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Does orthographic training on a phonemic contrast absent in the listener's dialect influence word recognition?

Sophie Dufour,^{a),b)} Noël Nguyen,^{b)} and Chotiga Pattamadilok^{b)}

Aix-Marseille Université, Centre National de la Recherche Scientifique, Laboratoire Parole et Langage, Unité Mixte de Recherche 7309, 13100 Aix-en-Provence, France

Ulrich Hans Frauenfelder^{c)}

Laboratoire de Psycholinguistique Expérimentale, Faculté de Psychologie et des Sciences de l'Éducation, Université de Genève, Boulevard du Pont d'Arve 40, 1204 Genève, Switzerland

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This study examined whether the ability of southern French speakers to discriminate between standard French word forms such as /pike/ and /pikε/ can be improved by a training procedure in which participants were exposed to the orthographic representations of words forming /e/-/ε/ minimal pairs. The results of the training procedure showed that southern French speakers were able to perceive the /e/-/ε/ contrast in word final position when they associated words containing these vowels with their correct spelled form. Further, participants in a priming experiment, which was run immediately after training, no longer showed the priming effect on the trained minimal pairs that they had shown in the pre-test. However, a priming effect on the untrained minimal pairs was still observed immediately after training, showing that this training failed to transfer to untrained items. Finally, the benefits of the training procedure were no longer observed the day after training, since southern French speakers once again showed a priming effect on the trained minimal pair of words in a one day post-test. Implications of these findings for the locus of the difficulties of the southern French speakers with the word-final /e/-/ε/ contrast are discussed. © 2016 Acoustical Society of America.

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I. INTRODUCTION

Numerous studies conducted in the last three decades have shown that our ability to discriminate non-native phonemic contrasts can be improved thanks to specific laboratory training procedures (e.g., Bradlow *et al.*, 1999; Bradlow *et al.*, 1997; Jamieson and Morosan, 1986, 1989; Lively *et al.*, 1994; Lively *et al.*, 1993; Logan *et al.*, 1991; Sadakata and McQueen, 2013). For example, Bradlow *et al.* (1997) showed that the forced-choice identification of /r/ and /l/ by Japanese speakers significantly improved after several weeks of intensive training using stimuli produced by multiple speakers of General American English. The improvements in /r/-/l/ identification generalized to novel stimuli produced by new speakers, and were maintained 3 months after completion of the perceptual training procedure (Bradlow *et al.*, 1999).

Our research (Dufour *et al.*, 2007, 2010) has extended this approach to the discrimination of phonemic contrasts that belong to the speakers' native language, but that do not occur in their regional variety and has asked whether similar improvement can be observed after training. Specifically, we studied the discrimination of the word-final /e/-/ε/ contrast

that exists in standard but not southern French, which only has the close-mid /e/ vowel in this position. For example, the words *épée* “sword” and *épais* “thick” are pronounced [epe] and [epε], respectively, by standard French speakers, whereas they are both pronounced [epe] by southern French speakers. In a first study (Dufour *et al.*, 2007), we observed that southern French speakers treated the word forms [epe] and [epε] as being identical in a primed lexical decision task. More specifically, a decrease in reaction times (RTs) was observed to the word form /epe/ when the word form /epε/ was presented first, and to the word form /epε/ when the word form /epe/ was presented first. This decrease in RTs, a minimal pair priming effect, was of exactly the same magnitude as in case of a repetition of the same word, that is when /epe/ or /epε/ were encountered for a second time. This finding suggests that the words *épée* and *épais* are associated with a single phonological representation, namely, /epe/ in southern French, and that at a stage of phonemic categorization both [e] and [ε] are assimilated to the same phoneme /e/ (see the perceptual assimilation model, Best *et al.*, 1988).

In a subsequent study (Dufour *et al.*, 2010), we examined whether the ability of southern French speakers to discriminate between the standard French /e/ and /ε/ phonemes could be improved, by means of a training procedure in which these speakers learned minimal pairs of new words based on the /e/-/ε/ contrast in association with visual shapes. At the end of the training, participants reached 80% correct

^{a)}Electronic mail: sophie.dufour@lpl-aix.fr

^{b)}Also at: Brain and Language Research Institute, Aix-Marseille Université, Aix-en-Provence, France.

^{c)}Also at Fondation Universitaire à Distance, Sierre, Switzerland.

responses for the novel final-/e/ words and 84% correct responses for those with a final /ɛ/. This performance was relatively high and reflected the ability of southern French speakers to use the /e-/ɛ/ contrast in word final position, at least when they have to associate novel words with their corresponding visual shapes. In this study the efficiency of our training was assessed in a primed lexical decision task which offered three main advantages. First, it allowed us to test whether the good performance in the discrimination of the /e-/ɛ/ contrast in nonwords during training can also be found in on-line spoken word recognition. Second, it allowed us to test southern French speakers on existing words for which difficulties in the discrimination of that contrast had already been shown. Third, the impact of training was examined on a task in which participant's attention was diverted away from the target phonemic contrast, thus reducing strategic processes. Importantly, our lexical decision experiment showed that participants did not use the knowledge of the contrast they acquired during training in the subsequent recognition of words they already knew. Immediately after training, they still treated words such as /epe/ and /epɛ/ as homophones, in a primed lexical decision task. Hence, despite training on the /e-/ɛ/ contrast in novel words, southern French speakers did not use knowledge of this contrast during on-line spoken word recognition.

