

## RESEARCH NOTE

# Word and pseudoword superiority effects in Italian–English bilinguals\*

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*Two indices of automatic orthographic processing, the word and pseudoword superiority effects, were explored in native Italian speakers familiar with English (late learners) and native English-speaking controls unfamiliar with Italian. Participants performed a forced-choice letter identification task with five categories of words: Italian words and pseudowords, English words and pseudowords, and nonwords. Native Italian speakers showed superiority effects for both languages, whereas English-speaking controls showed superiority effects only for English. These results suggest that orthographic processing can become automatic with extensive training in late bilinguals.*

## Introduction

In alphabetic languages, learning to read requires becoming familiar with not only a specific set of alphabetic symbols but also the letter combinations that characterize the orthography, that is, the arrangement of letters into sequences according to specific combinatorial rules of the language. The process underlying this increased familiarity with letters and letter sequences is considered a form of perceptual expertise: the visual system becomes increasingly efficient in recognizing the visual form of words, an ability that is considered crucial for the development of fluent reading skills (e.g., McCandliss, Cohen and Dehaene, 2003). Indeed, research has shown that orthography plays an important role in word recognition and reading. For example, in lexical decision tasks, in which participants are required to decide whether or not strings of letters are real words, readers are faster at rejecting illegal (e.g., GLWK) than legal (e.g., LAPE) strings of letters (e.g., Forster, Mohan and Hector, 2003). Moreover, studies have demonstrated that single letters are recognized more efficiently when embedded in orthographically legal sequence of letters (even when that sequence of letters does not form a real word) compared to random combinations of letters or letter in isolation, a phenomenon termed the “word superiority effect” (e.g., Reicher, 1969).

The word superiority effect has been observed across several experimental conditions and tasks (e.g., Reicher,

1969; Wheeler, 1970; McClelland, 1976; Prinzmetal, 1992) and has later been divided into two separate effects (McClelland, 1976). The advantage of real word over legal nonwords (or pseudowords), that is, participants’ higher accuracy in identifying letters embedded in words compared to letters embedded in pseudowords, is considered an index of familiarity with specific words and therefore hinges on word identification (McClelland, 1976; Grainger, Bouttevin, Truc, Bastien and Ziegler, 2003; Grainger and Jacobs, 2004). We will refer to this effect as the word superiority effect.<sup>1</sup> The advantage of pseudowords over illegal letter strings (or nonwords), that is, participants’ higher accuracy in identifying letters embedded in pseudowords compared to letters embedded in nonwords, is considered an index of familiarity with the orthographic structure of a language (McClelland, 1976; Carr and Pollatsek, 1985; Grainger et al., 2003). We will refer to this effect as the pseudoword superiority effect. Importantly, these two effects reflect mainly orthographic, not phonological, regularity (Baron and Thurston, 1973; Baron, 1974; Spoehr and Smith, 1975; Krueger, 1992) and they are not eliminated by presenting the stimuli as a mix of uppercase and lowercase letters (e.g., McClelland, 1976). These findings suggest that orthographic regularities are applied to abstract orthographic codes and that basic visual features play a minimal role in letter recognition under experimental conditions that elicit these effects (Henderson and Chard, 1980). Therefore, word and pseudoword superiority effects can be considered behavioral indices of familiarity

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<sup>1</sup> In this paper, we adopt this definition of word superiority effect, as distinct from the original definition of the word superiority effect proposed by Reicher (1969). The present definition allows us to contrast the word superiority effect with the pseudoword superiority effect and to disentangle the effect of the familiarity with the words of a language from the effect of the familiarity with the orthography of the language.

with the words of a language and familiarity with the orthography of the language, respectively.

The specific mechanisms underlying these effects are still a matter of debate (McClelland, 1979; McClelland and Rumelhart, 1981; Grainger et al., 2003; Grainger and Whitney, 2004; Dehaene, Cohen, Sigman and Vinckier, 2005). Regardless of their nature, the effect of the context on letter identification is hypothesized to operate automatically, that is, be stimulus-driven and initiated without deliberate intention (Posner and Snyder, 1975; LaBerge, 1981; Logan, 1992), and reflect how words are represented and processed at the neural level (e.g., Dehaene et al., 2005). In this sense, the presence of these effects is considered to be a window on the architecture of the brain circuitries involved in word recognition.

