes of a word, while deep orthographic systems might cause speakers to rely on *lexical* decoding without breaking the word into smaller parts (Escudero and Wanrooij 2010).

The results of Erdener and Burnham (2005) suggest that speakers with transparent L1 orthographies cannot easily learn new L2 words when there is not a straightforward relationship between orthography and phonology, as in the case of languages with an opaque orthographic system. Escudero et al. (2014) argued that the effect of L1 orthography depends on the similarity of the L1–L2 grapheme–phoneme correspondences. For example, when the grapheme–phoneme correspondences between Spanish and Dutch were congruent, Spanish learners of Dutch were facilitated in the learning of Dutch words, whereas when the grapheme–phoneme correspondences were incongruent, the learning of Dutch words was hindered. This shows that learners of native languages with transparent orthographies do not always have difficulties in the acquisition of sounds from opaque L2 orthographic systems since this ability is determined by the similarity of the correspondence of graphemes and phonemes between the two languages.

A well-known debate regarding the development of reading is the grain size of the orthography–phonology correspondences that are important for the learning of reading. It was suggested that children employ both *small-size* (i.e., grapheme–phoneme mappings) and *large-size* correspondences (i.e., rhyme and whole word recognition) in reading; this depends on several factors such as reading task type, the type of words, etc. (Goswami and East 2000; Perry and Ziegler 2000). Small unit correspondences are difficult to be read by children with orthographically inconsistent languages (e.g., English), whereas larger units are phonologically easier to process, and thus they are developed from the beginning of reading. In contrast, children with orthographically consistent languages (e.g., Greek, Italian, Spanish) develop orthographic representations that code phonology at the smallest grain size from the beginning of reading (Goswami et al. 2003). An interesting finding provided by Goswami et al. (2003) is that English-speaking children developed more than one recoding strategy in an effort to cope with the challenge of decoding the opaque orthography of English. It was found that they develop both "small grain" and "large grain" size strategies at the same time, confirming the *flexible-unit-size* hypothesis (Goswami et al. 2003).

Several studies demonstrate that L2 is subject to L1 influence at the phonological and phonetic level (Best and Strange 1992; Georgiou et al. 2020; Georgiou 2021a). Non-native acoustic information is filtered through the listeners' L1 resulting in deficient L2 speech perception and production patterns. In this line, it is predicted that Greek speakers will attempt to decode English words using patterns of their L1, and more specifically, processes of shallow orthography (i.e., decode one by one the phonemes of a given word) rather than processes of deep orthography for the decoding of English words. Thus, we expect that learners will have better performance in the auditory test compared to the orthography test. For instance, it is predicted that in most cases, there will be a selection of the English grapheme <i> instead of <ee> when listening to words representing the English contrast /ɪ/ - /iː/ because the latter English grapheme might be associated with the Greek vowels /e/ + /e/ since the learners' L1 decodes phonemes one by one. For the English contrast /ɑː/ - /æ/, it is predicted a preference for the English grapheme <a> instead of <ea> as the latter English grapheme might be associated with the Greek vowels /e/ + /a/. With respect to the English contrast /ɑː/ - /ʌ/, it is hypothesized that learners will mostly associate both English target phonemes with the grapheme <a> instead of <u> because they are heard as acoustic instances of the Greek /a/, which is transcripted with the English <a>. Finally, in regard to the English contrast /ɔː/ - /ɒ/, Greek learners will probably mostly select the English grapheme <o> instead of <ou>, since these English vowels are heard as acoustic instances of the Greek /o/ which is transcripted with the English <o>. Note that the English <ou> is often associated with the Greek /u/ due to its graphemic similarity to the Greek digraph <ου>, which stands for /u/. Thus, a negative effect of orthography is predicted since the English language has a deep orthographic system with one grapheme to stand for several phonemes, which Greek does not possess. We believe that the discrimination of all contrasts will be difficult since the grapheme–phoneme correspondences between the two languages are incongruent. We also predict that there will be orthographic effects at the sublexical level (i.e., grapheme–phoneme correspondence). However, we cannot specify whether this effect would be either on the prelexical or postlexical level due to the nature of the task. Table 1 shows the English graphemes and phonemes and the possible association of English graphemes with Greek phonemes.