Our first attempt at training southern French speakers to use the word final /e-/ɛ/ contrast had limited success since the effects of our training were not observed in a task known to reflect on-line word recognition. The challenge now is thus to find a better training procedure that allows southern French speakers to apply their acquired knowledge of the phonological contrast to word recognition. This study thus proposes another training procedure. Southern French participants were trained to associate words ending with the /e-/ɛ/ vowels and forming minimal pairs with their respective spelled forms. Indeed, it has been shown repeatedly that orthographic knowledge affects the way listeners process speech (e.g., [Dijkstra et al., 1993](#); [Ehri and Wilce, 1980](#); [Hallé et al., 2000](#); [Pattamadilok et al., 2007](#); [Seidenberg and Tanenhaus, 1979](#)). For example, in a well-known study, [Morais et al. \(1979\)](#) showed that people who have never learned to read and write have difficulties deleting or adding a phoneme at the beginning of spoken non-words. More relevant for the present purpose, it has been shown recently that exposure to orthographic form influences the way phonemic contrasts, absent in the native language, are perceived in a second language that contains these contrasts ([Escudero et al., 2008](#); [Escudero et al., 2014](#)). In the study of [Escudero et al. \(2008\)](#), Dutch learners of English were presented with English nonwords containing the vowels /æ/ and /ɛ/, a contrast that does not exist in Dutch, which has only the /ɛ/ vowel. In a first phase, participants were trained to associate each nonword with a drawing of the nonsense object that corresponded to it. Alongside the nonsense object, half of the participants were exposed to the spelled forms of the nonwords in addition to the auditory tokens, and the other half only heard the auditory tokens and was not exposed to the spelled forms. In the subsequent testing phase in which the recognition of the newly acquired words was examined

by means of an eye-tracking paradigm, these authors found that participants who were not exposed to the spelled forms confused /æ/ and /ɛ/ auditory tokens, that is, both /ɛ/ and /æ/ tokens triggered looks to pictures containing both /æ/ and /ɛ/. In contrast, participants who were exposed to the spelled forms showed an advantage in the recognition of the newly acquired words containing the /ɛ/ vowel. They only looked at pictures of words containing /ɛ/ when presented with /ɛ/ tokens, while they looked at pictures of words containing both /æ/ and /ɛ/ when presented with /æ/ tokens. [Escudero et al. \(2014\)](#) subsequently tested Spanish learners of Dutch and found that orthographic exposition during training facilitated the later recognition of newly acquired minimal pairs of words with congruent orthography. Following on these studies, we examine here whether orthographic exposure to the /e/ and /ɛ/ vowels can change the way these two vowels are perceived by southern French speakers during on-line spoken word recognition.

The present experiment utilized the same pre- and post-test design to assess training effects as in our previous study ([Dufour et al., 2010](#)). During the pre-test, participants performed a primed lexical decision task with both minimal and identical pairs. This phase allowed us to assess the perception of the /e-/ɛ/ contrast by our speakers before training. As in [Dufour et al. \(2007, 2010\)](#), we expected to find a priming effect on both identical and minimal pairs, that is, shorter RTs for both /epe/ and /epɛ/ forms when either the word /epe/ or the word /epɛ/ was presented first. During the training phase, participants were exposed to the orthographic representations of words forming /e-/ɛ/ minimal pairs. They thus learned that when the word final vowel is pronounced /e/ as in *piquer* /pike/ “to sting,” the spelled form is “ER,” while when the word final vowel is pronounced /ɛ/ as in *piquet* /pike/ “stake,” the spelled form is “ET.”¹

Two major changes were made in the training procedure with respect our previous study ([Dufour et al., 2010](#)). First, we trained our participants on words rather than nonwords to maximize our chances of modifying the way in which already known words are processed, and thus to avoid the risk that the effects of our training be specific to newly acquired words. Second and most importantly, rather than using pictures we presented participants with orthographic representations of the words in the minimal pairs.

During the post-test, the same procedure as the pre-test was used to assess changes in the perception of the /e-/ɛ/ contrast during spoken word recognition. If such training proves to be efficient in modifying the way in which /e-/ɛ/ ending words are processed and represented, no repetition priming effect should be observed on the minimal pairs of words after training, since there should no longer be an exact match between the phonological representations associated with the two members of the minimal pairs. To examine the transfer of the knowledge acquired during training to words that participants had not been exposed to in the training phase, half of the minimal pairs used in the pre-test were not used in the training. To examine the persistence of the training, the post-test was administered not only immediately after the training, but also one day later.

TABLE I. Characteristics of the /e/-/ɛ/ minimal pairs used in the experiment (mean values).

	/e/ words			/ɛ/ words		
	Number of phonemes	Frequency ^a	Duration ^b	Number of phonemes	Frequency ^a	Duration ^b
Training pairs	4.25	10.75	639	4.25	10.17	642
Transfer pairs	4.50	25.17	636	4.50	10.25	633
Mean	4.38	17.96	638	4.38	10.21	638

^aIn occurrence per million; taken from VoCox, a lexical database for the French language (Dufour *et al.*, 2002).