Behavioral evidence regarding superiority effects in bilinguals could prove valuable in the study of how expertise with a new orthography develops during second language acquisition. Such behavioral evidence could both inform and constrain understanding of the development of orthographic processing skills at the neural level. While a number of studies investigating the development of the word and pseudoword superiority effects have been conducted with young readers and individuals with dyslexia (e.g., Krueger, Keen and Rublevich, 1974; McCaughey, Juola, Schadler and Ward, 1980; Chase and Tallal, 1990; Grainger et al., 2003), only a handful of studies have used these effects to explore the development of orthographic processing in second language acquisition. In one such study (Favreau, Komoda and Segalowitz, 1980), a word superiority effect (measured as the difference in accuracy between words and anagrams of the same words) was observed for the first but not the second language in fluent English–French bilinguals, although a superiority effect for the second language emerged when stimuli were presented for a longer period of time. According to the authors, these results indicate that bilinguals, even when fluent in a second language, show less automated processing of orthographic redundancies in the second language. It is important to note that the bilinguals in this study were chosen specifically because they showed slower reading rates for the second language in pre-screening tests. Therefore, it is difficult to draw conclusions about the causes of their less efficient use of orthographic redundancies.

Studies employing different indices of orthographic processing suggest that proficient bilinguals do show evidence of automatic orthographic processing for the second language. For example, skilled bilinguals were found to use orthographic redundancies in the second language when visually encoding and processing unfamiliar letter strings (Altenberg and Cairns, 1983; Frenck-Mestre, 1993) or words belonging to their first language (van Heuven, Dijkstra and Grainger, 1998). In masked lexical decision tasks, when participants are

unaware of prime words, the orthographical relationship between primes and targets was observed to slow down target recognition regardless of whether primes and targets were from the same language or different languages (Bijeljac-Babic, Biardeau and Grainger, 1997); moreover, such inhibition increased with proficiency in the second language. These studies show that the orthography of a second language can be integrated in a bilingual reader's linguistic system and can affect word recognition even for the native language.

The purpose of the present study was to determine whether word and pseudoword superiority effects for a second language could be found in late learners of that language. We tested Italian native speakers who were fluent speakers of English. Although Italian and English orthographies are partially overlapping, remarkable differences exist between the two languages. For example, some letter combinations, such as ⟨wha⟩ and ⟨tha⟩, are extremely frequent in English but completely absent in Italian. Similarly, Italian orthography is characterized by letter combinations that are very infrequent in English (e.g., ⟨chia⟩, ⟨suo⟩, ⟨sui⟩, ⟨cie⟩, ⟨glia⟩, ⟨sgh⟩, ⟨aiu⟩). Further, all Italian words end with a vowel, whereas most English words end with a consonant.

Participants were tested in a forced-choice letter identification task (also known as the Reicher-Wheeler paradigm) designed after Chase and Tallal (1990) and Grainger et al. (2003). In this task, participants are presented with briefly displayed strings of letters, subsequently masked, and asked to choose from two options which letter was presented in a given position in the string. Each group was presented with two blocks of trials, one comprised of Italian stimuli, the other of English stimuli. We made the following predictions:

- Prediction 1. Based on the pattern of results described in previous studies (e.g., Chase and Tallal, 1990; Grainger et al., 2003), word and pseudoword superiority effects were predicted in both groups for their native languages.
- Prediction 2. Because the native Italian participants lived in the United States at the time of testing and were highly familiar with English, it was predicted that they would show superiority effects for English stimuli as well.
- Prediction 3. Because English-speaking controls were unfamiliar with Italian, it was predicted that they would show no word superiority effect for Italian stimuli, and either no pseudoword superiority effect for Italian or a reduced effect as compared to English stimuli (this last prediction was justified on the basis that the two languages share a subset of letter combinations). Therefore, a two-way interaction between language and stimulus type was predicted for this group.