Table 1. Target English graphemes and phonemes and possible association of English graphemes with Greek phonemes by the Greek learners of English.

English Grapheme	English Phoneme	Possible Association
<i> - <ee>	/ɪ/ - /iː/	/i/ - /ee/
<ea> - <a>	/ɑː/ - /æ/	/ea/ - /a/
<a> - <u>	/ɑː/ - /ʌ/	/a/ - /u/
<ou> - <o>	/ɔː/ - /ɒ/	/u/ - /o/

2. Methodology

2.1. Participants

Fourteen Greek learners of English (8 males, 6 females) participated in the study. The English learners were recruited from universities in Cyprus; specifically, they were BA, MA, or PhD students. First, a questionnaire was provided to the participants to obtain information about their characteristics such as age, age of English learning onset, etc., as well as information about their proficiency level in English. All learners were living permanently in Cyprus, and none of them had ever lived either for a short or a long period of time in another country. Their ages varied from 21 to 30 years (M_{age} = 26.9), and the mean onset of learning English was 8.9 years. Moreover, the questionnaire asked learners to rate their speaking, writing, understanding, and reading skills in English on a 1–5 point Likert scale (1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good). According to their mean ratings, they had moderate speaking and understanding skills (M = 3.2, M = 3.2) and good writing and reading skills (M = 4.1, M = 4.3) in English. All participants had normal hearing and did not have any language disorders.

2.2. Stimuli

The stimuli consisted of four English vowel contrasts: /ɪ/ - /iː/, /ɑː/ - /æ/, /ɑː/ - /ʌ/, and /ɔː/ - /ɒ/. The English vowels were recorded at a 44.1 kHz sample by two adult native speakers of English (Received Pronunciation); one female and one male. The native speakers were asked to produce at a normal speaking rate carrier phrases that included monosyllable nonsense words, which targeted the members of the vowel contrasts in the frame of /CVC/. The nonsense words corresponded to the phonotactics of real words and were of low probability (for the calculation of word probability, see Vitevitch and Luce 2004). The carrier phrase was "I said /CVC/ to some friends" (following Levy and Strange 2008). Two different acoustic versions of the same vowels emerged from the productions of the two English speakers. The /CVC/ words were detached from the carrier phrases in Praat speech processing software (Boersma and Weenink 2020) and transferred to the script.

2.3. Procedure

2.3.1. Auditory Test

The participants of the study completed an auditory AXB discrimination test (Best et al. 2001) in which they listened in a random order to a triad of tokens that targeted the English vowel contrasts, and they were asked to decide whether the second vowel (X) was the same as the first (A) or the third (B) vowel. Words were presented in four possible trial types: AAB, ABB, BAA, and BBA. Participants were asked to decide by clicking on the appropriate response that was visually provided through the PC script. The learners saw two boxes with the label "first" for the first vowel and "third" for the third vowel; they discriminated a total of 96 items each (4 contrasts × 4 trials × 3 vowels × 2 repetitions) in four different AXB tests (one for each contrast). The interstimulus interval was set at 1 s. To prevent solely auditory discrimination of the tokens, the A and B tokens were produced by a single female voice, whereas the X tokens were produced by all female and male English speakers (following Escudero and Wanrooij 2010).