^bIn ms.

II. METHOD

A. Participants

Sixty southern French speakers from Aix-Marseille University participated in the experiment and were paid for their participation. Each participant gave written informed consent prior to the experiment. They all reported having no hearing or speech disorders. Before running the experiment, we ensured, by means of a reading task, that our participants produced the /e/ vowel in word-final position for both members of the minimal pairs.

B. Materials

Twenty-four /e/-/ɛ/ minimal pairs of words, two syllables in length, were taken from Dufour *et al.* (2010). The /e/ vowel spelled “ER” as in *voler* “to fly” and the /ɛ/ vowel spelled “ET” as in *volet* “flap.” Only half of the /e/-/ɛ/ minimal pairs served in the training. The characteristics of the /e/-/ɛ/ minimal pairs are given in Table I, and the minimal pairs are listed in Table II. The label *training pairs* refers to the minimal pairs used in the training, and the label *transfer pairs* refers to the minimal pairs not used in the training, but for which generalization of the training was assessed.

For the purpose of the lexical decision task, the material included 24 bisyllabic /e/-/ɛ/ minimal non-word pairs. Four counterbalanced lists were also created, so that each member of a minimal pair was either repeated or followed by the other member of the minimal pair. The prime preceded the target (i.e., the same item or the other member of the minimal pair) by 8 to 13 items. The items forming a pair appeared in the same positions across the four lists. Sixty-six

words and 66 non-words were also included as fillers in the experimental lists.

C. Procedure

The stimuli were recorded by a female native speaker of standard French with a Parisian accent, and digitized at a sampling rate of 44 kHz with 16-bit analog-to-digital recording. The participants were tested individually in a quiet room, and the stimuli were presented over headphones at a comfortable sound level.

Pre- and post-tests measured the priming effect for the /e/-/ɛ/ minimal and repetition pairs. Participants were asked to make a lexical decision as quickly and accurately as possible and to give “word” responses using their dominant hand. Response times (RTs) were measured from the onset of the test item. An interval of 2000 ms elapsed between the participant’s response and the presentation of the next stimulus. Each participant was tested on only one experimental list and began the session with six practice trials.

Training consisted of 12 blocks of 24 trials. Within each block, the structure of the training was as follows. First, a fixation point appeared on the middle of the screen. Next, participants heard one of the two words forming a minimal pair. At the end of the auditory word, the written form of the two words making up a minimal pair were presented on either side of the fixation point. The position of the word spelled with the “ER” vowel and that spelled with the “ET” vowel was counterbalanced across participants so that half of the participants saw a word ending with the spelling “ER” to the right of the fixation point, while the other half saw it to the left of the fixation point. They were instructed to click on the written words that they thought corresponded to the word that they heard. In case of an error, a beep sounded, and the correct answer appeared in red in the middle of the screen for 1000 ms. An interval of 2000 ms elapsed between the participant’s response or the feed-back in case of errors and the presentation of the next trial. Each of the word forming a minimal pair was presented one time per block.

III. RESULTS AND DISCUSSION

Due to technical problems, one participant was excluded from the analyses. One training pair that gave rise to an error rate of more than 50% in the pre-test was also discarded from all the analyses. Mean correct RTs for the pre-test, post-test, and one day post-test are shown in Figs. 1, 2, and 3, respectively. For each phase, RTs greater than 1800 ms were excluded from the analyses. Adopting these criteria,

TABLE II. /e/-/ɛ/ minimal pairs used in the experiment.

Training pairs		Transfer pairs	
bouler	boulet	coffrer	coffret
carreler	carrelet	creuser	creuset
coupler	couplet	miner	minet
hocher	hochet	piquer	piquet
signer	signet	siffler	sifflet
souffler	soufflet	tirer	tiret
catcher	cachet	coller	collet
lacer	lacet	livrer	livret
sommer	sommet	briquer	briquet
feuiller	feuille	corser	corset
tiquer	ticket	voler	volet
violier	violet	banquer	banquet