- Prediction 4. Because the native Italian speakers were highly familiar with English, it was predicted that they would process English stimuli similarly to native English speakers. Statistically, a significant stimulus type effect was expected, but not an interaction between group and stimulus type. According to this prediction, and in contrast to Favreau et al.'s (1980) conclusions, late learners can, with intensive training, process some aspects of the orthography of a second language similarly to native speakers of that language, as demonstrated in other experimental paradigms (e.g., Altenberg and Cairns, 1983; Frenck-Mestre, 1993; Bijeljac-Babic et al., 1997; van Heuven et al., 1998).
- Prediction 5. Following these predictions, the three-way interaction between group, language, and stimulus type was also predicted to be significant. The presence of this interaction would indicate that performance on the three types of stimuli in the two languages varies as a function of the participants' familiarity with the two languages.

## Methods

### Subjects

Fourteen native Italian speakers (9 female, mean age = 44 years, range = 22–56 years) and 14 monolingual English-speaking controls (9 female, mean age = 44.5 years, range = 22–58 years) participated in the experiment. All participants but one (female control) were right-handed (Edinburgh Handedness Inventory; Oldfield, 1971). The two groups of participants were matched by age, gender, and years of education (Italian participants: mean years of education = 18.6, SD = 2.00; English-speaking controls: mean years of education = 18.3, SD = 1.9). All participants had self-reported normal or corrected-to-normal vision and were paid \$10 for their participation. Five Italian participants were college professors and two were teaching assistants; the remaining participants were either professionals or employees of local businesses. All English-speaking controls were unfamiliar with Italian and any other Romance languages.

English proficiency in Italian participants was assessed in two ways. First, a linguistic background questionnaire was administered before the Reicher-Wheeler task. According to self-report in the questionnaire, all Italian participants had lived in the northeastern United States for at least one year (average time in the United States = 15.9 years, SD = 12.7). All participants but two (who learned English during childhood) learned English as a second language during or after puberty (starting in middle school or after; mean age of acquisition = 11.31 years, SD = 4.4). Participants reported that, while in the United States, they spoke

English 69% of the time (SD = 16.3) and Italian 30% of the time (SD = 16.7; they spoke other languages 1% of the time). Participants were also asked to report how they felt when they spoke and read in English. The choices for spoken English were: (i) native speaker or native-like, can carry out extensive conversations; (ii) not a native speaker, can carry out basic conversations; and (iii) not a native speaker, only know some words and expressions. The choices for written English were: (i) very fluent, can read any type of text; (ii) somewhat fluent, can read some types of texts; and (iii) only able to recognize some words and expressions. All participants rated their fluency as native-like, except for two (one participant felt that her spoken English fell in the category “not a native speaker, can carry out basic conversations”, whereas the other participant felt that her ability to read in English was “somewhat fluent”). Finally, Italian participants reported using English for recreational reading 57% of the time (SD = 21.4).

Second, proficiency was assessed after the Reicher-Wheeler task with two additional tasks. Participants were given pairs of English words and pseudowords (created from the real words, see the “Stimuli” section below; e.g., FRAME–PRAME) used in the task and asked to indicate which of the two stimuli was a real word. Moreover, they were asked to provide the Italian translation of the known words. Participants' accuracy was 96.9% (SD = 6.30) on the forced-choice task and 92.7% (SD = 11) on the translation task. Participants were also asked to translate the alternate English words (see the “Stimuli” section) used in the Reicher-Wheeler task. Participants' accuracy on alternates was 92.5% (SD = 6.6).