2.3.2. Orthography Test

The participants also completed an orthography AXB discrimination test that was identical to the auditory test. Only the response labels differed. Instead of presenting the labels "first" and "third" for the first and the third vowel, respectively, the labels contained the orthographic representation of English vowels. Because an English phoneme might have several orthographic representations, we selected English graphemes that would have a high chance of being perceived as correspondences of the wrong phonemes rather than the actual ones due to the effect of L1 orthography; this would allow us to investigate any orthographic effects. Specifically, the /ɪ/ - /iː/, /ɑː/ - /æ/, /ɑː/ - /ʌ/, and /ɔː/ - /ɒ/ contrasts were represented by the graphemes <i> - <ee>, <ea> - <a>, <a> - <u>, and <ou> - <o>, respectively. All participants performed the orthography test after the auditory test.

3. Results

The results of the auditory test demonstrated that the participants' performance in the discrimination of contrasts in nonsense L2 words was poor, ranging from 57% to 69%. In the orthography test, their discrimination performance was even worse compared to the auditory test, ranging from 42% to 65%. Table 2 shows the mean discrimination accuracy of English vowel contrasts by Greek learners in both the auditory and the discrimination test. Figure 2 illustrates the boxplots of discrimination accuracy.

A *two-way repeated measures ANOVA* with *Scores* as the dependent variable (percentages of correct responses), and *Test* (two levels) and *Contrast* (four levels) as the within-subject factors was used. The results revealed a significant effect of *Test* ($F(3, 13) = 8.33$, $p < 0.05$), *Contrast* ($F(3, 13) = 6.74$, $p < 0.05$), and a *Test* × *Contrast* interaction ($F(3, 13) = 10.09$, $p < 0.05$).

Table 2. Mean discrimination accuracy (%) and Standard Deviations (*SD*) of English contrasts by Greek learners and significant difference for the discrimination accuracy between auditory and orthography tests.

	Auditory Test	**Orthography Test**	**Significance of Difference**
Contrast	**Mean (*SD*)**	**Mean (*SD*)**	***p* Value**
/ɪ/ - /iː/	69 (6.6)	65 (4.6)	>0.05
/ɑː/ - /æ/	66 (6)	46 (9.4)	<0.05
/ɑː/ - /ʌ/	57 (4.9)	38 (5.3)	<0.05
/ɔː/ - /ɒ/	59 (10)	42 (6)	<0.05