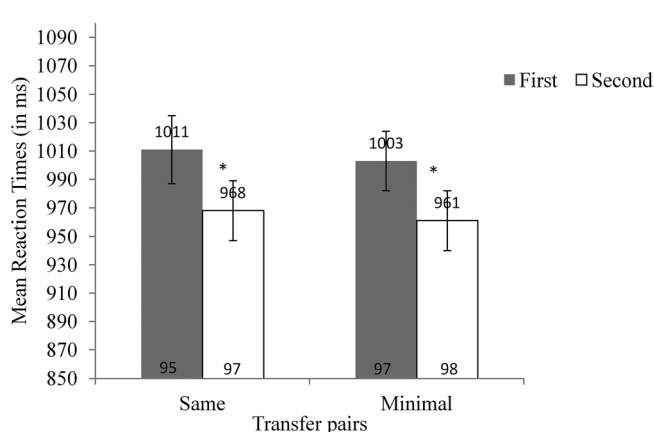
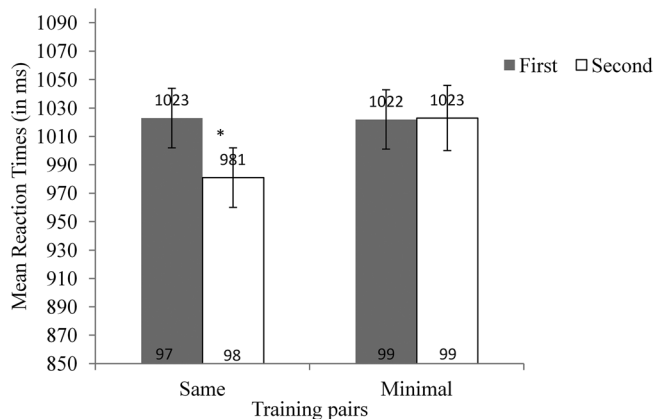
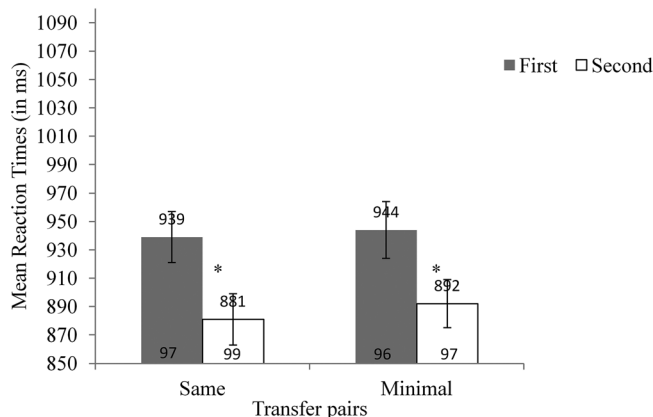
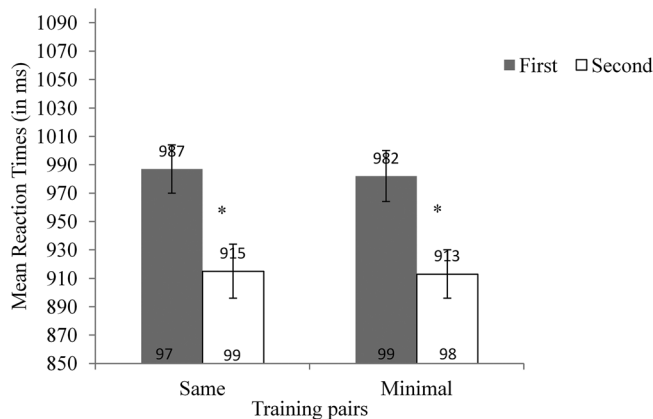


FIG. 1. Mean reaction times (in ms) and standard errors for the first and second presentation as a function of pair type (same, minimal) for the training and transfer pairs in the pre-test. Percentages of correct responses are shown below the bar for each condition. Asterisks indicate significant priming effects.

FIG. 2. Mean reaction times (in ms) and standard errors for the first and second presentation as a function of pair type (same, minimal) for the training and transfer pairs in the post-test. Percentages of correct responses are shown below the bar for each condition. Asterisks indicate significant priming effects.

less than 5% of the data were rejected (1.81%, 4.35%, and 3.08% of the data rejected in the three phases, respectively).

A. Training results

Accuracy in the training across the twelve blocks is shown in Table III. As we can see the performance was already high and above the chance level at the beginning of training. This performance reflects the ability of Southern French speakers to perceive the /e/-/ɛ/ contrast in word final position when they associate the vowels of the contrast with their correct spelled form. At the end of the training, participants reached 97% correct responses for the final-/e/ words and 96% correct responses for the final-/ɛ/ words.

B. Pre-test lexical decision results

For both the *training* and the *transfer* pairs, *a priori* single sample *t* tests by participants (*t*₁) and by items (*t*₂) were first performed to assess the priming effect (first vs second presentation) within each pair (same, minimal). Significant priming effects were observed on the *same* pairs. RTs were shorter for target words encountered for the second time compared with the first time [*training* pairs: *t*₁(58)=5.98, *p*<0.0001; *t*₂(10)=4.75, *p*<0.001, *transfer* pairs: *t*₁(58)=6.05, *p*<0.0001; *t*₂(11)=5.43, *p*<0.001]. Also, significant priming effects were observed on the *minimal*

pairs. RTs were shorter for the second than the first presentation [*training* pairs: *t*₁(58)=5.87, *p*<0.0001; *t*₂(10)=4.08, *p*<0.01, *transfer* pairs: *t*₁(58)=4.30, *p*<0.0001; *t*₂(11)=4.54, *p*<0.001]. Subsequent analyses of variance (ANOVA) by participants (*F*₁) and by items (*F*₂) with presentation (first, second) and pair (same, minimal) as variables showed no presentation × pair interaction for both the *training* [*F*₁(1,58)=0.04, *p*>0.20; *F*₂(1,10)=0.08, *p*>0.20] and the *transfer* pairs [*F*₁(1,58)=0.10, *p*>0.20; *F*₂(1,11)=0.16, *p*>0.20], thus indicating that the magnitude of the priming effect did not vary as a function of pair type. Hence, as expected, before training southern French speakers treated the second member of /e/-/ɛ/ minimal pairs as a repetition of the first member. We will now examine whether exposition to the orthographic representations of the /e/ and /ɛ/ ending words has changed the way southern French speakers perceive the /e/-/ɛ/ contrast during on-line spoken word recognition.