### Stimuli

Two lists of stimuli were prepared. The Italian list was composed of 20 Italian words, 20 pseudowords, and 20 nonwords. The English list was composed of 20 English words, 20 pseudowords, and 20 nonwords. The words were five-letter words selected such that, by changing one letter in either the second or the fourth position (critical positions), another legal five-letter word would be formed (alternate; e.g., PORCH–PERCH, COUNT–CCOURT, AIUTO–ACUTO, AMARO–AMATO). The word that could be formed by a letter change in either the second or fourth position determined the alternative letter given in the two-alternative forced-choice task. For example, the two choices in the task for the stimulus “PORCH” would be <O> and <E>. In each list, pseudowords were created from the word stimuli by changing one letter in a non-critical position (e.g., “NORCH” from “PORCH”; “SIUTO” from “AIUTO”). Nonwords were formed by replacing the letters in non-critical positions with random consonant letters (e.g., “GOMNB” from “PORCH”; “ZIFLR” from “AIUTO”). With this design, the same critical letters were tested in three different conditions: legal and familiar context (words; e.g., “PORCH”,

Table 1. *Bigram frequencies (and relative standard deviations) of English and Italian stimuli used in the present experiment.*

|               | Words      | Pseudowords | Nonwords  |
|---------------|------------|-------------|-----------|
| English norms |            |             |           |
| English       | 39.8 (9.5) | 33.2 (8.8)  | 5.2 (7.8) |
| Italian       | 16.0 (7.7) | 16.5 (7.1)  | 6.2 (6.0) |
| Italian norms |            |             |           |
| English       | 9.9 (1.0)  | 9.7 (1.0)   | 3.5 (3.1) |
| Italian       | 10.6 (0.5) | 10.7 (0.5)  | 4.6 (3.5) |

Based on Davis (2005; English norms) and Barca, Burani and Arduino (2002; Italian norms).

“AIUTO”), legal but unfamiliar context (pseudowords; e.g., “NORCH”, “SIUTO”), and illegal and unfamiliar context (nonwords; e.g., “GOMNB”, “ZIFLR”).

English words had a mean frequency of 25.25 per million (SD = 33.9; Kucera and Francis, 1967). Alternate words had a mean frequency of 63.15 (SD = 85.1). The difference in frequency between word targets and alternates was not significant ( $p = 0.08$ ). Italian words were chosen from a textbook of Italian (Federici and Riga, 2003);<sup>2</sup> their mean frequency was 390.2 per three million (SD = 500; Corpus e Lessico di Frequenza dell’Italiano Scritto; Laudanna, Thornton, Brown, Burani and Marconi, 1995). Alternate words had a mean frequency of 863.4 (SD = 1,297). The difference in frequency between word targets and alternates was not significant ( $p > 0.1$ ).

In order to characterize the stimuli orthographically, the frequency of two-letter combinations, or bigram frequency, was computed for both sets of stimuli based on both English (software “N Watch”; Davis, 2005) and Italian norms (Barca, Burani and Arduino, 2002; see Table 1). In N Watch, bigram frequency for a string of letters is defined as the average bigram frequency across the entire letter string, both position- and length-sensitive.<sup>3</sup> Bigram frequency according to Italian norms

<sup>2</sup> All Italian words chosen for the present experiment are commonly taught in introductory courses in Italian. This choice was made to allow comparison of performance between native speakers of Italian and late learners in follow-up experiments.

<sup>3</sup> The frequency considered here is what Davis (2005) refers to as type frequency. The following example illustrates how it is calculated: the stimulus *edge* contains three bigrams (<ed>, <dg>, and <ge>). For the first of these (<ed>), the corresponding bigram frequency is based on the number of four-letter words that begin with <ed>. Thus the frequency for <ed> is 4 (the four types being *eddy*, *edge*, *edgy*, and *edit*). The bigram frequency for *edge* then equals  $(4 + 2 + 9) / 3 = 5$  (Davis, 2005, p. 67).

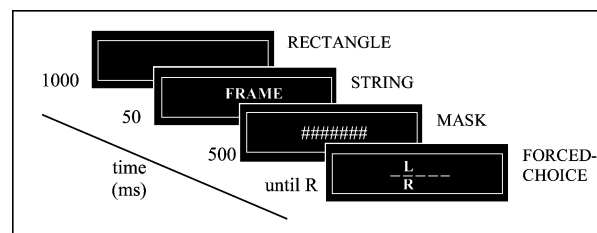


Figure 1. Illustration of the sequence of events used in the experiment. Presentation time in milliseconds for each event is indicated by the number to the left of each rectangle. Inter-stimulus interval between events is zero. Note that the presentation time of the string (50 ms) varied as a function of accuracy, as described in the text.

is similarly defined, but it is neither position- nor length-sensitive.

