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Are goats *chèvres*, *chévres*, *chēvres*, and *chevres*?

Unveiling the orthographic code of diacritical vowels

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Short title: Diacritics in word recognition

The stimuli, data, scripts, and output of the experiments are available at https://osf.io/e9kup/

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Abstract

An often overlooked but fundamental issue for any comprehensive model of visual-word recognition is the representation of diacritical vowels: Do diacritical and non-diacritical vowels share their abstract letter representations? Recent research suggests that the answer is "yes" in languages where diacritics indicate suprasegmental information (e.g., lexical stress, as in cámara [ˈka.ma.ɾa] camera; Spanish), but "no" in languages where diacritics indicate segmental information such as a different phoneme (e.g., the German vowels ä /ɛ/ and a /a/). Here we examined this issue in French, a language that contains a complex set of diacritical vowels (e.g., for the letter e: é, è, ê, and ë). In Experiment 1, using a semantic categorization task, we compared the word identification times to intact diacritical words (e.g., chèvre, goat in English) with a condition with omitted diacritics (chevre). Results showed that the two conditions behaved similarly. In Experiments 2-4, we compared the intact diacritical words with a condition containing a mismatching diacritic, either existing in French (e.g., chévre, chêvre) or not (the macron sign, as in chēvre). We only found a reading cost when replacing the diacritic with an existing one. In Experiments 5-6, we compared the semantic categorization times to intact non-diacritical words (e.g., cheval, horse in English) versus a condition with an added diacritic, either existing (chèval) or not (chēval). We found a reading cost for the words with the added diacritical mark in both cases. We discuss how models of visual-word recognition can be modified to represent diacritical vowels.

Keywords: word recognition, diacritics, lexical-semantic access, cross-language differences

A striking element for native speakers of English is the abundance of diacritics in other Latin-based orthographies (e.g., French: "*Éléanor a reçu un diplôme de l'école la plus chère de Genève.*" [Eleanor received an award from the most expensive school in Geneva.]). These diacritics were introduced several centuries ago to adapt the letters from the Latin alphabet to the nuances of each language, including, among other functions, those phonemes that did not exist in Latin (e.g., *ñ* /ɲ/ vs. *n* /n/ in Spanish). A less frequent option is to use a letter from another alphabet (e.g., the letter þ /θ/ in Icelandic, derived from the runic alphabet).

Despite the presence of diacritical letters in nearly all Latin-based orthographies, current neurally-inspired accounts of visual-word recognition (e.g., Dehaene et al., 2005; Grainger et al., 2008), being focused on the English orthography, have overlooked how diacritical letters are represented in the journey from print to meaning. For instance, in Dehaene et al.'s (2005) Local Combination Detector model, arrays of case-invariant abstract letter detectors guide the process of lexical access. Dehaene et al. (2005) explicitly noted that these abstract letter units would be invariant to letter CASE, font, color, and size. However, there was no mention of how these abstract letter detectors would encode diacritical letters.

A similar scenario occurs in the vast majority of computational models of visual word recognition and reading: the letter level is constituted by the 26 letters of English (e.g., LTRS model: Adelman, 2011; Spatial Coding model: Davis, 2010; Bayesian Reader model: Norris & Kinoshita, 2012; Multiple Read-Out model: Grainger & Jacobs, 1996; CDP+ model: Perry et al., 2007; E-Z Reader: Reichle et al., 1998; OB1-reader model: Snell et al., 2018). A notable exception is the Multiple-Trace Memory model (Ans et al., 1998). This model, formulated for French, includes separate abstract letter units for non-diacritical and diacritical letters. Specifically, the letter level in this model contains the 26 non-diacritical letters from Latin, 12 diacritical vowels (à, â, è, é, ê, ë, î, ï, ô, ù, û, ü), and one diacritical consonant [ç]. However, Ans et al. (1998) did not justify their choice of representing the various French diacritical letters as separate units from their non-diacritical counterparts. Of note, the Multiple-Trace Memory model remains neutral regarding the initial perceptual stages of letter and word recognition (i.e., the mapping from visual features onto abstract letter representations). Instead, it assumes that the word recognition system has already extracted the perceptual features and activated the abstract letter units.

A general framework for representing diacritical letters

Concerning those diacritical consonants that correspond to phonemes that did not exist in Latin (e.g., ñ /ɲ/ in Spanish, š /ʃ/ in Czech, etc.), one might reasonably assume that they activate different letter units than their non-diacritical counterparts. Indeed, the letters ñ and š represent speech-specific sounds and form part of the Spanish and Czech alphabets, respectively (e.g., see Marcet et al., 2020, for discussion). While these diacritical letters are visually similar to their non-diacritical counterparts, this is not a unique case in the Latin alphabet: other pairs of letters also share most of their visual features (e.g., t/f, i/j, C/G, E/F, among others).

Thus, when modeling experiments of visual-word recognition in Latin-based languages with diacritical consonants using platforms such as easyNet (Adelman et al., 2018), one would need to add these consonants to the letter level. This modification would require a more refined letter feature level to capture the extra visual features of the diacritical marks. Keep in mind that the font employed by the family of interactive activation models (i.e., the Rumelhart & Siple, 1974, font) cannot be used to represent diacritical marks.

More interesting is the case of diacritical vowels, which is the central issue of the present paper. The reason is that the function of diacritics in vowels differs greatly across languages (see Wells, 2000, for review). Diacritics may indicate: 1) another phoneme (i.e., vowel quality; e.g., German: ä /ɛ/ vs. a /a/); 2) lexical stress (i.e., the stressed syllable under some rules; e.g., Spanish: pájaro [ˈpa.xa.ɾo] bird); 3) both vowel quality and lexical stress (e.g., Catalan: després [dəsˈpɾes] later); 4) vowel length (e.g., Czech: vagón [ˈva.gɔːn] wagon); 5) vowel length and vowel quality (e.g., Hungarian: compare ez [ɛz] this vs. él [eːl] alive); 6) tone information (Vietnamese: ẻ→/ɛ˨/ [mid falling tone]); or 7) distinguishing otherwise homonyms (e.g., Spanish: él [el] he vs. el [el] the {masculine singular}).

A sensible working hypothesis is that whether or not diacritical and non-diacritical vowels have separate abstract letter units depends on their function in the language (see Marcet et al., 2022; Perea et al., 2022c). Before introducing the rationale of the experiments, which examine the role of diacritical vowels in French, we first examine two extreme scenarios: German vs. Spanish.

First, in a language like German, diacritical vowels explicitly refer to a different phoneme than their non-diacritical counterparts. Specifically, German has three diacritical vowels, always with an umlaut (ä, ö, ü; ä /ɛ/ vs. a /a/; ö /ø/ vs. o /o/; ü /y/ vs. u /u/). Following the above reasoning on diacritical consonants, one might assume that these diacritical and non-diacritical vowels activate separate abstract letter units (e.g., a ≠ ä). It is just that, as also occurs with C/G or O/Q, they are visually similar. Notably, diacritical vowels in German are considered separate letters from their non-diacritical counterparts at all levels (e.g., when learning to read; in the alphabet; in dictionaries; on computer keyboards, etc.). Consistent with this hypothesis, Hutzler et al. (2003) implemented a connectionist model of word recognition in German containing separate letter units for diacritical and non-diacritical vowels.

To test this account, Perea et al. (2022c) compared, in a semantic categorization task, the word recognition times to diacritical German words (e.g., Kröte [toad]) when presented intact and when the diacritical mark was omitted (e.g., Krote). Participants were instructed to categorize words as animals or non-animals, regardless of whether the diacritic was present or omitted (e.g., both Kröte and Krote would be categorized as animals). The logic of the Perea et al. (2022c) experiment was that if the German vowels o and ö share their abstract letter units, then word identification times would be virtually similar for the intact word Kröte and its counterpart with the omitted diacritics Krote. Alternatively, if the vowels o and ö activate separate abstract letter units, word identification times would be slowed down by the diacritics' omission. Results showed that, while participants were extremely accurate at categorizing the words with the omitted diacritics (i.e., participants could successfully reconstruct the base words), word identification times were substantially longer (around 28-33 ms) when the diacritics were omitted than when they were present (e.g., Krote > Kröte). Thus, these findings support Hutzler et al.'s (2003) assumptions concerning separate letter units for diacritical and non-diacritical vowels in German.

Second, in a language like Spanish, diacritical vowels do not modify individual phonemes (e.g., a and á are always pronounced /a/, and the same occurs for e-é /e/, i-í /i/, o-ó /o/, and u-ú /u/). Instead, they indicate lexical stress following some accentuation rules (see Appendix A in Labusch et al., 2022a, for a detailed description) (Footnote 1). In this scenario, there would be no reason why diacritical and non-diacritical vowels would be represented as separate units in the mental lexicon (see

Chetail & Boursain, 2019; Schwab, 2015). Indeed, when simulating word recognition experiments in Spanish, researchers typically omit the accent marks from diacritical words (e.g., pájaro [ˈpa.xa.ɾo] [bird] being encoded as pajaro; see Conrad et al., 2010; Perea & Rosa, 2000, for simulations with Grainger & Jacobs', 1996, Multiple Read-Out model).

Consistent with the above idea, in a sentence reading task in Spanish, Marcet and Perea (2022) found remarkably similar first-pass eye fixation times on diacritical words when they were presented intact (e.g., ratón [mouse]) and when the diacritics were omitted (e.g., ratón = raton; the difference was only 3 ms in the first-pass durations on the target word). Parallel evidence has been reported in a semantic categorization task in which participants had to indicate whether the target item was an animal or not. Perea et al. (2022c) found similar word response times for diacritical Spanish words when presented intact and when the diacritical mark was omitted (e.g., ratón = raton).

Please_Insert_Figure_1_Around_Here

Thus, the above findings suggest that the function of diacritical vowels in a language shapes their representations in the word recognition system. In languages where diacritics unambiguously modify segmental information, such as the grapheme-phoneme mapping (i.e., vowel quality; e.g., a /a/ vs. ä /ɛ/), as in German, they would be represented as separate letters units. As a result, omitting the diacritical marks in a diacritical word would convey a sizeable reading cost. Alternatively, in languages where diacritics only modify suprasegmental information such as lexical stress, as in Spanish, diacritical and non-diacritical vowels would share their abstract representations. In this latter scenario, omitting a word's diacritics would not entail an appreciable reading cost (see Figure 1 for illustration).

The case of French diacritics

An important remaining question is whether the above ideas can be generalized to a language where the function of diacritical vowels is less straightforward than German (ä, ö, ü, denoting a different phoneme) or Spanish (á, é, í, ó, ú, marking the stressed syllable). We chose French because, as pointed out earlier, there is an influential computational model of word recognition in French that assumes separate letter units for diacritical vowels (Multiple Trace-Memory model; Ans et al., 1998).

French contains 12 diacritical vowels, including acute accents (é), grave accents (à, è, ù), circumflexes (â, ê, î, ô, and û), and diereses (ë, ï, and ü). These diacritics often have a phonological function (e.g., see Le Petit Robert, 2001; Peereman et al., 2007, for a more detailed overview). This is particularly prominent for the vowel e, which is consistently pronounced /e/ when presented with an acute accent (i.e., é), and it is pronounced /ɛ/ when presented with a grave accent (i.e., è). The vowel ê is usually pronounced /ɛ/, but it can be pronounced /e/ in many words (e.g., bêtise [be.tiz] foolishness; blêmir [ble.miʁ] to pale). In addition, the non-diacritical vowel e can be pronounced, depending on some rules, /e/ or /ə/ (or mute at the end of a word). For instance, compare élève [eˈlɛv] pupil vs. élevé [e.ləˈve] elevated. Instead, the diacritics do not typically alter the sound of the vowels i (i.e., i and î are pronounced /i/) and u (i.e., u, ù, and û are pronounced /y/)—note that there are exceptions (e.g., compare jeune [ʒœ:n] young vs. jeûne [ʒø:n] fasting). The vowels a and à are typically pronounced /a/ (e.g., acheter [a.ʃə.te] to buy). In contrast, the vowel â is typically pronounced with a long /ɑ/ (e.g., bâton [bɑ.tɔ̃] stick)—however, the /a/-/ɑ/ distinction tends to disappear in European French. Depending on some rules, the vowel o can be pronounced /o/ or /ɔ/, whereas the vowel ô is consistently pronounced /o/.