C. Post-test lexical decision results

For both the *training* and the *transfer* pairs, *a priori* single sample *t* tests were again performed to assess the priming effect (first vs second presentation) within each pair (same, minimal). Significant priming effects were observed on the *same* pairs. RTs were shorter for target words encountered for

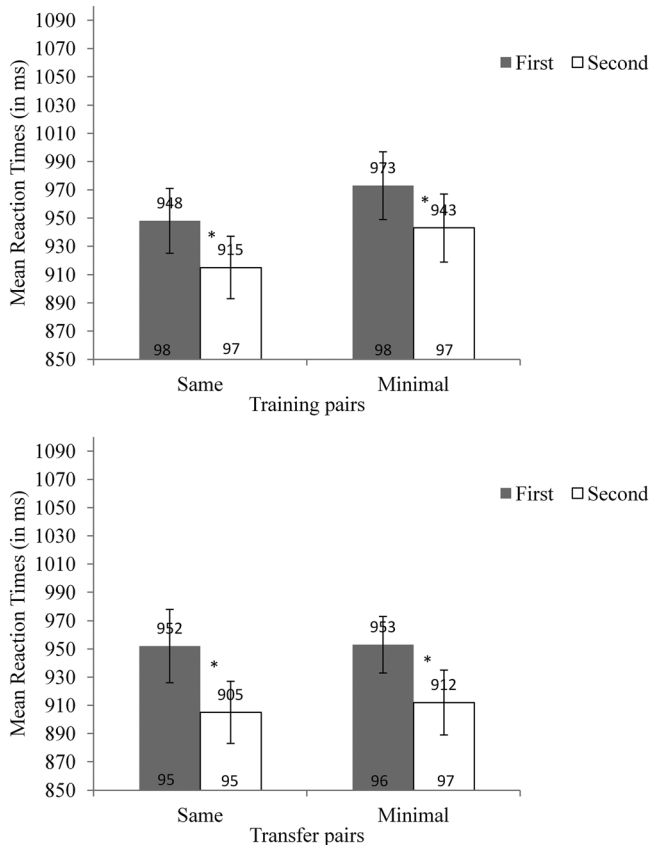


FIG. 3. Mean reaction times (in ms) and standard errors for the first and second presentation as a function of pair type (same, minimal) for the training and transfer pairs in the one day post-test. Percentages of correct responses are shown below the bar for each condition. Asterisks indicate significant priming effects.

the second time compared with the first time [*training pairs*: $t1(58) = 3.07$, $p < 0.01$; $t2(10) = 2.53$, $p < 0.05$, *transfer pairs*: $t1(58) = 3.37$, $p < 0.01$; $t2(11) = 2.39$, $p < 0.05$]. A significant priming effect was also observed on the *transfer minimal pairs* with RTs shorter for the second than the first presentation [$t1(58) = 2.67$, $p < 0.01$; $t2(11) = 3.67$, $p < 0.01$]. Crucially, immediately after training, no priming effect was observed on the *training minimal pairs* [$t1(58) = 0.08$, $p > 0.20$; $t2(10) = 0.83$, $p > 0.20$]. Subsequent ANOVAs assessing the impact of the training on the magnitude of the

TABLE III. Accuracy in training.

Block	Overall	Words with final /e/	Words with final /ɛ/
1	87	85	89
2	92	94	91
3	94	94	93
4	95	96	94
5	96	96	96
6	95	96	93
7	96	97	95
8	95	96	95
9	95	95	94
10	96	96	96
11	96	97	95
12	96	97	96

priming effects revealed a significant presentation (first vs second presentation) \times phase (pre- vs post-test) interaction only for the *minimal pairs* included in the training but not for those not included in the training [*training pairs*: $F1(1,58) = 13.49$, $p < 0.001$; $F2(1,10) = 15.16$, $p < 0.01$, *transfer pairs*: $F1(1,58) = 0.29$, $p > 0.20$; $F2(1,11) = 0.08$, $p > 0.20$]. No presentation \times phase interaction was observed on the *same pairs* [*training pairs*: $F1(1,58) = 2.51$, $p = 0.12$; $F2(1,10) = 3.14$, $p = 0.11$, *transfer pairs*: $F1(1,58) = 1.04$, $p > 0.20$; $F2(1,11) = 1.08$, $p > 0.20$].