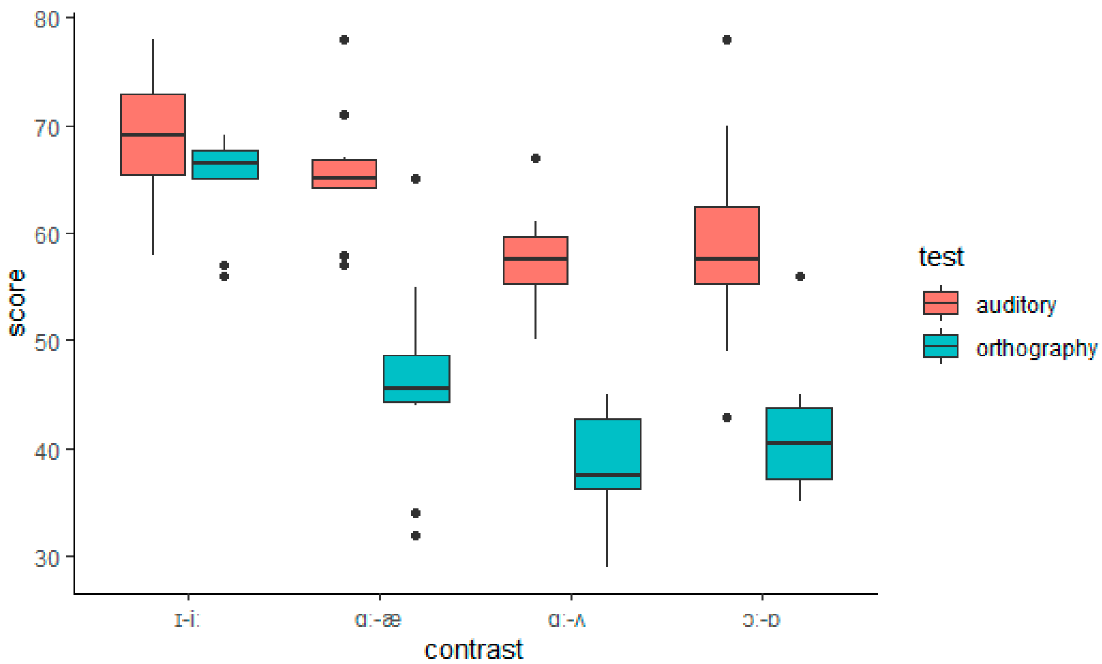

Figure 2. Boxplot representing the discrimination of English vowel contrasts in the auditory and orthography test.

Two *one-way repeated measures ANOVA* were conducted to determine differences in the discriminability of each contrast in the two tests. *Scores* was the dependent variable, and *Contrast* was the independent variable. The findings showed that there was a significant effect of *Contrast* ($F(3, 13) = 6.13$, $p < 0.05$) in the auditory test. Follow up Bonferroni posthoc tests indicated significant differences between /ɪ/-/iː/ - /ɑː/-/ʌ/, /ɪ/-/iː/ - /ɔː/-/ɒ/, /ɑː/-/æ/ - /ɑː/-/ʌ/, and /ɑː/-/æ/ - /ɔː/ - /ɒ/. Moreover, the findings showed a significant effect of *Contrast* ($F(3, 13) = 9.54$, $p < 0.05$) in the orthography test. The Bonferroni posthoc test revealed significant differences between the /ɪ/ - /iː/ and the other vowel contrasts, and between /ɑː/ - /æ/ and /ɑː/ - /ʌ/.

We employed *paired sample t-tests* to investigate differences between the auditory and the orthography test for each contrast. The findings showed that there were significant differences between the auditory and the orthography test for the contrasts /ɑː/ - /æ/ ($t(13) = 5.12$, $p < 0.05$), /ɑː/ - /ʌ/ ($t(13) = 5.77$, $p < 0.05$), and /ɔː/ - /ɒ/ ($t(13) = 4.85$, $p < 0.05$). In contrast, no significant differences emerged for the /ɪ/ - /iː/ contrast ($t(13) = -0.92$, $p > 0.05$).

4. Discussion

The present study aimed to investigate the effect of orthography on the discrimination of English vowel contrasts by Greek learners of English. Moreover, it aimed to examine the locus or loci for orthographic effects on speech perception. To this end, the participants completed two different ABX tests: one auditory-oriented test and one orthography-oriented test.

The findings showed that all vowel contrasts under investigation except for /ɪ/ - /iː/ could be discriminated better in the auditory than in the orthography test. Therefore, there is an obvious interference of the speakers' L1 orthographic system with the discrimination of non-native sounds. This is consistent with the findings of several studies (e.g., Escudero et al. 2014), which indicate that speakers of languages with shallow orthographies use their L1 orthographic patterns to decode input from languages with a deep orthographic system. Specifically, Greek, which is the learners' L1 in this study, has a transparent orthographic system in which a grapheme stands for a single phoneme, while English, which is the learners' L2, has an opaque orthographic system in which a grapheme can stand for various phonemes. Nevertheless, the /ɪ/ - /iː/ contrast was discriminated in the same manner in both tests. We assume that learners might have known that the long duration of /i/ is associated with the English digraph <ee> rather than <i>, and thus upon hearing a vowel that was perceived as long, they associated it with the aforementioned L2 digraph. Therefore, orthography did not affect the responses of learners since they mostly concentrated on the acoustic properties of vowels.