In addition, diacritics in French may have other functions: (1) they serve to distinguish otherwise homonym words (e.g., la [feminine "the"] vs. là [there]); (2) they reflect the etymology of a word (e.g., the circumflexes in a word like hôpital [hospital] indicate that its Latin ancestor contained the letter "s"); and (3) the diereses indicate that the vowel is pronounced differently from the preceding vowel, creating a hiatus (e.g., compare mais [mɛ] but vs. maïs [ma.is] corn).

Some empirical support for the special role of diacritical vowels in French, as posited by Ans et al.'s (1998) Multiple-Trace Memory model, came recently from two masked priming experiments conducted by Chetail and Boursain (2019). The logic of these experiments was that if diacritical and non-diacritical vowels in French (e.g., â, a) shared their abstract letter units, the prime â and the prime a would be equally effective for the letter A. However, in a masked priming alphabetic decision task, they found faster response times to a-A than â-A. To generalize these findings to a word recognition scenario, Chetail and Boursain (2019) conducted a masked priming lexical decision experiment. They found that word identification times to a non-diacritical French target word (e.g., TAPER [to type]) were faster when preceded by a lowercase prime that could be the same (e.g., taper) than when the prime had an extra diacritical mark (tâper). Furthermore, the diacritical prime tâper was only slightly more effective (i.e., a non-significant 7-ms difference) than a control replacement-letter prime such as tuper (e.g., taper-TAPER < tâper-TAPER ≈ tuper-TAPER). (Footnote 2). Chetail and Boursain (2019) concluded that "base letters and their diacritic counterparts activate separated letter representations in scripts such as French" (p. 351).

Chetail and Boursain's (2019) findings offer relevant information on processing diacritical marks in French. However, one might argue that, for a non-diacritical target word (e.g., TAPER), the diacritical mark in a prime like tâper adds some perceptual noise that could have slowed down target processing relative to the identity prime taper. Indeed, in masked priming lexical decision experiments in English (i.e., a language with no diacritics), the pair clóck-CLOCK produces longer response times than the pair clock-CLOCK (Perea et al., 2022a). Thus, at least part of the difference between taper-TAPER vs. tâper-TAPER in the Chetail and Boursain (2019) experiment could have been due to perceptual, non-orthographic elements (see also Perea et al., 2020a, for a similar observation in Spanish).

Furthermore, we must bear in mind that, in general terms, priming paradigms do not inform us of the direct activation of a target word. Instead, they inform us about the degree to which a target word is affected by an explicitly presented prime (see Andrews, 1996; Gómez et al., 2021, for discussion). That is, what (masked) priming paradigms tell us is whether a prime modulates the processing of a target stimulus (e.g., the primes taper vs. tâper for the target word TAPER).

The use of an unprimed procedure is a more direct approach to examine whether the abstract letter representations of diacritical vowels are shared with non-diacritical vowels during access to lexical-semantic information in the mental lexicon (see Andrews, 1997, for a similar observation regarding the effects of orthographic neighborhood in word recognition). In the present experiments, we chose an unprimed semantic categorization task ("*is the word an animal?*"). The semantic categorization task requires participants to access lexical-semantic knowledge, and, unlike lexical decision, it is not easily influenced by visual format (e.g., in lexical decision, hOuSe produces slower response times than HOUSE, but this difference does not occur in semantic categorization; see Perea et al., 2020b). Another interpretive issue related to the use of the lexical decision task when comparing diacritical vs. non-diacritical items is that participants may treat the diacritical item as more wordlike. For instance, Marcet et al. (2021) found a dissociative pattern for words and nonwords in the lexical decision task: participants responded to faster to intact diacritical Spanish words than to those with an omitted diacritic (e.g., `ratón` [mouse] faster than `raton`) but they responded to slowed to diacritical than non-diacritical pseudowords (e.g., `bugón` slower than `bugon`) (see Perea et al., 2020b, for a similar dissociation when comparing same-case vs. mixed-case stimuli in the lexical decision task). Critically, this difference vanished when the diacritical items were presented in one block, and the non-diacritical items were presented in another block. Marcet et al. (2021) interpreted the differences for word stimuli in their first experiment as being due to the characteristics of the task rather than an inherent cost of diacritical processing—indeed, these same words did not show a cost in a semantic categorization task or a silent sentence reading experiment (see Marcet & Perea, 2022). Furthermore, using the semantic categorization task allowed us to readily compare the present experiments in French with the findings of parallel experiments in Spanish and German (e.g., Perea et al., 2022c; see also Labusch et al., 2022a). (Footnote 3)

Rationale of the experiments

The main goal of the present set of experiments was to test whether diacritical and non-diacritical vowels in French have shared or separate abstract letter representations in the mental lexicon. Prior theoretical and empirical work has suggested that diacritical and non-diacritical vowels in French may entail separate letter units (see Ans et al., 1998; Chetail & Boursain, 2019); however, the empirical evidence is too scarce to reach firm conclusions.

The present experiments can be divided into three blocks (Experiment 1; Experiments 2-4; Experiments 5-6). In Experiment 1, the key experiment, the logic was parallel to the German and Spanish experiments discussed in an earlier subsection. We selected a set of diacritical words (e.g., `chèvre` [goat]) and examined whether word recognition in a semantic categorization task was slowed down, relative to the intact words, when omitting the diacritical marks (e.g., `chevre`). As in prior work, we only selected words with unambiguous spelling (e.g., words like `jeûne` [fasting] could not be chosen because its non-diacritical counterpart `jeune` is also a word [young]).

If diacritical and non-diacritical vowels in French are processed as separate letter entries when accessing the mental lexicon, one would expect a substantial reading cost when omitting the diacritics relative to the intact words (e.g., `chevre` substantially slower than `chèvre`). This outcome, parallel to that reported in German (see Perea et al., 2022c), would support the idea that in French, diacritical and non-diacritical vowels are represented separately in the mental lexicon (Multiple-Trace Memory model, Ans et al., 1998; see also Chetail & Boursain, 2019). Alternatively, if diacritical and non-diacritical vowels in French activate the same letter units when accessing lexical-semantic memory, one would expect very similar word identification times to words like `chèvre` and `chevre` (i.e., the same pattern as in Spanish; see Perea et al., 2022c). This last outcome would suggest that, in French, despite their ample variety of functions, diacritical vowels share their abstract letter units with their non-diacritical counterparts. Thus, a direct implication of this data pattern is that the letter level in the Multiple-Trace Memory model (Ans et al., 1998) would need to be simplified.

To anticipate the findings of Experiment 1, we found no signs of a reading cost when omitting a word's diacritic (i.e., the pattern of data was similar to the parallel Spanish experiment conducted by Perea et al., 2022c). While this finding alone has straightforward theoretical implications, we then tested whether there was a reading cost due to placing a mismatching diacritic on French words in the following five experiments. Specifically, we examined the impact of replacing the correct diacritic with an incorrect diacritical mark (e.g., `chévre`, `chêvre`, or `chēvre` for the word `chèvre`; Experiments 2-4) and the impact of adding a diacritical mark on non-diacritical words (e.g., `chéval` or `chēval` for the word `cheval` [horse]; Experiments 4-6). We leave a more detailed explanation of these experiments for brevity's sake until later.

Experiment 1 (Intact vs. Omitted Diacritic)

Methods

Participants

We recruited 50 participants (23 women; mean age = 27.8 years [SD = 5.27]) via the online crowd-working platform Prolific Academic (http://prolific.ac). This sample size ensured at least 1,800 observations in each condition (intact vs. omitted), following Brysbaert and Stevens's (2018) guidelines for small-sized effects. In this and all subsequent experiments: (1) we used Prolific Academic's recruitment filters to only include native French speakers with no reading problems and with normal or corrected-to-normal vision; and (2) participants gave informed consent before the experiment, receiving monetary compensation according to Prolific's average participant salary. Ethical approval for this research was obtained from the Research Ethics Committee of the University of Valencia, and the study followed the requirements of the Helsinki convention.

Materials

We selected a set of 72 French words with diacritics (e.g., étui [case]) from the LEXIQUE 3 database (www.lexique.org; New et al., 2004, 2007). None of these words were animal names or referred to concepts related to animals (e.g., plants or body parts). All words were common nouns, and according to French spelling rules, they normatively required diacritics. In addition, we selected a set of 36 French words with diacritics that were animal names (e.g., chèvre [goat]) from the LEXIQUE database (New et al., 2004, 2007). The number of letters, the word frequency, OLD-20, and the amount and type of diacritics according to the LEXIQUE-database (New et al., 2004, 2007) were matched between animal names and non-animal words (see Table 1). The ratio of animals vs. non-animals was the same as in Perea et al.'s (2020a) and Labusch et al.'s (2022a) semantic categorization experiments on the role of diacritics during word recognition. We chose this ratio due to the limited amount of diacritical animal words in French—note that prior research using this same ratio has shown the same pattern of findings for animal and non-animal words using other manipulations (e.g., letter rotation: Fernández-López et al., 2022; case alternation; Perea et al., 2020a). Each item, always in lowercase, was presented intact (i.e., with its corresponding diacritic, e.g., chèvre, étui) or without the diacritic (e.g., chevre, etui). We created two counterbalanced lists in which 54 words were presented with the diacritic (18 animal nouns, 36 common nouns), and 54 words were presented without the diacritic (18 animal nouns, 36 common nouns). Those words that kept the diacritic in List 1 were presented without it in List 2 and vice versa. Each participant was assigned randomly to one of the two lists. The list of stimuli is presented in the Appendix.

Please_Insert_Table_1_Around_Here

Procedure

The experiment was created with PsychoPy 3 software (Peirce & MacAskill, 2018) and was conducted in an online setting using the servers Pavlovia (www.pavlovia.org) and LimeSurvey (www.limesurvey.org). Before the beginning of the experiment, participants filled out a questionnaire with demographic data (age, gender, level of education). They also went through sixteen practice trials to be familiarized with the task. They were instructed to do the experiment in a quiet room without any distractions. During the experiment, participants had to complete a semantic categorization task by answering whether the presented word referred to an animal name or not. As each word was presented individually, they had to press the button "L" on their keyboard for "yes" and the button "S" on their keyboard for "no" as fast and accurately as possible. Participants were instructed to classify a word as "animal" irrespective of whether it was written with the correct diacritic or not. Thus, both `chèvre` and `chevre` ought to be classified as "animals". Before presenting each word, a fixation cross appeared for 500 ms in the center of the screen. Afterward, the word appeared at the same location until a response was made (or until a time limit of 2000 ms). The trials were presented in a randomized order for each participant. Altogether, the experiment took 7-8 minutes, including a short break after 56 trials.