D. One day post-test lexical decision results

Four participants did not take part in the one day post-test. Mean RTs in the one day post-test were thus calculated on 55 participants. Note that these four participants were also discarded from the following analyses comparing the magnitude of the priming effects in the one day post-test to those in the pre-test.² Significant priming effects were observed on the *same pairs*. RTs were shorter for target words encountered for the second time compared with the first time [*training pairs*: $t1(54) = 2.14$, $p < 0.05$; $t2(10) = 2.34$, $p < 0.05$, *transfer pairs*: $t1(54) = 2.73$, $p < 0.01$; $t2(11) = 2.36$, $p < 0.05$]. Significant priming effects were also observed on both the *training* [$t1(54) = 2.08$, $p < 0.05$; $t2(10) = 2.26$, $p < 0.05$] and the *transfer* [$t1(54) = 3.15$, $p < 0.01$; $t2(11) = 2.44$, $p < 0.05$] *minimal pairs* with RTs shorter for the second than the first presentation. A trend presentation \times phase interaction was found for the *minimal pairs* included in the training [$F1(1,54) = 3.37$, $p = 0.07$; $F2(1,10) = 4.69$, $p = 0.06$], indicating that the priming effect observed on the *minimal pairs* used in the training tends to be weaker in the one day post-test than in the pre-test. The presentation \times phase interaction on the *same pairs* included in the training was significant by participants [$F1(1,54) = 4.19$, $p < 0.05$] but not by items [$F2(1,10) = 2.62$, $p = 0.14$]. No presentation \times phase interaction on both the *transfer minimal* [$F1(1,54) = 0.22$, $p > 0.20$; $F2(1,11) = 0.32$, $p > 0.20$] and the *transfer same pairs* [$F1(1,54) = 0.26$, $p > 0.20$; $F2(1,11) = 1.26$, $p > 0.20$] was found.

IV. GENERAL DISCUSSION

In this study, we have tried to find a training procedure leading southern French speakers to use the word-final /e-/ɛ/ contrast during on-line spoken word recognition. As mentioned before, our first attempt (Dufour *et al.*, 2010) at training southern French speakers had a limited impact, since they did not use the knowledge of the contrast they acquired during training in the subsequent recognition of words they already knew. We thus renewed our efforts here by exposing southern French speakers to the orthographic representations of words forming /e-/ɛ/ minimal pairs. The results of the training procedure showed that Southern French speakers could use the /e-/ɛ/ contrast in word final position when they had to associate the vowels forming the contrast with their correctly spelled form. This replicates what was previously found (Dufour *et al.*, 2010) with visual shapes.

The exposure during training to the orthographic representations of /e-/ɛ/ minimal pairs of words proved to be more effective than with visual shapes since, immediately after

training, southern French speakers no longer showed a minimal pair priming effect. Indeed, they did not treat the second member of trained minimal pairs as a repetition of the first member in a lexical decision task. Such a finding is particularly relevant since to our knowledge this is the first study that reports the application of knowledge gained in training to a lexical decision task, a situation in which the participants' attention is shifted away from the target phonemic contrast. We have thus shown that the training affects the on-line recognition of existing words containing the learned contrast.

Despite the demonstrated efficiency of our training procedure, it also has some limitations. A first limit is that our training did not transfer or change the way in which the untrained minimal pairs are processed and represented. Indeed, after training, southern French speakers still treated the second member of the untrained /e/-/ɛ/ minimal pairs as a repetition of the first member. A second limit is that the benefit of this training procedure was no longer observable the day after training, since southern French speakers once again showed a priming effect on the trained minimal pair of words in the one day post-test, as in the pre-test. This priming effect was, however, smaller on the one day post-test than on the pre-test, and it could be that this decreased priming effect in the one day post-test results from some residual benefit due to training with southern French speakers still able to discriminate between /e/-/ɛ/ minimal pairs of words during on-line spoken word recognition. Nonetheless, this priming effect is exactly of the same magnitude as that observed on the identical pairs, and thus we believe that it is again a repetition priming effect with /e/ and /ɛ/ ending words treated as homophonous.

There are at least two accounts for the difficulty that our southern French participants had in dealing with the /e/-/ɛ/ contrast in on-line spoken word recognition as observed in the lexical decision task. The first, the lexical account, considers that these speakers have only a single lexical representation for the two members of the /e/-/ɛ/ minimal pairs, such as /epe/ for the two words *épée*/epe/ "sword" and *épais*/epɛ/ "thick" (Pallier *et al.*, 2001; see also Escudero *et al.*, 2008; Hayes-Harb and Masuda, 2008). As a result, southern French speakers treat the two members of the /e/-/ɛ/ minimal pairs as homophonous since exactly the same lexical entry is contacted by the inputs [epe] and [epɛ]. According to the second pre-lexical account, these participants have both variants (e.g., /epe/ and /epɛ/) stored in their mental lexicon. Southern French speakers are assumed to be able to encode the /e/-/ɛ/ contrast lexically despite being unable to perceive it for several reasons. They are most likely exposed to the /ɛ/ pronunciation of words such as *épais*/epɛ/ ending with the /ɛ/ vowel in standard French via the media or their interactions with speakers from other French-speaking regions. Further, their knowledge of the spelled form of words can help them to encode distinctively the two members of minimal pairs (Cutler *et al.*, 2006). According to this account, the observed minimal pair priming effect in the lexical decision task results from perceptual confusions at a pre-lexical stage of processing with the /e/ and /ɛ/ vowels assimilated to same /e/ phoneme (Best *et al.*, 1998; see also Cutler *et al.*, 2006). Hence, regardless of which word (*épée*/epe/ or *épais*/epɛ/) is

present in the input, the two variant forms are accessed by the same phonological code /epe/ (see Escudero *et al.*, 2008; Hayes-Harb and Masuda, 2008). Because in the lexical decision task, participants can make word/nonword decision by estimating the amount of overall lexical activation that words generate in comparison to nonwords (Dufau *et al.*, 2012), it is not easy to determine precisely upon which word form representation /epe/ or /epɛ/, southern French participants have made their word decision. Nonetheless, as in this particular task, words are presented in isolation with no meaningful context to favor activation of the one or the other lexical representation, it is likely that the lexical representation containing the dominant category /e/ is predominantly activated by the pre-lexical code /epe/.

