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Does accentual variation in the pronunciation of French words influence their recognition?

It depends on the ear of presentation.

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Abstract: This repetition priming study examined how word accentual variation in French is represented and processed during spoken word recognition. Mismatched primes in the accentual pattern were less effective than matched primes in facilitating target word recognition, when the targets were presented in the left ear but not in the right ear. This indicates that in French, accentual pattern of words influences their recognition when processing is constrained in the right hemisphere. This study pleads in favor of two memory systems, the one retaining words in an abstract format, and the other retaining words in their various forms.

Key-words: Spoken word recognition, French accentuation, long-term repetition priming, hemispheric asymmetries.

During conversational exchanges, French speakers produce words in two forms, either accented or unaccented, depending on their position in the accentual phrase. For example, the word *bonbon* /bɔ̃bɔ̃/ “candy” is accented on its last syllable, resulting in a lengthening of this syllable accompanied by a typical fundamental frequency (f0) rise, when a speaker says /sə.ʒoli.bɔ̃**bɔ̃**/ “this pretty candy”. In contrast, the word /bɔ̃bɔ̃/ is unaccented when the same speaker says /sə.bɔ̃bɔ̃.a'**sid**/ “this sour candy” because in this specific case it is no longer the one which is located at the final position in the accentual phrase. Despite this fact, a recent study conducted in our laboratory (i.e., with binaural presentation of target words; Michelas & Dufour, 2019) indicated that French speakers do not retain accentual information in word representations, and only the variant /bɔ̃bɔ̃/, devoided of any information regarding accentuation, seems to be stored in their mental lexicon. This finding was interpreted in reference to abstractionist models of spoken word recognition (e.g., Marslen-Wilson, 1990; McClelland & Elman, 1986; Norris, 1994) in which all acoustic details deemed irrelevant for identification (e.g., syllable duration and f0 rise in French) are treated as noise and removed from the speech signal before making contact with abstract lexical representations that do not include details about how these words are pronounced.

The observation that French speakers do not encode words in their accented and unaccented versions does not mean however that French speakers do not retain in memory information related to word accentual pattern, and subsequently that this information does not influence spoken word recognition. In other studies conducted by our group (Michelas & Dufour, 2021), we showed that French speakers use word accentual information in discrimination tasks, and that they are better at discriminating between an accented and an

unaccented version of words when processing is constrained in the right hemisphere. This hemispheric difference in the processing of word accentual variation with an advantage of the right hemisphere is particularly important since it suggests that word accentual information in French could be represented and processed as non-linguistic information. Indeed, there are numerous demonstrations in the literature in favor of hemispheric differences in the processing of non-linguistic and linguistic information. In particular, cognitive neuroscience studies indicate either a left hemispheric dominance in the processing and representation of linguistic information (e.g., DeWitt & Rauschecker, 2012 for phonemes and words; Dundas et al., 2014 for written words; Shestakova et al., 2002 for phonemes) or no hemispheric difference with activity generated in both the left and right hemispheres (e.g., Hickok & Poeppel, 2000 for phonemes/syllables; Huth et al., 2016 for semantic information)¹. In contrast, cognitive neuroscience studies indicate that the right hemisphere is more reliant than the left hemisphere on the representation and processing of non-linguistic information such that information related to the voice and/or identity of the talker (e.g., Belin et al., 2004; Van Lancker & Canter, 1982; Von Kriegstein et al., 2003).

Behavioral experiments also indicate an advantage of the right hemisphere in the representation and processing of information related to the voice and/or identity of the talker. For example, in a series of long-term priming experiments, González and McLennan (2007) have examined the role of talker-specific information in spoken word recognition in the left and right

¹ Although a growing body of studies reports an implication of the right hemisphere in the representation of words (e.g., Huth et al., 2016), recent reviews of literature (Ries et al., 2016; Vigneau et al., 2011) indicate that the right hemisphere activation is often smaller and less robust than the left hemisphere activation. As a result, it is the left hemisphere which is dominant and the more implicated in the representation and processing of words.

hemispheres by manipulating the ear of presentation of the words. In this kind of paradigm, participants are presented with two blocks of stimuli, the first consisting of the primes, and the second consisting of the targets. During the second block, some of the words from the first block are repeated or consisted in new words, and among the repeated words some of them match the primes or mismatch the primes on a specific dimension (e.g., repeated by the same or by a different talker). They reported that matched and mismatched primes in talker-specific information were equally effective in facilitating the subsequent processing of the target words, when the words were presented in the right ear, and thus due to contralateral projections were primarily processed by the left hemisphere. In contrast, they found that mismatched primes were not as effective as matched primes in facilitating the subsequent processing of the target words, when the words were presented in the left ear and thus were primarily processed by the right hemisphere. The differential impact of matched and mismatched primes as a function of the ear of presentation clearly indicates that information related to talker identity is processed differently by the two hemispheres, and that the right hemisphere is more reliant than the left hemisphere on the representation and processing of acoustic details about how words are pronounced. In a more general way, this study suggests that during spoken word recognition tasks, the left hemisphere relies on abstract representations while the right hemisphere relies on acoustic detailed representations. Consequently, when processing is pushed in the left hemisphere, it is the same form-based representation as the one activated by the primes which is reactivated during processing of the targets, thus causing a repetition priming effect. In contrast, when processing is pushed in the right hemisphere, it is not the same acoustic representation which is reactivated during processing of the targets, thus causing a diminution in the magnitude of the repetition priming effect.