Data Analysis

This study was not preregistered. We created Bayesian linear mixed-effects models for each dependent variable using the *brms* package (Bürkner, 2016) in the R environment (R Core Team, 2021). The two fixed factors of the models were Format (diacritical vs. non-diacritical; encoded as -0.5 and 0.5) and Type of Word (animal vs. non-animal; encoded as -0.5 and 0.5)—note that the critical factor was Format. Following the suggestion of Barr, Levy, Scheepers, and Tily (2013), we fit the models with the maximal random-effect structure in the design:

```
Response Time [accuracy] ~ Format * TypeWord + (1 + Format * TypeWord
| subject) + (1 + Format | item)
```

As latency data typically shows a positive skew, we chose to model these data with the gaussian distribution (`family = gaussian()`) after the -1000/RT transformation. This transformation equals the number of words per second, and the negative sign was to keep the same direction of the effects as the untransformed data. As accuracy data occurs in a binary manner (correct = 1; incorrect = 0), we modeled these data with the Bernoulli distribution (`family = bernoulli()`). Each model was executed with four chains, including 5,000 iterations with a warm-up of 1,000 iterations in each chain. The model's output provided an estimate of each parameter (i.e., the mean of its posterior distribution in *brms*), its standard error, and the 95% Credible Intervals (95% CrI). We considered evidence of an effect when the 95% CrI of its estimate did not contain zero. We also presented the posterior distributions of each estimate in both RT and accuracy models. The data, scripts, and outputs of this and the rest of the experiments are available at: https://osf.io/e9kup/

Results and Discussion

In this and the following experiments, we excluded incorrect responses and response times shorter than 250 ms from the response time (RT) analyses. Due to the 2,000 ms deadline, there were no latencies above that duration. The mean RTs and error rates in each condition are presented in Table 2. The Bayesian linear mixed-effects models on the RTs and the accuracy data converged successfully, and all $\hat{R}$s were less than 1.01. The focus of the analysis was to compare the intact words and the words with the omitted diacritic (or replaced/added diacritic in other experiments). For completeness, as in prior research (see Labusch et al., 2022a; 2022b; Perea et al., 2022c), we also reported the effect of the category (animal vs. non-animal) and the two-way interaction between the two factors—note that “animals” and “non-animals” require different responses. Thus, we prefer to analyze and report all outcomes.

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<u>Response Time Analysis</u>. Response times were only 7 ms faster to the intact words than to the words with the omitted diacritic (629 vs. 636 ms, respectively)—the 95% CrI of this difference crossed zero: b = 0.01, SE = 0.01, 95% CrI [-0.01, 0.04].

In addition, response times were only slightly faster to animal words than to non-animal words (628 vs. 636 ms, respectively; b = -0.01, SE = 0.03, 95% CrI [-0.05, 0.05]). Finally, there were no signs of an interaction between the two factors (b = 0.01, SE = 0.02, 95% CrI [-0.03, 0.04]). For the posterior distributions, see the left panel of Figure 2.

<u>Accuracy Analysis</u>. There were similar error rates for words that were written with their diacritic and words without diacritic (4.9 vs. 4.8%, respectively; b = 0.01, SE = 0.27, 95% CrI [-0.53, 0.53]).

Participants made fewer errors to non-animal than to animal words (3.7% vs. 6.0%, respectively; b = 1.00, SE = 0.37, 95% CrI [0.30, 1.76]). No signs of an interaction between the two factors were observed (b = -0.26, SE = 0.34, 95% CrI [-0.93, 0.40]). For the posterior distributions, see the right panel of Figure 2.

Please_Insert_Figure_2_Around_here

The present experiment showed a minimal advantage for those words presented intact than when the diacritical mark was omitted (629 vs. 636 ms, respectively). This minor difference resembles more that reported in a parallel experiment in Spanish (a 4-ms difference) than that reported in German (a 30-ms difference; Perea et al., 2022c).

For consistency with the Perea et al. (2022c) experiments, we conducted a descriptive quantile-based analysis of the reading cost (omitted condition minus intact condition) using delta plots (see Ridderinkhof, 2002, for a description of the utility of these plots). Specifically, we obtained the average reading cost across participants at the .1, .3, .5, .7, and .9 quantiles for animal and non-animal words. Then, we computed the subtraction of these average RTs (i.e., RTs in the condition with the omitted diacritics – RTs in the intact condition). A flat line centered in zero would reflect no reading cost (i.e., a null cost across the various quantiles of the RT distribution). As shown in Figure 3, there were no apparent signs of a reading cost across the RT distribution in French. Indeed, this plot resembles much more that of the parallel Spanish experiment than the German one (see Figures 2 and 4, respectively, in Perea et al., 2022c). As in the Spanish experiment, there was a slight cost for the higher quantiles; however, this effect was negligible at the .5 quantile or lower.

Please_Insert_Figure_3_Around_here

Therefore, omitting the diacritical mark only has a minimal effect using a task that measures access to lexical-semantic information. This finding suggests that diacritical vowels may not have separate letter representations in French. If they were, one would have expected substantially faster word identification times to chèvre than to chevre, as recently reported in German (e.g., Kröte [toad] produces much faster word identification times than Krote; Perea et al., 2022c).

This outcome aligns with the observations of the daily usage of diacritics in native speakers of computer-mediated French (see Anis, 2007). For instance, van Compernolle (2010) found that the percentage of omission of acute, circumflex, and grave diacritics in an online forum of an internet dating site was relatively high (10.9, 31.2, and 32.6%, respectively). A similar observation is that diacritics in French are often not written in uppercase words, despite being mandatory in both lowercase and uppercase (Académie française, 2011)—note that a similar scenario occurs in Spanish.

Rationale of Experiments 2-4: Replacement of diacritics

Given the lack of a sizeable reading cost due to the omission of a diacritical mark in Experiment 1, an important question is whether diacritical marks are encoded and used during visual word recognition in French. To examine this issue, we designed Experiments 2-4. In these experiments, we tested whether access to the lexical-semantic information of a diacritical word was delayed when replacing the word's diacritical mark with a mismatching diacritic—note that this manipulation cannot be done with existing diacritics in the experiments in Spanish or German (i.e., Spanish only uses acute accent marks [á, é, í, ó, ú] and German only uses umlauts [ä, ö, ü]).

Experiment 2 focused on the change from acute é to grave è (or vice versa) in French diacritical words. We chose the letter e because this modification involves unambiguously different phonemes (i.e., é /e/ vs. è /ɛ/: chévre [ʃevʁ] vs. chèvre [ʃɛvʁ]). Thus, this scenario is closer to the German experiments conducted by Perea et al. (2022c) in the sense that, as occurs with the vowels a and ä in German, the French vowels é and è correspond to different phonemes. In Experiment 3, using the same set of intact words as Experiment 2, we replaced the diacritical mark of the letter e with another diacritic that did not necessarily change the word's phonology (i.e., a circumflex, e.g., chêvre). Finally, Experiment 4 tested whether there was a reading cost when replacing the word's diacritic with a mismatching diacritic that had no orthographic/phonological value (i.e., the macron, a non-existing diacritic in French, e.g., chēvre). As in Experiment 1, participants were told that the word's diacritical mark could be altered in some of the words (e.g., chèvre→chévre) but that both forms would correspond to the same answer (e.g., "yes" for chèvre and chévre).

Experiment 2 employed the most extreme manipulation: e.g., chèvre → chévre), as it switched an explicit marker of vowel quality (é /e/ vs. è /ɛ/). If an incorrect unambiguous marker of vowel quality of one of the letters (é for the word chèvre, as in chévre) has an impact on the access to lexical-semantic information, word recognition times would be faster for the intact words than for the words with the modified diacritic (e.g., chèvre < chévre). Alternatively, if the word recognition system in French is virtually insensitive to the type of diacritics, even those explicitly marking vowel quality, then one would expect similar response times to the intact words and the words with the inverted diacritical mark (e.g., chèvre ≈ chévre).

Experiment 2 (Correct vs. French diacritic that changes vowel quality)

Methods

Participants

Using Prolific Academic, we tested 50 additional participants (23 women; mean age = 26.7 years [SD = 5.21]) to obtain the same number of observations as Experiment 1. Participants had to fulfill the same recruitment criteria as in the previous experiment. They all gave informed consent before the experiment and received monetary compensation for their participation.

Materials

We selected the same set of words as in Experiment 1, except that we replaced 16 words that did not contain the diacritical vowels é or è with 16 words containing one of these diacritics. The resulting 72 French common nouns and 36 French animal names were matched in word frequency, word length, OLD-20, amount, and type of diacritics (see Table 3, for an overview) and were all written either with the diacritic é (e.g., guépard, étui) or with the diacritic è (e.g., chèvre, cuillère). Thus, each item was presented with its corresponding diacritic (e.g., étui, chèvre) or with the inverted form of its diacritic (e.g., ètui, chévre). As in Experiment 1, we created two counterbalanced lists and assigned participants to them in the same manner than in the previous experiment. For the full list of words, see Appendix.

Procedure

The experimental procedure was parallel to that in Experiment 1. Participants were instructed to classify a word as "animal" irrespective of whether it was written with the correct diacritic or not (e.g., both chèvre and chévre would correspond to "animal").

Data Analysis

We followed the same steps for data analysis as in Experiment 1.

Please_Insert_Table_3_around here

Results and Discussion

Table 4 shows the average RT and error rate for each experimental condition. Again, the Bayesian linear mixed-effects models on the latency and accuracy data converged successfully ($\hat{R}$ = 1.00 in all estimates).

Please_Insert_Table_4_Around_Here

Response Time Analysis. Participants responded, on average, 20 ms faster to words with the correct diacritic than to words with an inverted diacritic (669 vs. 689 ms, respectively; *b* = 0.04, *SE* = 0.01, *95% CrI* [0.01, 0.07]).

In addition, the differences in response times between animal words and non-animal words were minimal (678 vs. 682 ms, respectively; *b* = -0.01, *SE* = 0.03, *95% CrI* [-0.07, 0.04]). There were also no signs of interaction between the two factors (*b* = 0.00, *SE* = 0.02, *95% CrI* [-0.03, 0.03]) (see the left panel of Figure 4 for the posterior distributions).

Accuracy Analysis. There was no effect of the type of diacritics on accuracy ratings, *b* = 0.38, *SE* = 0.25, *95% CrI* [-0.09, 0.91].

In addition, participants made fewer errors to non-animal words than animal words (3.9% vs. 8.3%, respectively; *b* = 1.19, *SE* = 0.41, *95% CrI* [0.37, 2.00]), but this effect did not interact with the type of diacritics, *b* = -0.25, *SE* = 0.33, *95% CrI* [-0.88, 0.40]. The right panel of Figure 4 presents the posterior distributions.

Please_Insert_Figure_4_Around_here

The present experiment showed that intact words were identified faster than those with an inverted diacritical mark. This difference occurred similarly for animal words (666 ms vs. 689 ms, respectively, e.g., chèvre < chévre) and non-animal words (673 ms vs. 690 ms, respectively, flèche [arrow] < fléche). Therefore, it is possible to obtain a reading cost in French when replacing a word's diacritical mark with another diacritical mark, at least when it involves mismatching orthographic and phonological information (e.g., chèvre [ʃɛvʁ] < chévre [ʃevʁ]).

Experiment 3 examined whether access to lexical-semantic information in diacritical French words is slowed down when replacing a word’s diacritical mark with another diacritical mark that does not necessarily involve a change in phonology: the circumflexed vowel ê (e.g., as in chêvre). This diacritical mark, which exists in French orthography, is often pronounced /ɛ/. However, the letter ê can also be pronounced /e/ depending on the words and the speakers. For instance, as stated in the Introduction, there are a number of French words in which the letter ê is consistently pronounced /e/ (e.g., blêmir [ble.miʁ] blush) or in which the letter ê may be pronounced /ɛ/ or /e/ depending on the speaker (e.g., crêpière [kʁe.pjɛʁ] or [kʁɛ.pjɛʁ] pancake maker).

Thus, in Experiment 3, the replaced diacritical mark did not involve an unambiguous change in the word’s pronunciation. Therefore, if the reading cost found in Experiment 2 were entirely due to the activation of incorrect phonological codes (e.g., /e/ for chévre vs. /ɛ/ for chèvre), one would expect similar response times for the intact words and for those words with a circumflex replacing the correct diacritical mark (e.g., chêvre ≈ chèvre). Conversely, if the reading cost due to the replaced diacritic is mainly due to the mere presence of a mismatching diacritical mark (i.e., the letter ê in chêvre instead of the correct vowel è), one would expect longer word response times for the words with the circumflex mark when compared to the intact words (e.g., chêvre > chèvre). Of note, we conducted some exploratory analyses to study whether the reading cost differed for those circumflexed words in which native speakers of French detected a change in phonology and for those circumflexed words that would be pronounced as the intact word.