As expected, analyses revealed differences in bigram frequency between languages and types of stimuli. Based on English norms, overall bigram frequency was higher for the English stimuli than the Italian stimuli ( $F(1,114) = 84.2$ ,  $p < 0.0001$ ) and for orthographically legal stimuli than nonwords (stimulus type,  $F(2,114) = 93.03$ ,  $p < 0.0001$ ). Similarly, based on Italian norms, overall bigram frequency was higher for the Italian stimuli than the English stimuli ( $F(1,114) = 6.5$ ,  $p = 0.01$ ) and for orthographically legal stimuli than nonwords (stimulus type,  $F(2,114) = 124.26$ ,  $p < 0.0001$ ). Therefore, based on English orthographic norms, Italian stimuli were characterized by less frequent letter combinations (specifically, bigrams) than English stimuli. Similarly, based on Italian orthographic norms, English stimuli were characterized by less frequent letter combinations than Italian stimuli. Moreover, regardless of language and norms, words and pseudowords did not differ in bigram frequency, whereas both words and pseudowords had a higher bigram frequency than nonwords.

### Procedure

After giving informed consent and being randomly assigned to one of the two possible list orders (Italian list first or English list first), participants were tested in a sound-attenuating and dimly lit booth; they were seated 100 cm directly in front of a 19-inch monitor on which stimuli were presented, such that each stimulus subtended  $2.5^\circ$  of horizontal visual angle and  $0.5^\circ$  of vertical visual angle. The sequence of events was as follows (see Figure 1): stimuli (English words, English pseudowords, and nonwords in the English list; Italian words, Italian pseudowords, and nonwords in the Italian list) were briefly presented in the center of the monitor and replaced by a mask (#####). The mask was then replaced by two letters, one above and one below either

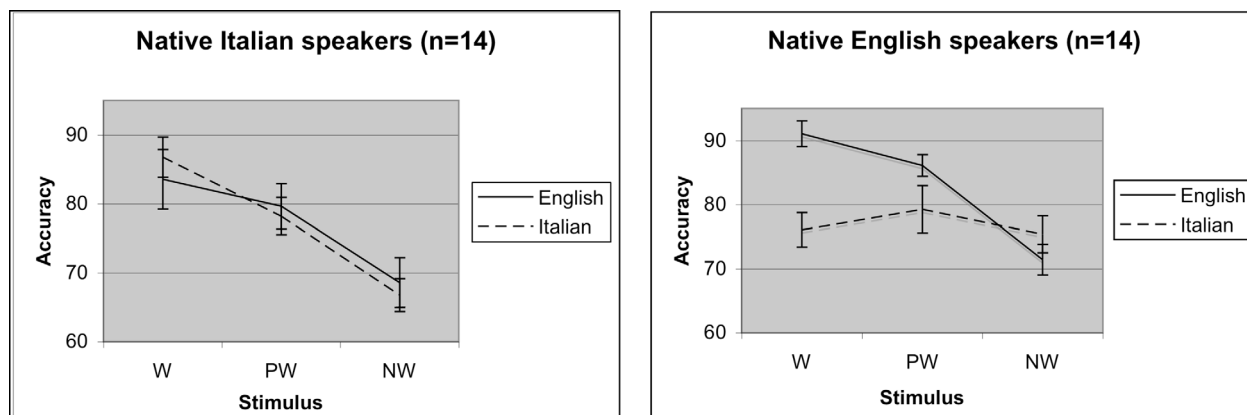


Figure 2. Performance (accuracy) of Italian–English bilinguals and English-speaking controls in the Reicher–Wheeler task. Bars indicate standard errors. (W = words, PW = pseudowords, NW = nonwords)

the second or the fourth letter position of the stimulus. The critical letter was in the second position for half of the stimuli and in the fourth position for the other half. The two letters remained on the screen until participants chose which of the two letters was presented in the specified position in the previous string of letters by pressing one of two buttons on a joystick (the two buttons were also positioned vertically). Participants were informed that the critical positions were the second and the fourth.