Let us now consider how the present findings permit us to evaluate these two accounts. According to the lexical account, southern French speakers are assumed to have only one lexical representation for the two word forms, /epe/ and /epɛ/, which is activated independently of which the word was heard. The training led to the creation of two lexical representations, the one for the /e/ word form and the other for the /ɛ/ word form. As a result, after training, the inputs /epe/ and /epɛ/ activate their corresponding lexical entry, namely, /epe/ when the input /epe/ is presented, and /epɛ/ when the input /epɛ/ is presented. Since two distinct lexical representations were activated, no priming effect emerged for the trained minimal pairs. According to the pre-lexical account, the training helped southern French speakers to extract the /ɛ/ phoneme from the speech signal, in such a way that when the spoken input contains the /ɛ/ vowel, only the /ɛ/ member is activated, and when the auditory input contains the /e/ vowel, only the /e/ member is activated. Thus after training the participants could recognize the two phonemes of the contrast correctly and activate the appropriate lexical entry.

Our observation that training only modified the way in which trained minimal pairs are processed during on-line spoken word recognition argues in favor of the lexical account. This account predicts no training transfer to the untrained minimal pairs, since in this case, the speakers did not have the opportunity to create a new lexical entry for the member of the minimal pairs ending with the /ɛ/ vowel. Consequently, after training, both the /e/ and /ɛ/ inputs activate the same lexical representation, and a priming effect still occurs for the untrained minimal pairs. In contrast, the pre-lexical account incorrectly predicts a transfer of the training to the untrained minimal pairs since it is the extraction of the /ɛ/ phoneme from the input which has been improved and thus even new minimal pairs should be correctly processed.

Our results also showed that as early as the next day of the training, the two members of the trained minimal pairs were no longer treated as being distinct by southern French speakers. This short-lived impact of our training is compatible with this lexical account according to which the new lexical entry is unstable and needs to be reinforced with repeated exposure to the orthographic representations of words over the course of several days (e.g., Gaskell and Dumay, 2003).

To sum-up, our results suggest that the difficulty of southern French participants in distinguishing /e/-/ɛ/ minimal pairs of words has to do with how these words are

represented in the mental lexicon.³ They also suggest that a training procedure that draws the speakers' attention to the contrastive nature of two word forms, for example, by means of orthographic exposure can be successful in establishing a lexical contrast. Our study thus extends the growing body of research on second language word perception which shows that orthographic exposure can help second language learners to build separate lexical representations for confusable L2 words (Cutler *et al.*, 2006; Escudero *et al.*, 2008; Escudero *et al.*, 2014). We can conclude that perceiving words in a second language and in a non-native dialect appears to share some important processing mechanisms.

¹We avoided exposing participants to multiple orthographies for the same sound and thus only used "ER" and "ET" orthographic representations. This is because Escudero *et al.* (2014) recently showed that orthographic exposition during training facilitated the subsequent recognition of newly acquired minimal pairs of words with congruent orthography, but hindered performance in case of incongruent orthography.

²Note that removing the four participants did not change the pattern of results observed in the pre-test. The mean RTs calculated on 55 participants in the pre-test are as follow: 987 ms for the training same pair first presentation, 915 ms for the training same pair second presentation, 984 ms for the training minimal pair first presentation, 918 ms for the training minimal pair second presentation, 938 ms for the transfer same pair first presentation, 880 ms for the transfer same pair second presentation, 943 ms for the transfer minimal pair first presentation, and 892 ms for the training minimal pair second presentation.

³As explained above, our results favor a lexical account for the difficulty of southern French speakers in dealing with the /e/-/ɛ/ phonemic contrast in on-line spoken word recognition. However, they do not permit us to choose between abstractionist (e.g., McClelland and Elman, 1986) and exemplar-based models for lexical representations (e.g., Goldinger, 1998). Indeed, these two classes of models predict that training would not transfer to minimal pairs of words not included in the training, either because the abstract representation for each of the untrained /e/ words has not been created or reinforced or because during training, our participants have not stored the /ɛ/ memory traces for the untrained /e/ words. Whatever the view of the mental lexicon, the lexical locus for the difficulties of southern French speakers in discriminating /e/-/ɛ/ minimal pairs requires that participants be trained on every minimal pairs to create two separate lexical entries. As discussed, it is only a pre-lexical locus of the difficulties of southern French speakers that predicts the generalization of pairs not presented in the training and that does not require that participants be trained on every minimal pair.

Best, C. T., McRoberts, G. W., and Sithole, N. M. (1988). "Examination of perceptual reorganization for non-native speech contrasts: Zulu click discrimination by English-speaking adults and infants," *J. Exp. Psychol.: Human Percept. Perform.* **14**, 345–360.

Bradlow, A. R., Akahane-Yamada, R., Pisoni, D. B., and Tohkura, Y. (1999). "Training Japanese listeners to identify English /r/ and /l/: Long-term retention of learning in speech perception and production," *Percept. Psychophys.* **61**, 977–985.