Experiment 3 (Correct vs. French diacritic that does not imply a change in pronunciation)

Methods

Participants

We recruited an additional 50 participants (21 women, mean age = 27.5 years [SD = 5.32]) via Prolific Academia. We used the same recruitment filters as in the previous experiments, presented a consent form, and got the same number of observations per condition.

Materials

We used the same materials as in Experiment 2 (see Table 3). The only difference was that we replaced the diacritical marks é or è with a circumflex (ê; e.g., chèvre was compared with chêvre).

Data Analysis and Procedure

They were the same as in the previous experiments.

Results and Discussion

Table 5 shows the average RT and error rate for each experimental condition. Again, the Bayesian linear mixed-effects models on the latency and accuracy data converged successfully ($\hat{R}$ = 1.00 in all estimates).

Please_Insert_Table_5_Around_Here

Response Time Analysis. Participants responded around 10 ms faster to words with the correct diacritic than to words with an incorrect diacritic (624 vs. 634 ms, respectively; *b* = 0.04, *SE* = 0.01, *95% CrI* [0.01, 0.06]).

In addition, we found no differences in response times between animal words and non-animal words (631 vs. 627 ms, respectively; *b* = -0.02, *SE* = 0.03, *95% CrI* [-0.07, 0.04]). There were no signs of an interaction between the two factors (*b* = -0.01, *SE* = 0.02, *95% CrI* [-0.05, 0.02]) (see the left panel of Figure 5 for the posterior distributions).

Accuracy Analysis. We found no signs of an effect of the type of diacritics, *b* = -0.13, *SE* = 0.24, *95% CrI* [-0.59, 0.31].

In addition, participants made fewer errors to non-animal words than animal words (4.3% vs. 6.4%, respectively; *b* = 0.82, *SE* = 0.37, *95% CrI* [0.10, 1.54]), but this effect did not interact with the type of diacritics (*b* = -0.12, *SE* = 0.31, *95% CrI* [-0.74, 0.47]). The right panel of Figure 5 presents the posterior distributions.

Please_Insert_Figure_5_Around_Here

The present experiments revealed a reading cost of the circumflexed words (chêvre) relative to the intact condition (chèvre). The posterior distributions showed that the evidence was clear (see left panel of Figure 5); however, the size of the effect was numerically smaller (10 ms) than in Experiment 2, where the replaced diacritical mark necessarily involved a change in vowel quality (20 ms; chèvre < chévre; i.e., é is always pronounced /e/ whereas è is always pronounced /ɛ/).

To examine whether the diminished reading cost in the present experiment was affected by phonology, we conducted an exploratory post hoc analysis. Eight additional native speakers of French indicated, on an item basis for all the words, whether the circumflexed words caused a change in the pronunciation relative to the intact words (e.g., “how would ê be pronounced in ‘pêdicure’?”). For 73% of the words, participants indicated that the pronunciation of the circumflexed word was identical to that of the intact word (e.g., *pêdicure* would be pronounced as the original word, *pédicure*; i.e., [pe.di.kyʁ]). About 26% of the words were classified as ambiguous (e.g., the word *cafêine* [base word: *caféine* [ka.fe.in] could be pronounced as [ka.fe.in] or [ka.fɛ.in]) and, finally, for only one word, participants unanimously decided to pronounce the circumflexed ê differently than in the original word (e.g., *chronomêtre* would be pronounced as *chronométre* [kʁɔ.nɔ.metʁ], but the original word was *chronomètre* [kʁɔ.nɔ.mɛtʁ]). When averaging the reading cost across items, we found approximately similar costs for those circumflexed words with ambiguous pronunciation (12.2 ms) and those with a pronunciation that coincides with the original word (9.7 ms). While we prefer to remain cautious about these exploratory analyses, they suggest that the observed reading cost when replacing the acute/grave diacritic with a circumflex may not have been primarily affected by pronunciation.

In sum, Experiments 2-3 revealed a reading cost when replacing the intact diacritical marks with other diacritical marks that are naturally occurring in French (i.e., grave, acute, circumflex). A sensible question to ask is whether this reading cost was mainly due to: (1) the replaced diacritic being familiar to French speakers, thus producing some interference at an orthographic/phonological level; or (2) a general effect of perceptual noise generated by any mismatching mark that replaced the original diacritic.

To examine this issue, in Experiment 4, we replaced the original diacritical mark with a diacritical mark that does not exist in French (i.e., the macron sign; e.g., ē, as in chēvre) and compared them to the intact words (chèvre). We used the same set of words as in Experiments 2-3.

If the observed reading cost for the words with a mismatching diacritical mark found in Experiments 2-3 was due to the activation of mismatching orthographic/phonological codes, we would expect this cost to vanish when a macron replaced the correct diacritical mark (e.g., chēvre ≈ chèvre). Conversely, if the reading cost of the replaced diacritical marks in Experiments 2-3 was mainly due to the added perceptual noise caused by the presence of a mismatching diacritic (i.e., regardless of its function), one would expect longer word response times for the words with the macron-replaced mark when compared to the intact words (e.g., chēvre > chèvre).

Experiment 4 (Correct vs. Non-Existing Diacritic)

Methods

Participants

An additional sample of 50 participants (20 women; mean age = 27.2 years [SD = 5.37]) with the same profile as in the previous experiments was recruited via Prolific Academic, thus resulting in the same number of observations. Before the experiment, all participants signed a consent form and received a small monetary compensation.

Materials

We employed the same words as in Experiments 2-3 (see Table 3). The only difference was that each word was presented with its corresponding diacritic (e.g., `étui`, `chèvre`) or with a macron (i.e., a neutral diacritic that is never used in French; e.g., `ētui`, `chēvre`). The two counterbalanced lists were created in the same way as in the previous experiments.

Procedure and Data Analysis

They were parallel to the prior experiments.

Results and Discussion

The Bayesian linear mixed-effects models converged successfully and $\hat{R}$ = 1.00 in all estimates. Table 6 shows the average RT and error rate for each condition.

Please_Insert_Table_6_Around_Here

Response Time Analysis. Participants responded, on average, 5 ms faster to the intact words than to the words with a neutral diacritic (653 vs. 658 ms, respectively)—note that the estimate of this difference crossed zero: *b* = 0.02, *SE* = 0.01, 95% CrI [-0.01, 0.05].

There was also a negligible difference in response times between animal words and non-animal words (657 vs. 655 ms, respectively; *b* = -0.02, *SE* = 0.03, 95% CrI [-0.08, 0.04]), and no signs of an interaction between the two factors (*b* = -0.02, *SE* = 0.02, 95% CrI [-0.05, 0.02]). For the posterior distributions, see the left panel of Figure 6.

Accuracy Analysis. There were no signs of an effect of the type of diacritics (*b* = 0.04, *SE* = 0.24, 95% CrI [-0.41, 0.51]).
In addition, Participants made fewer errors in trials with non-animal words than in trials with animal words (3.6% vs. 7.1%, respectively; *b* = 1.01, *SE* = 0.34, 95% CrI [0.37, 1.69]). We found no signs of an interaction between the two factors (*b* = -0.10, *SE* = 0.31, 95% CrI [-0.71, 0.52]). For the posterior distributions, see the right panel of Figure 6.

Please_Insert_Figure_6_Around_here

The present experiment showed that word identification times were only minimally shorter when the words were presented intact than when a macron replaced the diacritical mark (653 vs. 658 ms, respectively), thus resembling the pattern observed in Experiment 1. In other words, replacing the original diacritic with a non-existing diacritical mark only entails a negligible reading cost. This outcome suggests that the reading cost observed in Experiments 2-3 (with an existing mismatching diacritic replacing the original diacritic) was primarily due to the mismatching information from a familiar diacritic.

Summary of Experiments 1-4. We have shown that the access to lexical-semantic information of diacritical French words (e.g., chèvre) is only minimally delayed when the diacritical mark is omitted (e.g., chevre; Experiment 1) or replaced with a non-existent diacritical mark (Experiment 4) (see Figures 2 and 6 for the posterior distributions of the effects). These data can be parsimoniously interpreted in terms of diacritical and non-diacritical vowels sharing their abstract letter representations in French, as has been claimed in Spanish (e.g., Marcet & Perea, 2022; Perea et al., 2020b, 2022c). At the same time, the findings of Experiments 2 and 3, in which the word's diacritical mark was replaced by an existing diacritic (e.g., chévre, chêvre), revealed a reading cost (see Figures 3 and 4 for the posterior distributions of the effects). Thus, replacing the correct diacritic with a mismatching existing diacritic may slow down access to lexical-semantic representations in French.

How can a model of word recognition account for this dissociative pattern? Cubelli and Beschin (2005) proposed a hypothesis that can explain the observed patterns in a conclusive way. They suggested that the word recognition system processes a word's diacritical mark in parallel to letter identity. More precisely, during visual word recognition, information on the diacritical marks of a word would be stored and processed as a visual cue for lexical access. A mismatch between the perceptual representation of the word and its stored representation would induce a reading cost. Thus, the Cubelli and Beschin (2005) model can readily account for the reading cost with mismatching diacritics in Experiment 2-3: the diacritical marks é in chévre or ê in chêvre would induce some orthographic/phonological mismatch relative to a stored representation of the word chèvre, thus delaying the access to lexical-semantic information. Notably, this interpretation can also explain the minor but consistent reading cost for the words with the omitted diacritical mark (or with non-existing diacritics) found in semantic categorization tasks in French (6 ms in Experiment 1; 5 ms in Experiment 4) and Spanish (4 ms slower for raton when compared to ratón [mouse], Perea et al., 2022c; see also Marcet & Perea, 2022).

Rationale of Experiments 5-6: Addition of Diacritics

To obtain a complete picture of the role of diacritics during the access to lexical-semantic information in French, it is important to also examine the potential cost of *adding* diacritics to non-diacritical words (i.e., not just replacing the correct diacritic with a mismatching one). Prior word recognition experiments on this issue are scarce. In French, Chetail and Boursain (2019) used masked priming lexical decision to compare the impact of an intact identity prime (e.g., taper) versus a prime with an additional diacritic (e.g., tâper) on the processing of non-diacritical target words (e.g., TAPER). They found longer response times in the condition with the additional diacritic than in the identity condition. This pattern was interpreted in terms of diacritical and non-diacritical French vowels activating separate letter units. However, as we indicated in the Introduction, the diacritical vowel may add some perceptual noise when identifying a non-diacritical target. Indeed, Perea et al. (2022a) found this same pattern in a masked priming lexical decision experiment in English (e.g., clóck-CLOCK produced longer latencies than clock-CLOCK)—note that, as English orthography lacks diacritics, native English speakers do not have orthographic representations for diacritical vowels.

Notably, in a recent semantic categorization experiment in Spanish (i.e., a language in which diacritical and non-diacritical vowels presumably share their abstract letter units), Labusch et al. (2022a) found a small, but reliable cost of adding a diacritical mark in the unstressed syllable in Spanish (around 7-9 ms). For instance, the intact word cebra [ˈθebɾa] (zebra) was responded to faster than cebrá [θebɾˈa]. In addition, Labusch et al. (2022a) found that this cost was negligible when the added diacritic occurred on the stressed syllable (e.g., cébra for cebra). Labusch et al. (2022a) interpreted their findings in terms of the Cubelli and Beschin (2005) proposal mentioned earlier: cebrá would involve some mismatching of orthographic and phonological information with the stored entry (i.e., cebra), slowing down its recognition.