Accuracy was stressed. Practice, fatigue, and floor and ceiling effects were avoided by varying the exposure duration to maintain accuracy at a predetermined level (75%) across trial blocks. This level was achieved by adjusting stimulus presentation time based on each participant's accuracy, which was calculated every 12 trials. Specifically, a refresh rate of 17 ms was added to the 50 ms presentation time if the participant's accuracy was below 75% or subtracted if the participant's accuracy was above 75%. The task lasted approximately 10 minutes. At the end of the experiment, participants were debriefed, paid, and thanked for their participation. The experimental session lasted approximately 45 minutes.

### Data analysis

Each subject's accuracy data were reduced to 6 averages (3 stimulus types  $\times$  2 language lists). Data were entered into a mixed-model ANOVA with stimulus type (word, pseudoword, nonword) and language (Italian, English) as the within-subjects variables, and group (Italian, English) as the between-subjects variable. Significant interactions were followed up by simple effects analyses (paired-samples *t* tests, two-tailed). Word and pseudoword superiority effects were quantified by analyses on words and pseudowords, and on pseudowords and nonwords, respectively. Stimulus presentation times were also analyzed, with group and language as variables.

### Results

Stimulus presentation times were generally faster for English stimuli compared to Italian stimuli (Italian: mean = 46.1 ms, SD = 13.6; English: mean = 36.8 ms, SD = 12.9;  $F(1,26) = 16.79$ ,  $p < 0.0001$ ). This effect was present in both Italian–English bilinguals and English-speaking controls ( $p = 0.05$  and  $p = 0.003$ , two-tailed, respectively). No differences between the two groups of participants were significant (group,  $F(1,26) = 0.16$ ,  $p = 0.7$ ; group  $\times$  language,  $F(1,26) = 2.75$ ,  $p = 0.1$ ). Because stimulus presentation times depended on participants' accuracy, these results show that – similarly to English-speaking controls – native Italian subjects were able to maintain an overall accuracy of 75% with presentation times faster than the ones recorded for Italian stimuli.

Mean percent correct letter recognition scores as a function of group, language, and stimulus type are shown in Figure 2. Overall accuracy was similar for the two groups ( $F(1,26) = 0.73$ ,  $p = 0.4$ ): mean accuracy for Italian participants was 77.26% (SD = 13.9) while mean accuracy for English-speaking controls was 79.27% (SD = 11.7). Therefore, our manipulation of the stimulus presentation time, aimed at maintaining accuracy at a predetermined level (75%) across trial blocks to avoid ceiling and floor effects, proved to be successful.

### Prediction 1 (word and pseudoword superiority effects in both groups for their native languages)

Analyses carried out separately for the two groups of participants revealed significant word and pseudoword superiority effects in both groups for their native languages. Stimulus type was significant for both native Italian ( $F(2,26) = 35.55$ ,  $p < 0.0001$ ) and English-speaking ( $F(2,26) = 34.01$ ,  $p < 0.0001$ ) controls. Simple comparisons for the Italian group showed that accuracy was higher for words than pseudowords (word superiority

effect,  $t(13) = 3.24$ ,  $p = 0.006$ ) and for pseudowords than nonwords (pseudoword superiority effect,  $t(13) = 4.32$ ,  $p = 0.001$ ). Simple comparisons for the English-speaking control group showed that accuracy was higher for words than pseudowords ( $t(13) = 2.25$ ,  $p < 0.05$ ) and for pseudowords than nonwords ( $t(13) = 5.77$ ,  $p < 0.0001$ ).