Another important finding is the variation in the discrimination scores of the vowel contrasts in both the auditory and the orthography test. For the auditory test, this is justified by the different acoustic characteristics of each English vowel and their perceived similarity with Greek vowels, considering that L1 and L2 vowels are located in a shared phonological space and affect each other (Best and Tyler 2007; Flege 1995). For the orthography test, we can conclude that L1 orthography exercises different effects in each L2 vowel contrast. This might be explained through the learners' interlanguage and the frequency in which a phoneme is represented by a specific grapheme. For example, it is rare for <ee> to represent /ɪ/, but it is very common for it to represent /iː/. To that end, learners will be able to better discriminate the /ɪ/ - /iː/ contrast in the orthography test in comparison to the /ɔː/ - /ɒ/ contrast since the vowels of the latter contrast are commonly represented either by <a> or <o> (e.g., <a> for 'call' /ɔː/, but also for 'wash' /ɒ/, and <o> for 'port' /ɔː/, but also for 'cost' /ɒ/).

A crucial question that this study aimed to answer was the locus or loci for orthographic effects. The present study showed an orthographic influence on the phonological discrimination of non-native contrasts and, therefore, a *sublexical* level is activated during the decoding of L2 input. What is already known is that there were no orthographic effects on a *lexical* level since we elicited phonological discrimination accuracy by using nonsense words. Therefore, orthography effects occurred at either a *prelexical* or a *postlexical* level. These findings corroborate earlier findings in the literature, which demonstrate a prelexical (e.g., Taft et al. 2008) or even both a prelexical and postlexical effect of orthography on auditory processing (Escudero and Wanrooij 2010). One critical point which has to be taken into consideration is that we are not able to know the chronological order of activation in such a type of behavioral test (e.g., if a prelexical effect took place first; c.f., Norris et al. 2000). This is because the effects on this lower-processing level might have occurred initially to a *postlexical* level and, at a later stage, this level might have yielded the activation of *prelexical* cues (Escudero and Wanrooij 2010).

Nevertheless, the nature of the behavioral tasks used in this study allows us to avoid to some extent the reflection of metalinguistic knowledge. Specifically, we used two forced-choice discrimination tasks rather than phoneme monitoring (Dijkstra et al. 1995), phoneme counting (Treiman and Cassar 1997), and phoneme deletion (Castles et al. 2003) tasks that reflect metalinguistic knowledge. This lets us conclude that L1 orthographic effects took place at a *prelexical* level, but such a claim should be treated with caution (see also Escudero and Wanrooij 2010).

Nonsense words are not directly associated with single lexical units since they do not carry meaning. In the absence of strong lexical competition effects, representations may be activated at the sublexical level, as previously mentioned. Nevertheless, nonsense words are not completely empty of lexical competition since phonotactics may facilitate the recognition of spoken words (Vitevitch and Luce 1999). The likelihood of a lexical effect even in the presence of nonsense words in this study was minimized by the inclusion of low-probability nonsense words. Previous evidence showed that phonotactic probability influenced the ratings of the word-likeness of nonwords, such that speakers rated high-probability nonwords as being more similar to English words compared to low-probability nonwords (Vitevitch et al. 1997, 2000). Thus, the lexical level had minimal involvement in this study.

5. Conclusions

The present study indicated that the effects of L1 orthography could be transferred to L2 speech perception. Moreover, the results are consistent with our initial prediction since the effects of L1 orthography emerged at a sublexical level. The findings of this study can be important for language teachers, who should pay attention to the fact that speakers of languages with transparent orthographies (e.g., Greek) may experience difficulties in accurately perceiving the sounds of a non-native language with an opaque orthographic system (e.g., English). Therefore, they should dedicate some time to teaching the correspondences between graphemes and phonemes. Although we tried to control the effect of sociolinguistic factors (e.g., age of English learning onset) and linguistic factors (e.g., L1), we are aware that other factors such as learners' cognitive functions (e.g., phonological short-term memory, intelligence) may determine the influence of L1 orthography on L2 speech perception; these functions can be taken into consideration in a future study. Finally, the addition of a control group of native L2 speakers in a future extension of the study would render the claims much stronger.

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