Thus, in this block of experiments, we examined whether adding a diacritical mark to a non-diacritical French word (e.g., cheval [horse]) delays access to lexical-semantic information. Similar to the experiments from the previous block, we added a diacritical mark that existed in French (Experiment 5) or a diacritic that did not exist in French (Experiment 6). Parallel to the previous experiments, participants were instructed to respond to “animal” vs. “non-animal” regardless of whether a diacritical mark was added to the word.

Thus, in Experiment 5, we examined whether the access to lexical-semantic information is hindered when adding an existing diacritical mark to a non-diacritical French word (e.g., whether chèval produced longer response times than cheval). If adding an existing diacritical mark to a non-diacritical French word hinders the access to lexical-semantic information, one would expect a reading cost relative to the intact words (e.g., chèval > cheval). This outcome would favor the proposal that the information from the diacritical mark is processed in parallel with abstract letter identities (Cubelli & Beschin, 2005), extending to French the recent findings reported in Spanish (see Perea et al., 2022a). Of note, we conducted an exploratory analysis to study whether the reading cost differed for those words where the diacritic was added to the vowel `e`—note that `é` or `è` are French vowels with unambiguous phonological codes—or to the other vowels.

Experiment 5 (Intact vs. Added [existing] Diacritic)

Methods

Participants

We recruited 50 additional individuals (22 women; mean age = 31.28 years [SD = 9.7]) via Prolific Academia with the same recruitment filters as in the previous experiments. All participants gave informed consent to participate in the study.

Materials

We selected a set of 108 French words from the LEXIQUE 3 database (www.lexique.org; New et al., 2004, 2007) of which 36 were animal names and 72 were non-animal common nouns that did not refer to animals or concepts related to animals. Importantly, all the words were common nouns and were written without any diacritical mark according to the French orthographic rules (for a full list of the words, see Appendix). The number of letters, the word frequency, and the OLD-20 according to the LEXIQUE database (New et al., 2004, 2007) were matched between animal names and non-animal words (see Table 7). Each item was presented in its usual form without a diacritical mark (e.g., `cheval`) or with a diacritical mark that was added to one of the vowels within the word (e.g., `chèval`). We chose only viable combinations of diacritics in French, and the amount and type of diacritics were counterbalanced for animal names and common (non-animal) nouns. The stimulus lists were created in the same way as in Experiments 1-4.

Please_Insert_Table_7_Around_Here

Procedure

The experimental procedure was the same as in Experiments 1-4. In this case, participants were told to classify a word as “animal” irrespective of whether it was written intact or with an added diacritic (e.g., `cheval` and `chèval` were ought to be classified as “animal”).

Data Analysis

We followed the same steps for data analysis as in Experiments 1-4. The fixed factors were Format (added diacritics vs. [intact] non-diacritics; encoded as -0.5 and 0.5) and Type of Word (animal vs. non-animal; encoded as -0.5 and 0.5).

Results and Discussion

The analyses were similar to those in previous experiments. Both Bayesian linear mixed-effects models converged successfully (all $\hat{R}$s = 1.00). The mean RTs and the error rates for each condition are given in Table 8.

Please_Insert_Table_8_Around_Here

<u>Response Time Analysis</u>. Responses to intact words were, on average, 19 ms shorter than to the words with an added diacritic (606 vs. 625 ms, respectively; *b* = 0.04, *SE* = 0.01, 95% CrI [0.01, 0.07]).

We also found a small difference in response times between animal words and non-animal words (621 vs. 611 ms, respectively), but its estimate crossed zero; *b* = -0.01, *SE* = 0.03, 95% CrI [-0.07, 0.04]. There were no signs of a two-way interaction, *b*

= -0.00, *SE* = 0.02, 95% CrI [-0.03, 0.03]. The left panel of Figure 7 displays the posterior distributions.

<u>Accuracy Analysis</u>. Responses to the intact words were only minimally more accurate than to words with an additional diacritic (error rates: 2.2% vs. 2.8%, respectively; *b* = 0.45, *SE* = 0.33, 95% CrI [-0.19, 1.14]).

In addition, participants made fewer errors in trials with non-animal words than in trials with animal words (0.8 % error rate for non-animal words vs. 4.2 % error rate for animal words; *b* = 2.21, *SE* = 0.45, 95% CrI [1.43, 3.20]). We did not find an interaction between the two factors (*b* = -0.63, *SE* = 0.56, 95% CrI [-1.74, 0.48]). The right panel of Figure 7 displays the posterior distributions.

Please_Insert_Figure_7_Around_Here

The current experiment showed faster responses to non-diacritical French words when presented intact than when adding an existing diacritical mark to one of the vowels (e.g., `cheval` [606 ms] < `chèval` [625 ms]; see Figure 7).

To further scrutinize this reading cost, we conducted an exploratory post hoc analysis that examined whether the effect differed for those words in which an acute/grave accent was added to the vowel `e` (e.g., `e` was changed to `é` \e\ or `è` \ɛ\; 48 words) and for those words in which the diacritical mark was added to another vowel (i.e., as in `î`, `û`; 60 words). As we noted earlier, the additional acute/grave diacritics to the letter `e` (resulting in `é` or `è`) may lead to a different pronunciation of the word, whereas this is not necessarily the case for other additional diacritical marks in French (compare cheval [ʃə.val] horse vs. chèval [ʃɛ.val] and loup [lu] wolf vs. loûp [lu]). When averaging the reading cost by items, for those words where the diacritical mark was added to the letter `e` (e.g., `cheval` [horse] vs. `chèval`), we found a reading cost of 30 ms relative to the intact condition. Instead, this reading cost was only 8 ms for those words when the diacritical mark was added to another vowel (e.g., loup [wolf] vs. loûp). Even though this post hoc analysis should be treated with caution, these findings seem to suggest that the bulk of the reading cost occurred mainly for those words in which the extra diacritical mark was placed on the letter e (i.e., there was a reading cost when reconstructing e from è in chèval). Instead, for those words in which the diacritical mark was placed on a letter other than e, the reading cost was small (8 ms; e.g., as in loup [lu] vs. loûp [lu]) and similar to that reported recently in Spanish (Labusch et al., 2022a).

Thus, the present experiment showed that adding a diacritical mark to a non-diacritical French word may entail a reading cost. This finding contrasts with the minimal cost observed in Experiment 1, where the omission of the diacritics barely reflected a reading cost. Nonetheless, this dissociation can be interpreted as reflecting that omitting a feature from a given stimulus is not the same as adding an element to the stimulus (see Treisman & Gormican, 1988; Tversky, 1977, for models of perceptual asymmetries). Consistent with this idea, several masked priming experiments have shown a perceptual asymmetry in several languages containing diacritics: a → á, but á ↛ a (see Perea et al., 2020b, 2021, for vowels; see Marcet et al., 2020, for consonants; see Kinoshita et al., 2021, for hiragana letters). Of note, the cost from the diacritical primes also occurs with native English speakers, in a language lacking diacritical vowels (e.g., mónth-MONTH slower than month-MONTH; see Perea et al., 2022c).

However, from the present experiment, it is uncertain whether the observed reading cost was due to adding a familiar, existing diacritical mark or whether the cost originated at a more perceptual level. Experiment 6 was designed to tease apart the familiarity vs. perceptual explanations. Specifically, in Experiment 6, we assessed whether adding a non-existent diacritical mark (i.e., a macron, as in `ē` [see Experiment 4 for the use of this same diacritical mark]) with no orthographic/phonological value to an otherwise non-diacritical word (e.g., `chēval` for `cheval`) hinders the access to lexical-semantic information. We used the same words as in Experiment 5.

If the sole addition of a diacritical mark to a non-diacritical word, even one that does not exist in the language, makes the percept less similar to the stored representation of the word in lexical memory, we would expect slower response times for those words with the added diacritical vowel than for the intact words (e.g., `chēval` slower than `cheval`). This outcome would favor a perceptual explanation of the reading cost due to the extra diacritical mark. Conversely, if adding a non-existing diacritical mark to a non-diacritical word like `cheval` does not affect the access to lexical-semantic information, we expect similar response times to the intact words and those with an extra macron sign (e.g., `cheval ≈ chēval`). This latter outcome would suggest that the reading cost found in Experiment 5 was dependent on the familiarity of the added diacritical marks. Further, we conducted post hoc analyses comparing the reading cost in those words where the diacritical mark was added to the letter `e` of the word and those pairs in which the diacritical mark was added to a vowel other than `e`.

Experiment 6 (Intact vs. Added [non-existing] Diacritic)

Methods

Participants

We recruited an additional sample of 50 participants (16 women, mean age = 31.18 years [SD = 9.51]), using Prolific Academia and the same recruitment filters as in the previous experiments. All participants gave informed consent before participating in the study.

Materials

We used the words from Experiment 5 (see Table 7 and Appendix). Each word was presented either intact (e.g., `cheval`) or with an added non-existent diacritic (e.g., `chēval`). The diacritical marks were added to the same locations of the words as in Experiment 5. The stimulus lists were created in the same way as in the previous experiments.

Procedure and Data Analysis

They were the same as in Experiment 5.

Results and Discussion

Both Bayesian linear mixed-effects models converged successfully ($\hat{R}$s = 1.00). The mean RTs and percentage of errors are given in Table 9.

Please_Insert_Table_9_Around_Here

Response Time Analysis. Responses to words were faster when presented intact than when they were presented with an extra diacritical mark (614 vs. 627 ms, respectively; b = -0.04, SE = 0.01, 95% CrI [-0.07, -0.02]).

There was virtually no difference in response times between animal words and non-animal words (620 ms for animal words vs. 621 ms for non-animal words; b = -0.02, SE = 0.02, 95% CrI [-0.06, 0.02]) and no interaction between the two factors (b = 0.01, SE = 0.02, 95% CrI [-0.02, 0.05]). For the posterior distributions, see Figure 8.

Accuracy Analysis. We found a similar accuracy for accented and non-accented words (3.0% of errors for non-accented words vs. 2.8% of errors for accented words; *b* = -0.10, *SE* = 0.30, 95% CrI [-0.67, 0.49]).

Participants made fewer errors in the non-animal nouns than in the animal nouns (1.6 % of errors for non-animal words vs. 4.2% of errors for animal words; *b* = 0.87, *SE* = 0.32, 95% CrI [0.27, 1.52]). There was no interaction between format and type of word (*b* = 0.44, *SE* = 0.42, 95% CrI [-0.38, 1.26]) (see Figure 8 for the posterior distributions).

Please_Insert_Figure_8_Around_Here

The present experiment showed slower word identification times for words with an added (non-existing) diacritical mark than the intact words (627 vs. 614 ms, respectively). This pattern reveals a reading cost due to adding an extra feature to a vowel, even when this feature has no internal representations.

Thus, the present findings suggest that the extra diacritical mark (even a non-existing diacritic in the language) slows down the processing of a non-diacritical word, extending recent findings obtained with masked priming experiments in languages lacking diacritical vowels (English, e.g., nórth-NORTH being slower than north-NORTH; Perea et al., 2022a) to an unprimed paradigm.

Like in Experiment 5, we conducted a post hoc analysis of the reading cost for those words where the diacritical mark was added to a vowel other than e and for those words where a diacritical mark was added to the letter e. For the words with an added diacritic on a vowel other than e (for instance, loūp), the reading cost was 8 ms—it was also 8 ms in Experiment 5. For the words with the diacritic on the vowel e (for instance, chēval), the reading cost was 15 ms (it was 30 ms in Experiment 5). A possible explanation for this reduced reading cost for the letter e in the present experiment is that unlike in Experiment 5, the diacritical mark had no orthographic/phonological value. We acknowledge that further experiments with a direct comparison of the various diacritical marks in French need to be done to examine the subtleties of this comparison.