Bradlow, A. R., Pisoni, D. B., Akahane-Yamada, R., and Tohkura, Y. (1997). "Training Japanese listeners to identify English /r/ and /l/: IV. Some effects of perceptual learning on speech production," *J. Acoust. Soc. Am.* **101**, 2299–2310.

Cutler, A., Weber, A., and Otake, T. (2006). "Asymmetric mapping from phonetic to lexical representations in second-language listening," *J. Phonet.* **34**, 269–284.

Dijkstra, T., Frauenfelder, U., and Schreuder, R. (1993). "Bidirectional grapheme–phoneme activation in a bimodal detection task," *J. Exp. Psychol.: Human Percept. Perform.* **19**, 931–950.

Dufau, S., Grainger, J., and Ziegler, J. C. (2012). "How to say 'no' to a non-word: A leaky competing accumulator model of lexical decision," *J. Exp. Psychol.: Learn. Mem. Cogn.* **38**, 1117–1128.

Dufour, S., Nguyen, N., and Frauenfelder, U. H. (2007). "The perception of phonemic contrasts in a non-native dialect," *J. Acoust. Soc. Am.* **121**, EL131–EL136.

Dufour, S., Nguyen, N., and Frauenfelder, U. H. (2010). "Does training on a phonemic contrast absent in the listener's dialect influence word recognition?" *J. Acoust. Soc. Am.* **128**, EL43–EL48.

Dufour, S., Peereman, R., Pallier, C., and Radeau, M. (2002). "VoCoLex: A lexical database on phonological similarity between French words," *L'Année Psychol.* **102**, 725–746.

Ehri, L. C., and Wilce, L. S. (1980). "The influence of orthography on reader's conceptualization of the phonemic structure of words," *Appl. Psycholing.* **1**, 371–385.

Escudero, P., Hayes-Harb, R., and Mitterer, H. (2008). "Novel second-language words and asymmetric lexical access," *J. Phonet.* **36**, 345–360.

Escudero, P., Simon, E., and Mulak, K. E. (2014). "Learning words in a new language: Orthography doesn't always help," *Bilingual. Lang. Cogn.* **17**, 384–395.

Gaskell, M. G., and Dumay, N. (2003). "Lexical competition and the acquisition of novel words," *Cognition* **89**, 105–132.

Goldinger, S. D. (1998). "Echoes of echoes? An episodic theory of lexical access," *Psychol. Rev.* **105**, 251–279.

Hallé, P. A., Chereau, C., and Segui, J. (2000). "Where is the /b/ in 'absurde' [apsyrd]? It is in French listeners' minds," *J. Mem. Lang.* **43**, 618–639.

Hayes-Harb, R., and Masuda, K. (2008). "Development of the ability to lexically encode novel L2 phonemic contrast," *Second Lang. Res.* **24**, 5–33.

Jamieson, D. G., and Morosan, D. E. (1986). "Training non-native speech contrasts in adults: Acquisition of English /θ/-/ð/ contrast by francophones," *Percept. Psychophys.* **40**, 205–215.

Jamieson, D. G., and Morosan, D. E. (1989). "Training new, nonnative speech contrasts: A comparison of the prototype and perceptual fading techniques," *Can. J. Psychol.* **43**, 88–96.

Lively, S. E., Logan, J. S., and Pisoni, D. B. (1993). "Training Japanese listeners to identify English /r/ and /l/: II. The role of phonetic environment and talker variability in learning new perceptual categories," *J. Acoust. Soc. Am.* **94**, 1242–1255.

Lively, S. E., Pisoni, D. B., Yamada, R. A., Tohkura, Y., and Yamada, T. (1994). "Training Japanese listeners to identify English /r/ and /l/: III. Long-term retention of new phonetic categories," *J. Acoust. Soc. Am.* **96**, 2076–2087.

Logan, J. S., Lively, S. E., and Pisoni, D. B. (1991). "Training Japanese listeners to identify English /r/ and /l/: A first report," *J. Acoust. Soc. Am.* **89**, 874–886.

McClelland, J. L., and Elman, J. L. "The TRACE model of speech perception," *Cogn. Psychol.* **18**, 1–86 (1986).

Morais, J., Cary, L., Alegria, J., and Bertelson, P. (1979). "Does awareness of speech as a sequence of phones arise spontaneously?," *Cognition* **7**, 323–331.

Pallier, C., Colomé, A., and Sebastián-Gallés, N. (2001). "The influence of native-language phonology on lexical access: Exemplar-based versus abstract lexical entries," *Psychol. Sci.* **12**, 445–449.

Pattamadilok, C., Morais, J., Ventura, P., and Kolinsky, R. (2007). "The locus of the orthographic consistency effect in auditory word recognition: Further evidence from French," *Lang. Cogn. Process.* **22**, 700–726.

Sadakata, M., and McQueen, J. M. (2013). "High stimulus variability in nonnative speech learning supports formation of abstract categories: Evidence from Japanese geminates," *J. Acoust. Soc. Am.* **134**, 1324–1335.

Seidenberg, M. S., and Tanenhaus, M. K. (1979). "Orthographic effects on rhyme monitoring," *J. Exp. Psychol.: Human Learn. Mem.* **5**, 546–554.