***Prediction 2 (word and pseudoword superiority effects in Italian–English bilinguals for English stimuli)***

Analyses carried out for Italian participants on English stimuli revealed that the effect of stimulus type was significant ( $F(2,26) = 11.66$ ,  $p = 0.002$ ); simple comparison showed that accuracy was similar for words and pseudowords ( $t(13) = 1.2$ ,  $p = 0.25$ ), and higher for pseudowords than nonwords ( $t(13) = 6.05$ ,  $p < 0.0001$ ). Therefore, Italian speakers did not show a word superiority effect for English stimuli but did show a pseudoword superiority effect. Analyses carried out on both sets of stimuli (English and Italian) revealed a main effect of stimulus type ( $F(2,26) = 37.65$ ,  $p < 0.0001$ ); word superiority effect,  $p < 0.02$ ; pseudoword superiority effect,  $p < 0.0001$ ), but no interaction between stimulus type and language ( $F(2,26) = 1.01$ ,  $p = 0.37$ , n.s.).

***Prediction 3 (no superiority effects in English-speaking controls for Italian stimuli)***

Analyses carried out for English-speaking controls on Italian stimuli revealed no significant differences between the three types of stimuli ( $F(2,26) = 0.84$ ,  $p = 0.43$ ). The different performance of the control group in the two languages was also demonstrated by a significant language by stimulus interaction ( $F(2,26) = 12.81$ ,  $p < 0.0001$ ).

***Prediction 4 (similar superiority effects in Italian–English bilinguals and English-speaking controls for English stimuli)***

Native Italian speakers' performance on English stimuli was not significantly different from the English-speaking controls' performance on the same stimuli (group  $\times$  stimulus type,  $F(2,52) = 0.72$ ,  $p = 0.5$ ). Separate analyses performed on words and pseudowords, and on pseudowords and nonwords revealed that both the word and the pseudoword superiority effects were significant ( $t(27) = 2.29$ ,  $p = 0.03$  and  $t(27) = 8.17$ ,  $p < 0.0001$ , respectively) and that these effects were similar in the two groups (group  $\times$  stimulus,  $F(1,26) = 0.73$ ,  $p = 0.79$ ,  $F(1,26) = 1.3$ ,  $p = 0.26$ , respectively).

***Prediction 5 (significant group  $\times$  language  $\times$  stimulus interaction)***

The three-way interaction among group, language, and stimulus was significant ( $F(2,52) = 9.74$ ,  $p < 0.0001$ ), indicating that, as predicted, accuracy for the three types of stimuli varied as a function of the participants' familiarity with the two languages.

**Discussion**

In the present study, participants' performance in the native language condition was, in terms of effect sizes, similar to results described in other studies (e.g., Reicher, 1969; McClelland, 1976; Chase and Tallal, 1990; Grainger et al., 2003). This finding demonstrates the robustness of word and pseudoword superiority effects even across languages. English-speaking controls unfamiliar with Italian showed word and pseudoword superiority effects for their native language and no superiority effects for Italian stimuli. These results provide valuable baseline data for follow-up studies on second language acquisition: while no superiority effects are expected in individuals unfamiliar with a language, these effects might serve as an index of familiarity or orthographic fluency with a language.

In contrast, native Italian speakers performed similarly with Italian and English stimuli (although the word superiority effect for English stimuli failed to reach significance), and performed similarly to English-speaking controls with English stimuli. This result is not surprising, given that all Italian participants lived in the United States and were highly familiar with and fluent in English; however, it is important because it demonstrates that orthographic processing for a second language can become automatic with extensive training. Therefore, the present data do not support the hypothesis that bilinguals, even after prolonged exposure to a second language, are less efficient than native speakers in making use of orthographic redundancies in that language (cf. Favreau et al., 1980); studies employing different indices of orthographic processing have reached similar conclusions (e.g., Altenberg and Cairns 1983; Frenck-Mestre, 1993; Bijeljac-Babic et al., 1997; van Heuven et al., 1998). This conclusion is also supported by the analysis of stimulus presentation times, which were faster for English stimuli for both groups of participants. It is therefore possible that Favreau et al.'s (1980) results reflected the selection of a particular sample of participants (fluent bilinguals with slow reading rates) and do not generalize to other fluent bilinguals.