General Discussion

An often unnoticed but essential issue for any universal model of visual-word recognition and reading in alphabetic orthographies is how the word recognition system represents diacritical letters. Recent research has suggested that the representation of diacritical vowels may depend on their function in the language (Figure 1): when they only indicate a supra-segmental value such as lexical stress—as occurs in Spanish—diacritical and non-diacritical vowels would share their letter units; in contrast, when diacritics designate a change in phonology, as in German, diacritical and non-diacritical vowels would be represented as separate letter units (see Perea et al., 2022c). The main aim of the present research was to examine this issue in French. We chose French because 1) it has a more extensive variety of diacritical marks than Spanish or German (e.g., e: é, è, ê, ë); 2) the function of these diacritical marks are quite diverse, unlike Spanish or German; and 3) there is an influential computational model of word recognition that assumes that diacritical and non-diacritical French vowels are processed as separate abstract letter units (Ans et al., 1998; see also Chetail & Boursain, 2019, for a similar view).

We employed a semantic categorization task (i.e., animal vs. non-animal) for comparison purposes with recent studies conducted in Spanish and German. We conducted three blocks of experiments. In the first two blocks (Experiments 1-4), we selected a set of diacritical words (e.g., chèvre). The most important finding was that omitting the word's diacritical mark (or its replacement with a non-existing diacritic) only produced a minimal non-reliable reading cost (5-6 ms). Critically, this pattern is similar to that reported with the omission of diacritics in Spanish (Perea et al., 2022c). At the same time, we found a deleterious effect, relative to the intact words, when replacing the correct diacritical mark of the diacritical word with a mismatching existing diacritic (10-20 ms; Experiments 2-3). In the third block (Experiments 5-6), we selected a set of non-diacritical words and added an existing or non-existing diacritical mark (e.g., cheval in Experiment 5; chēval, in Experiment 6). We found a reading cost of adding a diacritical mark in both cases (Experiment 5: 19 ms; Experiment 6: 13 ms). We now discuss the implications of these findings for models of visual word recognition.

First, the present experiments showed that, for diacritical French words, neither the omission of a diacritical mark nor its replacement with a non-existing diacritical mark has a substantial, deleterious effect on the access to lexical-semantic information: chevre and chēvre produced only slightly longer (around 5-6 ms, respectively) word identification times than the intact word chèvre. These findings pose doubts on the necessity of having twelve abstract letter units for the diacritical vowels in computational models of visual-word recognition in French, as in the Ans et al. (1998) model.

We believe that the most straightforward account of the above-described findings is that diacritical and non-diacritical vowels in French are not represented as entirely separate abstract letter identities. Instead, as suggested in another Romance language like Spanish (Marcet et al., 2021; Schwab, 2015), abstract letter units may be shared for diacritical and non-diacritical vowels. These conclusions align with observations of the daily usage of diacritics in native French speakers. Notably, diacritics are often omitted in computer-mediated French (see Anis, 2007). For instance, van Compernolle (2010) found that the percentage of omission of acute, circumflex, and grave diacritics in a forum of an internet dating site was relatively high (10.9%, 31.2%, and 32.6%, respectively). Furthermore, in a recent poll among 2500 French employers, 76% indicated that they struggled with written diacritical French words on a daily basis (Laffont, 2021). Likewise, it is not uncommon to find signs of stores and restaurants in French without the prescriptive diacritical mark even when written in uppercase (e.g., EPICERIE instead of ÉPICERIE [grocery store]). While a parallel scenario occurs in Spanish (e.g., PANADERIA instead of the prescriptive spelling PANADERÍA [bakery]), this is not the case in German with umlauts, where uppercase words keep their diacritical marks (e.g., BÜCHEREI [library]). Thus, the present findings coincide with the observations of the everyday use of diacritics in French and Spanish.

The above reasoning does not imply that diacritical marks are treated as visual characteristics such as font, color, or size during lexical access. Unlike these perceptual elements, diacritics convey useful information during lexical access and have several functions in French (e.g., distinguishing homonyms, indicating phonological information, demonstrating the difference between past/present tense, or displaying the origin of the words). A sensible account, first proposed by Cubelli and Beschin (2005) in Italian, is that diacritical marks serve as orthographic cues during visual word identification—note that this idea is similar to that put forward by Peressotti et al. (2003) for the coding of the initial capitalization of proper nouns (see Sulpizio & Job, 2018, for electrophysiological evidence). The logic of Cubelli and Beschin's proposal is that in parallel to processing the word's abstract letter units, the word recognition system also encodes the information from the diacritical vowels. As a result, the orthographic cues for the diacritical vowels in chévre would activate incompatible features that could cause interference when compared with the correct lexical entry chèvre, thus slowing down the access to lexical-semantic information. This way, this "orthographic cue" hypothesis can easily capture the reading cost of the words with mismatching diacritics in Experiments 2-3. The reading cost would be smaller when the diacritical information is omitted, or a non-existing diacritic replaces it. Thus, the "orthographic cue" account can also capture the minimal reading cost observed in Experiments 1 and 4 (around 5-6 ms overall). Notably, this account can also explain the small but consistent reading cost of the words with the omitted diacritics in parallel experiments in Spanish, where there is no principled reason why diacritical and non-diacritical vowels would activate separate abstract letter units (e.g., 4 ms, Perea et al., 2022a; see also Marcet et al., 2021; Marcet & Perea, 2022, for a similar pattern).

To fully delineate the role of diacritical vowels in French, we also conducted two experiments with non-diacritical French words (e.g., cheval). In these experiments, items were presented intact or with an added diacritical mark, either existing (e.g., chèval, Experiment 5) or non-existing (e.g., chēval, Experiment 6). The idea is that adding incompatible features to non-diacritical words could cause extra interference (either via bottom-up or lateral inhibition) during word recognition. In both cases, we found slower word response times for the words with an extra diacritic than for the intact words (e.g., cheval < chèval; cheval < chēval). Again, these findings can also be accommodated within the "orthographic cue" hypothesis proposed above. The logic is that adding incompatible features (i.e., the added diacritics) would induce some perceptual noise, making the visual input less similar to the word's representation stored in the mental lexicon and hence, producing a reading cost relative to the intact words. The reading cost was slightly higher for the case where the diacritical mark existed in the language (19 vs. 13 ms, respectively). Notably, the reading cost with the added existing diacritic occurred to a larger degree when it involved a marker of vowel quality like è or é (e.g., words like chèval produced a greater cost over its corresponding intact word than words like loûp). Thus, adding a familiar diacritical mark with unambiguous spelling (e.g., as in chèval) could involve an extra cost above the perceptual cost of adding an extraneous diacritic (see Perea et al., 2022a for a small cost when adding diacritics in English words). In line with this, future research could evaluate the special role of diacritical marks in cases where French diacritics may play a stronger role during processing, for instance when additional diacritical marks indicate a change from the French present to past tense (e.g., chante [sing] vs. chanté [sang]). Note that the current experiments have been done with nouns, and we intentionally excluded these ambiguous cases. Altogether, the present findings suggest that in French, not only the word's perceptual features play a role in the processing of the diacritical vowels but also their linguistic properties.

Another remarkable pattern in the present experiments is that adding a feature to a given letter harms word processing more than removing it. Specifically, adding a diacritical mark to a non-diacritical French word hindered lexical access, whereas removing it from a diacritical word only produced a minimal cost. This asymmetry is not new; it goes back to Tversky (1977) and Treisman & Gormican (1988). Critically, this dissociation can readily capture the advantage of taper-TAPER over tâper-TAPER in masked priming in French (Chetail & Boursain, 2019) without resourcing to assuming separate letter presentations: the added diacritical mark on the letter â makes the percept less similar to a than vice versa. Thus, the general idea is that incompatible features may cause interference while removing a feature does not cause interference (see Kinoshita et al., 2021, for a noisy-channel model of perceptual asymmetries during letter recognition).

How are diacritical vowels represented in neural and computational models of visual word recognition? As we indicated in the Introduction, in the case of French, the Multiple-Trace Memory model (Ans et al., 1998) assumes separate letter units for every diacritical vowel in French (12 extra letter units). Therefore, this model would have predicted a sizeable reading cost for chevre compared to chèvre, presumably with an effect size close to that reported in German (see Perea et al., 2022c). A more parsimonious account is to assume that diacritical vowels in French share their representations with their base letters. We acknowledge that the French vowels è and é (i.e., the ones in which the diacritics involve an unambiguous grapheme-phoneme mapping) could enjoy a special role, but its close examination would go beyond the scope of this paper. This option does not exclude that diacritical marks, in general, may serve as an orthographic cue to speed up lexical processing and help with the orthography-to-phonology mapping (see Cubelli & Beschin, 2005). Future computational models of visual word recognition should consider adding an orthographic marker for diacritical vowels in French instead of encoding the diacritical vowels as completely separate units at the letter level.

A similar explanation applies to Spanish and probably other languages (e.g., Italian) in which diacritics also have a suprasegmental role (i.e., lexical stress; see Protopapas & Gerakaki, 2009, for a similar observation in Greek). Importantly, the scenario is quite different for languages like German or Finnish, where there is a one-to-one correspondence between the diacritical vowels and their associated phoneme (e.g., *ä* /ɛ/ vs. a /a/ in German). In this latter case, diacritical vowels would be represented as different letter units; it just happens that vowels like a and ä are visually very similar (e.g., as i/j, or O/Q; see Marcet & Perea, 2017, 2018).

In sum, our findings favor the view that diacritical and non-diacritical vowels share their abstract letter units in French. Indeed, omitting a word's diacritical mark has little effect on the access to lexical-semantic information (e.g., chèvre ≈ chevre). More research is necessary to delineate the role of diacritics in French and other languages using techniques that may be more sensitive to the time course of the effects (e.g., sentence reading, event-related potentials) and across various populations (e.g., L1 and L2 learners).

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Footnotes

Footnote 1. Spanish also has the very infrequent diacritical vowel ü, which indicates that the vowel u must be pronounced in the sequence gue/gui, as in pingüino [piŋˈgwi.no] penguin.

Footnote 2. Prior research has reported small, but reliable visual similarity effects in masked priming (e.g., obiect-OBJECT faster than obaect-OBJECT; see Marcet & Perea, 2017, 2018; see also Perea et al., 2020b, 2022b).

Footnote 3. We also preferred the semantic categorization task over the naming task (i.e., another widely used word recognition task) because the latter does not necessarily reflect access to lexical-semantic representations (e.g., the French word élève /eˈlɛv/ can be pronounced following a grapheme-to-phoneme route).

Table 1. Comparison of the mean characteristics of the word items in Experiment 1. Standard deviations are given in parentheses.

Words	***Word frequency (per million)***	***Word length***	***OLD-20***	***Types of diacritics used***
Animal nouns	2.49 *(3.31)*	6.81 *(1.55)*	2.46 *(0.67)*	é, è, ê, î, â, ï
Common nouns	2.46 *(2.62)*	7.11 *(2.03)*	2.31 *(0.64)*	é, è, ê, î, â, ï
p-value (t-test)	0.95	0.42	0.25	

Table 2. Mean response times (in ms) and error rates (in percentages) for non-animal words and animal words written with their diacritics present or omitted in Experiment 1.

	Diacritic Present		**Diacritic Omitted**	
	Response time	**Error rate**	**Response time**	**Error rate**
Non-Animals	631	3.5	640	3.9
Animals	626	6.3	630	5.7

Table 3. Comparison of the mean characteristics of the word items of Experiment 2, 3 and 4. Standard deviations are given in parentheses.

Words	***Word frequency (per million)***	***Word length***	***OLD-20***	***Types of diacritics used***
Animal nouns	2.02 *(2.91)*	7.08 *(1.45)*	2.57 *(0.69)*	é, è (Exp. 2) ē (Exp. 3)
Common nouns	2.16 *(2.42)*	7.19 *(1.95)*	2.31 *(0.62)*	é, è (Exp. 2) ē (Exp. 3)
p-value (t-test)	0.81	0.77	0.051	

Table 4. Mean response times (in ms) and error rates (in percentages) for non-animal words and animal words written with their correct diacritics or inverted diacritics in Experiment 2.