The reason for the absence of the word superiority effect for English stimuli in native Italians is not clear, but analysis of single subject's performance suggests that it might be due to the high variability in accuracy

in Italian participants. The size of the effect, in terms of percentage accuracy, was similar in the two groups (4% for Italian and 5% for control participants) and the effect was present in more Italian (11 out of 14) than control (7 out of 14) participants although variability was higher in Italian participants. In one participant, accuracy was higher for pseudowords (90%) than words (60%). When this participant was excluded from the analyses, the word superiority effect for English stimuli was significant ( $t(12) = 3.05, p < 0.01$ , two-tailed). Therefore, it is possible that the presence of this outlier accounts for the absence of the word superiority effect for English stimuli in Italian speakers.<sup>4</sup>

As the Italian bigram norms in Table 1 show, the differences in bigram frequency between pseudowords and nonwords were similar in the two languages. Therefore, it might be argued that the pseudoword superiority effect for English stimuli in Italian participants could be expected based on their knowledge of Italian instead of their familiarity with English.<sup>5</sup> This alternative explanation is unlikely for three reasons. First, if behavioral results simply reflected stimulus characteristics, Italian participants should not have exhibited a word superiority effect for English stimuli, given that English words and pseudowords were characterized by the same bigram frequency based on Italian norms (this was true for Italian stimuli as well); however, as already discussed, most Italian participants showed a word superiority effect for English stimuli. Second, Italian participants were highly proficient in English based on both self-report and performance: they were familiar with the English stimuli used in the present experiment, as shown by their accuracy on the translation test and by the stimulus presentation times in the Reicher-Wheeler task, which were faster for the English stimuli compared to the Italian stimuli in both groups of participants. Further, all conversations with the participants during data collection took place in English (all of the data were collected by the second

author). Finally, unpublished data from Welsh–English bilinguals in a similar paradigm show that, although the orthographies of these two languages are remarkably different, similar pseudoword superiority effects are evident in the two languages (Grossi, Thierry, Thomas and Di Pietro 2008). Although these considerations do not exclude the possibility that Italian participants' knowledge of their native language did not influence their performance on English stimuli in the present design, they confirm that the Italian–English bilinguals were highly proficient in English. Perhaps the only way to convincingly rule out the influence of knowing Italian would be by showing a lack of pseudoword superiority effect in monolingual Italians using the same English stimuli. This issue, which is beyond the purpose of the present paper, should be addressed in future studies.

The results of the present study are consistent with the findings of studies on learning and visual expertise (e.g., Polk and Farah, 1995; Gauthier and Tarr, 1997) that show that the visual system can be shaped by systematic exposure to a new set of stimuli, even when exposure takes place late in life. Future research will address more specific questions concerning the development of orthographic expertise and reorganization in visual areas not only at the behavioral level but also at the neural level. For example, do neural systems involved in processing orthography for the first language reorganize to incorporate the orthography of the second language or does the second language recruit different, non-overlapping regions and systems? Is this process of reorganization modulated by the age of acquisition for the second language and by the orthography (shallow vs. deep) characterizing the two languages? Neuroimaging and electrophysiological methods, in combination with behavioral methods, will need to be employed to answer these questions. At the behavioral level, the Reicher-Wheeler paradigm represents a valuable method of measuring expertise with a new orthographic system in the context of second language acquisition.

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<sup>4</sup> This participant rated herself as having native-like knowledge of both spoken and written English and scored 100% in the translation test on English stimuli (and 90% on the alternate words). Most of her errors on words were made when the critical letter was in the fourth position (accuracy on the second position was 80% and accuracy on the fourth position was 40%; this position effect was not found for pseudowords and nonwords); analysis of her data shows that most of these stimuli (8/10) were presented when the stimulus presentation rate was extremely low (16.7 ms). As the order of presentation of stimuli was randomly generated for each subject, it is possible that the participant's low performance on words with the critical letter in the fourth position was due to the fact that most of these stimuli were, by chance, presented very fast (as already mentioned, the participant's knowledge of English, as revealed by the results on the translation tests, was excellent).

<sup>5</sup> We are indebted to an anonymous reviewer for providing this alternative explanation.

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