	Correct Diacritic		**Inverted Diacritic**	
	Response time	**Error rate**	**Response time**	**Error rate**
Non-Animals	673	3.7	690	4.0
Animals	666	9.0	689	7.5

Table 5. Mean response times (in ms) and error rates (in percentages) for non-animal words and animal words written with their correct diacritics or incorrect French diacritics that did not necessarily change the pronunciation in Experiment 3.

	Correct Diacritic		**Incorrect Diacritic**	
	Response time	**Error rate**	**Response time**	**Error rate**
Non-Animals	623	4.0	631	4.5
Animals	624	6.2	637	6.7

Table 6. Mean response times (in ms) and error rates (in percentages) for non-animal words and animal words written with their correct diacritic or a neutral diacritic in Experiment 4.

	Correct Diacritic		**Non-existing Diacritic**	
	Response time	**Error rate**	**Response time**	**Error rate**
Non-Animals	655	3.4	654	3.7
Animals	651	7.0	663	7.2

Table 7. Comparison of the mean characteristics of the word items in Experiments 5 and 6. Standard deviations are given in parentheses.

Words	***Word frequency (per million)***	***Word length***	***OLD-20***	***Types of diacritics used***
Animal nouns	18.89 *(30.2)*	6.17 *(1.38)*	1.88 *(0.52)*	é, è, î, â, ï, û, ô
Common nouns	18.88 *(24.3)*	6.61 *(1.36)*	1.95 *(0.44)*	é, è, î, â, ï, û, ô
p-value (t-test)	0.99	0.11	0.42	

Table 8. Mean response times (in ms) and error rates (in percentages) for non-animal words and animal words written intact (i.e., without diacritics) with an additional diacritic in Experiment 5.

	No Diacritic		**Additional Diacritic**	
	Response time	**Error rate**	**Response time**	**Error rate**
Non-Animals	603	0.9	618	0.7
Animals	609	3.4	632	4.9

Table 9. Mean response times (in ms) and error rates (in percentages) for non-animal words and animal words written intact (i.e., without diacritics) or with an additional non-existing diacritic in Experiment 6.

	No Diacritic		**Additional Diacritic**	
	Response time	**Error rate**	**Response time**	**Error rate**
Non-Animals	616	1.4	625	1.8
Animals	612	4.6	628	3.8

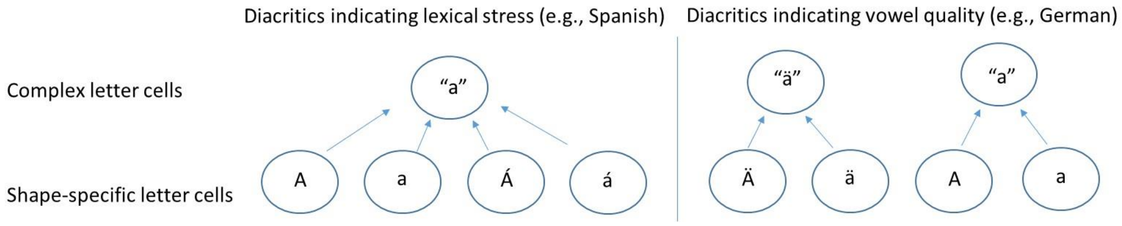

Figure 1. Proposed mechanism of the mapping from diacritical letters onto abstract representations ("complex letter cells") in Spanish (left panel) and German (right panel) inspired in the neural model of letter recognition proposed by Grainger et al. (2008). In Spanish, diacritical and non-diacritical variations of a vowel would be mapped onto the same abstract letter unit (left panel). In German, diacritical and non-diacritical vowels would have separate abstract representations—note that these abstract units would be insensitive to letter case (right panel).

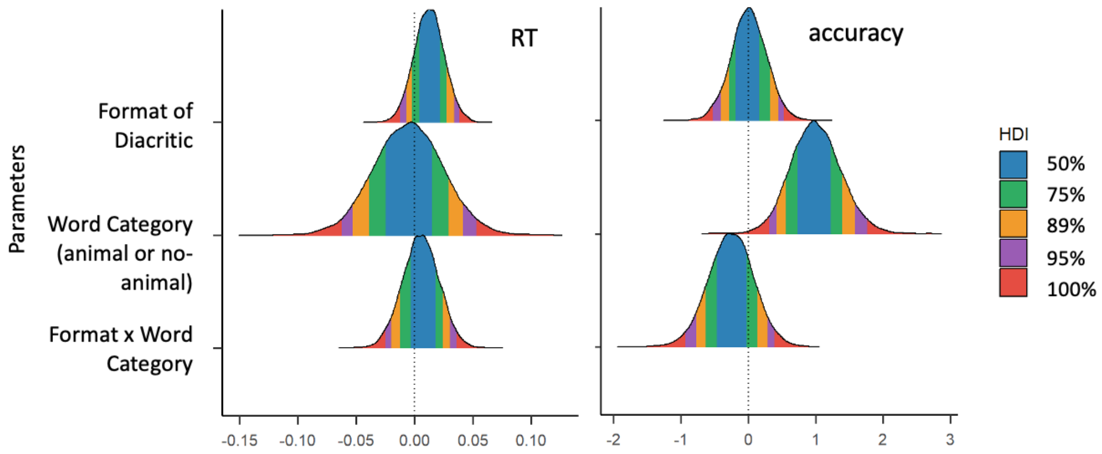

Figure 2. Highest Density Intervals of the posterior distributions with the 50%, 75%, 89%, 95%, and 100% Credible Intervals for each of the estimates of the Bayesian Linear Mixed-Effects models on response time (left panel) and accuracy (right panel) for French words with a correct diacritic and without a diacritic (Experiment 1). In this and the following experiments the scale of the latency data is -1000/RT.

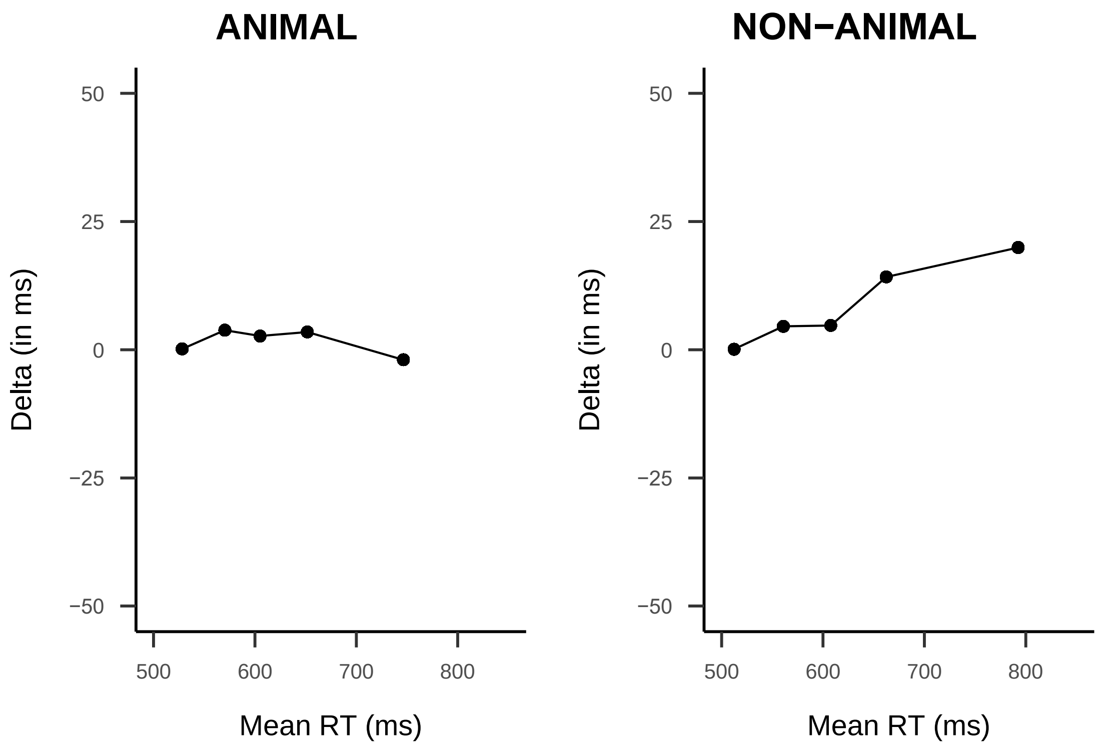

Figure 3. Delta plot of the reading cost of the words with the omitted diacritics relative to the intact diacritical words for the .1, 3., .5, .7, and .9 quantiles in Experiment 1. The left panel presents the plot for the “animal” words and the right panel presents the plot for the “non-animal” words.

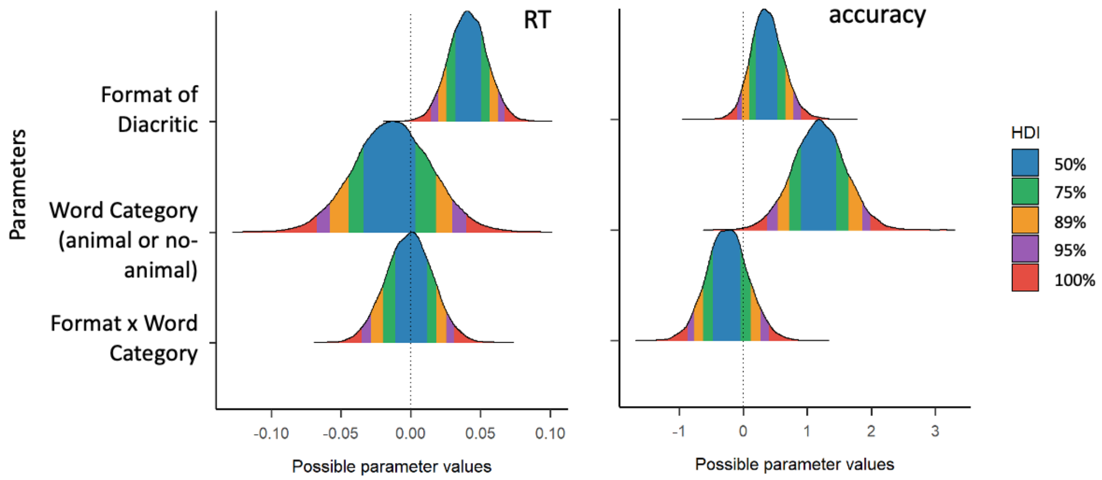

Figure 4. Highest Density Intervals with the 50%, 75%, 89%, 95%, and 100% Credible Intervals for each of the estimates of the Bayesian Linear Mixed-Effects models on response time (left panel) and accuracy (right panel) for French words with a correct diacritic and with an incorrect existing diacritic that changes pronunciation (é vs. è) (Experiment 2).

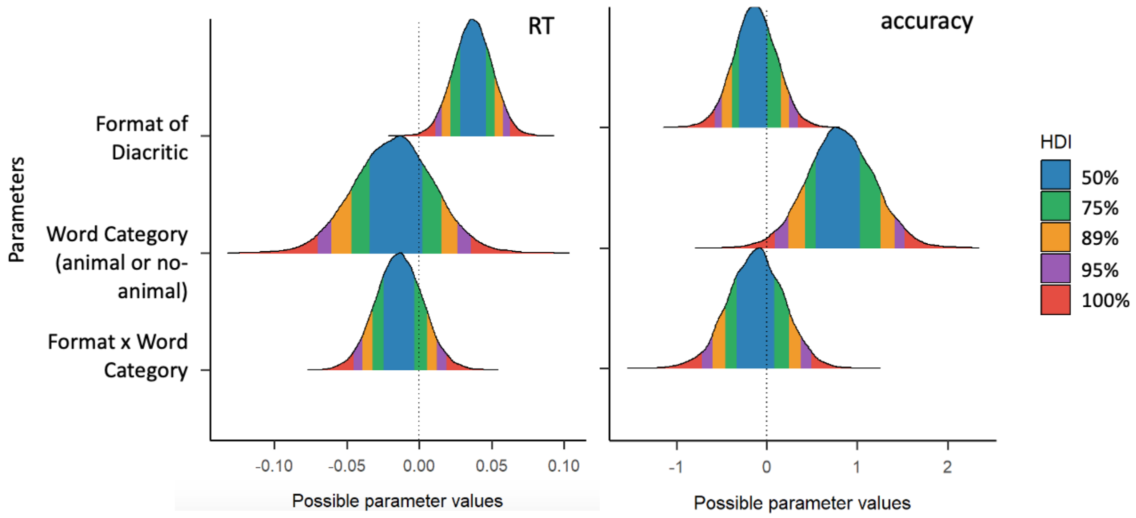

Figure 5. Highest Density Intervals with the 50%, 75%, 89%, 95%, and 100% Credible Intervals for each of the estimates of the Bayesian Linear Mixed-Effects models on response time (left panel) and accuracy (right panel) for French words with a correct diacritic and with an incorrect existing diacritic that does not necessarily change the pronunciation (é/è vs. ê) (Experiment 3).

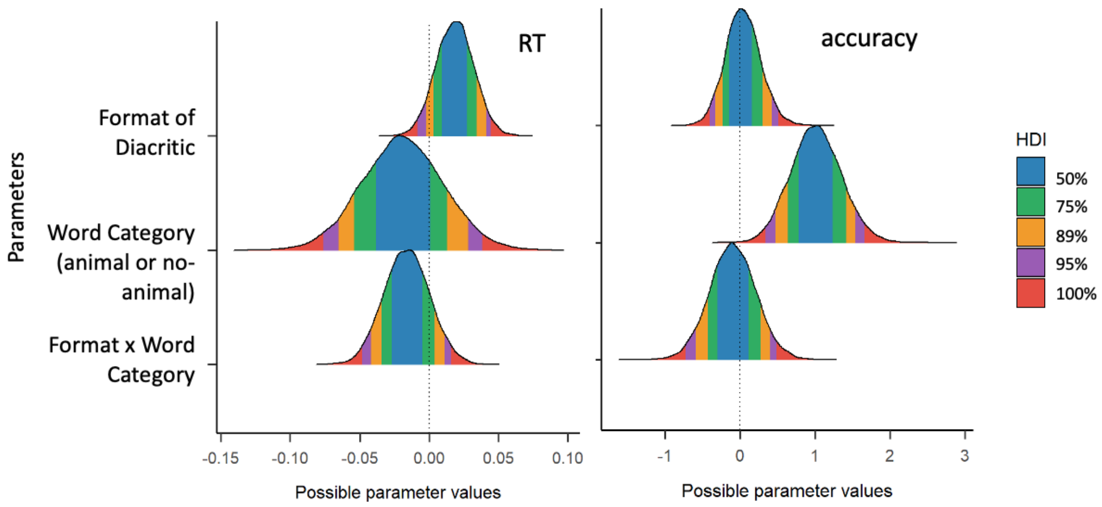

Figure 6. Highest Density Intervals with the 50%, 75%, 89%, 95%, and 100% Credible Intervals for each of the estimates of the Bayesian Linear Mixed-Effects models on response time (left panel) and accuracy (right panel) for French words with a correct diacritic and with a neutral diacritic (é/è vs. ē) (Experiment 4).

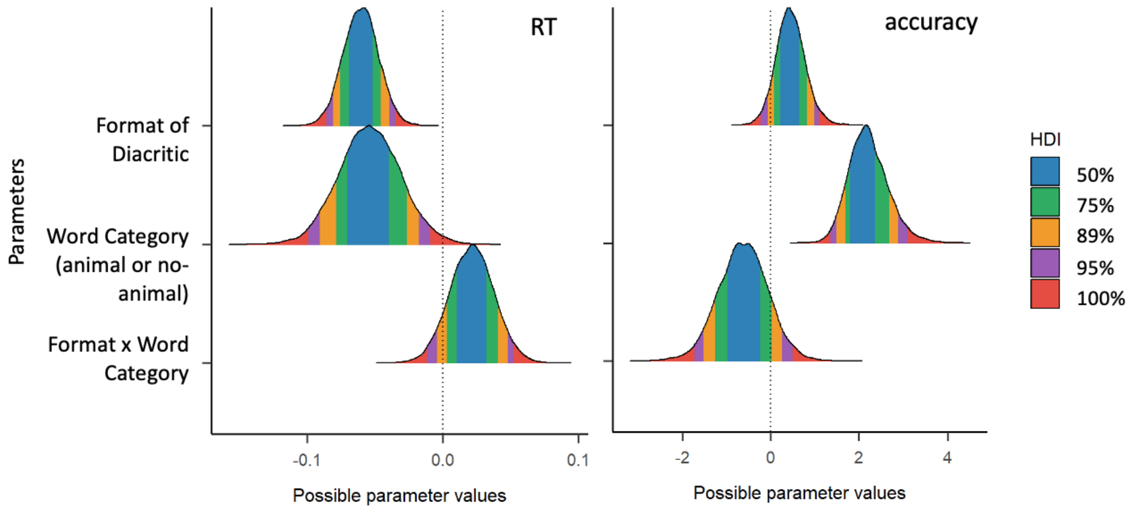

Figure 7. Highest Density Intervals with the 50%, 75%, 89%, 95%, and 100% Credible Intervals for each of the estimates of the Bayesian Linear Mixed-Effects models on response time (left panel) and accuracy (right panel) for French words correctly written without a diacritic and with an added existing diacritic (Experiment 5).

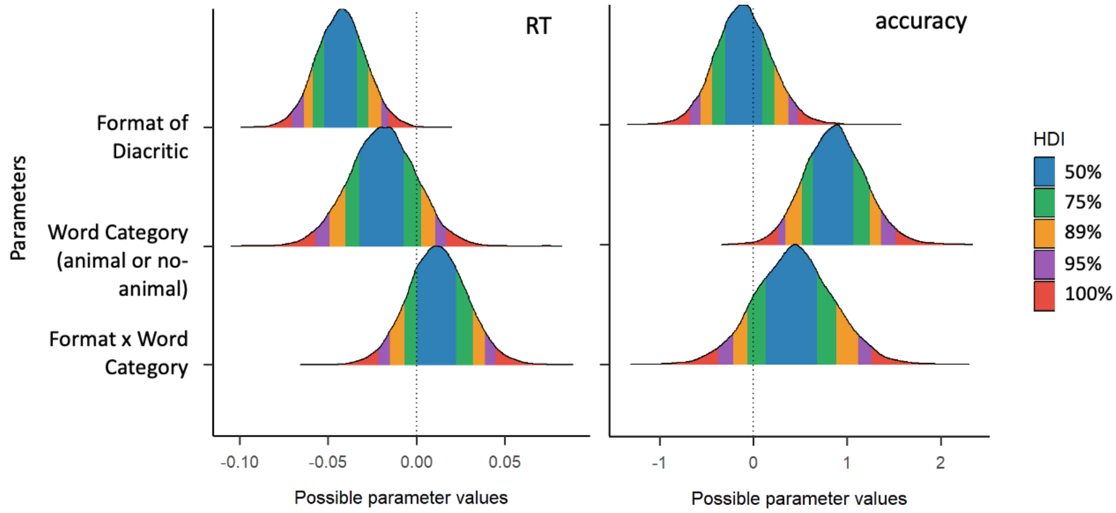

Figure 8. Highest Density Intervals with the 50%, 75%, 89%, 95%, and 100% Credible Intervals for each of the estimates of the Bayesian Linear Mixed-Effects models on response time (left panel) and accuracy (right panel) for French words correctly written without a diacritic and with an added neutral (non-existing) diacritic (Experiment 6).

Appendix. Materials of the experiments

Experiment 1 (correct diacritic vs. omitted diacritic)

Non-animals: dièse, étendue, mélodie, orfèvre, sortilège, récit, abréviation, écrou, éclair, évier, dégustation, arête, diadème, débat, régisseur, légume, mécanisme, sénat, sphère, étui, purée, manège, brèche, étau, mosaïque, pédale, emblème, virée, décorateur, hémisphère, bénévole, vêtement, absurdité, légion, cuillère, guéridon, palmarès, stabilité, tanière, ébauche, vidéothèque, glacière, démarrage, téléviseur, préau, gîte, îlot, abécédaire, croisière, régulateur, étincelle, contrée, képi, économie, gérant, symétrie, dégât, déodorant, cavité, flèche, festivité, kilomètre, étape, flûte, pédicure, météore, démontage, démographie, héroïsme, dragée, dôme, fève

Animals: murène, mésange, hérisson, têtard, cacatoès, huître, caméléon, lièvre, araignée, bélier, écrevisse, chimpancé, panthère, étourneau, scarabée, mérou, goéland, éléphant, écureuil, crustacé, vipère, chèvre, âne, léopard, guépard, guêpe, épervier, lévrier, zébu, hyène, pélican, lézard, zèbre, héron, caïman, rhinocéros

Experiments 2, 3, and 4 (correct diacritic vs. existing diacritic that changes pronunciation [Exp. 2], existing diacritic that does not necessarily change pronunciation [Exp. 3], and non-existing diacritic [Exp. 4])

Non-animals: étape, écrou, mélodie, légion, météore, hémisphère, diadème, pédicure, sénat, bouffée, brèche, chronomètre, péniche, caféine, bénévole, dragée, stabilité, économie, réglage, dièse, étendue, diversité, guéridon, palmarès, sphère, virée, étalage, étau, résidu, préau, décorateur, démographie, récit, cuillère, créneau, démontage, régulateur, rivalité, abréviation, orfèvre, comète, réclamation, gérant, débat, évier, purée, contrée, glacière, démarrage, vidéothèque, éclair, cavité, flèche, sortilège, abécédaire, absurdité, pédale, légume, mécano, fève, régisseur, festivité, déodorant, céleri, képi, hélice, ébauche, épice, dégustation, étui, emblème, symétrie

Animals: cacatoès, émeu, pélican, chimpancé, lévrier, épervier, panthère, lézard, crustacé, scarabée, mérou, rhinocéros, mésange, zèbre, zébu, lémurien, héron, chèvre, murène, écrevisse, éléphant, flétan, léopard, guépard, épagneul, coléoptère, caméléon, hérisson, bélier, vipère, araignée, étourneau, hyène, lièvre, écureuil, goéland

Experiments 5 and 6 (no diacritic vs. additional diacritic [existing diacritic in Experiment 5; non-existing diacritic in Experiment 6])

Non-animals: clavier, piscine, flamme, brume, libraire, galerie, bonheur, savon, poubelle, piquet, cloison, raquette, casino, bassin, manche, allergie, foulard, veste, gobelet, emballage, bus, remous, escale, colline, glaise, science, extrait, cantine, diversion, magasin, carte, plage, tapis, bandeau, jupe, largeur, tablette, triage, chapitre, accent, magie, moniteur, demain, pollution, plateau, baguette, hoquet, four, chemin, pilotage, fromage, optimisme, tisane, carnet, cartouche, rideau, billet, bruit, disque, chapeau, grammaire, repos, cahier, matelas, futur, papier, camion, bille, couchette, pochette, espoir, ascenseur

Animals: mouche, chien, canari, chat, cheval, renard, mouette, poule, lapin, poisson, sanglier, moineau, cochon, limace, loup, requin, singe, tortue, papillon, dauphin, chameau, abeille, chiot, cigogne, perroquet, aigle, canard, vache, phoque, girafe, souris, rat, baleine, moustique, crocodile, cygne