In this study, we provide a more in-depth examination of the hemispheric difference previously found in the discrimination of accented and unaccented words (Michelas & Dufour, 2021) by examining how this kind of variation is represented and influences processing in spoken word recognition tasks. To do it, we used the same experimental design as in González and McLennan (2007), except that the words were pronounced either in their accented version (/bɔ̃'bɔ̃/ *bonbon* 'candy') or in their unaccented version (/bɔ̃bɔ̃/), rather than to be pronounced either by a male or a female speaker. The primes were binaurally presented while the target words were presented either in the left or in the right ear. Note that this was in this specific configuration, with primes binaurally presented, that González and McLennan (2007) obtained the better demonstration of an impact on word recognition of a change in talker (see also Marsolek, 2004 for visual word recognition). This is likely due to the fact that a binaurally presentation allows a normal encoding of the information present in the primes, that can then be reused during target word processing. In accordance with the observations made by González and McLennan (2007) regarding talker-specificity effects, we predicted that primes that mismatch the target words on the accentual pattern should be less effective in facilitating the subsequent processing of the targets than primes that match the target words on the accentual pattern, when the target words were presented in the left ear, and thus when the processing is constrained in the right hemisphere. Of particular interest is thus the difference between matched and mismatched prime conditions, and how this difference modulates as a function of the ear of target word presentation.

Method

Participants: Seventy-two right-handed native speakers of French, between 18 and 45 years old, participated in the experiment. They all reported having no hearing or speech disorders. Each of them gave written informed consent prior to experimentation, and they received either a course credit or 10 Euros for their participation. Half of them heard the target words in the right ear and the other half in the left ear.

Materials: Forty-eight words with a CVCV syllabic structure were selected from VoCoLex, a lexical database of the French language (Dufour et al., 2002) and were used as primes and targets. They have a mean frequency of 8 occurrences per million. 16 additional words with the same syllabic structure were selected and used as control primes. They have a mean frequency of 10 occurrences per million.

In order to have the 64 words in their accented and unaccented versions, each of the words was inserted in two carrier sentences, and was unaccented (e.g., *On m'a parlé [d'un bonbon 'bleu] qui est très bon* "I was told about a blue candy which is pretty good") or accented on its last syllable (e.g., *On m'a parlé [d'un petit bon'bon] qui est très bon* "I was told about a blue candy which is pretty good") depending on their position within the accentual phrase. The sentences were produced by a native speaker of French. To avoid coarticulation effects due to contextualized-speech, the two versions of each word were then extracted from their carrier sentence and auditorily presented to the speaker in isolation. The speaker was instructed to imitate each version of the words. The recordings were made in a sound-attenuated room, and

digitized at a sampling rate of 48,000 kHz. Each version of the 64 words was then normalized at a level of 60 dB.

Acoustic analyses were conducted to ensure that the 48 target words and the 16 control primes were produced with the two accentual patterns. Pre-boundary lengthening and f0 rises were measured and are summarized in Table 1. The final syllable of the target words was longer ($t(47) = 20.46, p < .0001$) and associated with a stronger f0 rise ($t(47) = 21.76, p < .0001$) than the first syllable for the accented versions, but not for the unaccented versions (Duration: $t(47) = -1.18, p > .20$; f0: $t(47) = 1.23, p > .20$). The average durations of the target words were 355 and 265 ms in their accented and unaccented versions, respectively. Also, the final syllable of the control prime words was longer ($t(15) = 10.55, p < .0001$) and associated with a stronger f0 rise ($t(15) = 8.95, p < .0001$) than the first syllable for the accented versions, but not for the unaccented versions (Duration: $t(15) = 1.35, p > .20$; f0: $t(15) = -1.07, p > .20$). The average durations of the control prime words were 357 and 263 ms in their accented and unaccented versions, respectively. Figure 1 shows the word *bonbon* ‘candy’ in its accented [bõ'bõ] and unaccented version [bõbõ].

For the purpose of the lexical decision task, 64 pseudo-words with a CVCV syllabic structure were created by changing the last phoneme of real words not previously used (e.g., /byʊ/ created from the word /byʊ/ ‘desk’). This allowed us to have non-word like words, and to constrain the participants to listen to the stimuli up to the end prior to giving their response. The non-words followed the same criteria as the words, and thus were recorded and produced in their accented (e.g., /by'ʊ/) and unaccented (e.g., /byʊ/) versions. Finally, an audio file of 40

dB containing pink noise was created. The length of the audio file was 510 ms which roughly corresponds to the duration of the longest target word. As in González and McLennan (2007)' study, pink noise was chosen because as for speech, its spectral level decreases with increasing frequency.

Design: Two blocks of stimuli were presented. The first consisted of the primes and the second of the targets. The prime block consisted of 48 prime words and 48 pseudo-words. Among the 48 prime words, 16 served as matched primes, 16 as mismatched primes and 16 were the control primes. Within each priming condition, half of the prime words were presented in their accented version, and the other half were presented in their unaccented version. The target block also consisted of 48 words and 48 pseudo-words. Among the target words, 16 consisted of the repetition of the primes with the same accentual pattern (e.g., /b̃'b̃/ - /b̃'b̃/), 16 consisted of the repetition of the primes with a different accentual pattern (e.g., /b̃b̃/ - /b̃'b̃/), and the 16 others were unrelated to any of the primes (i.e., control condition). Among the unrelated targets, half of them were presented in their accented version and the other half were presented in their unaccented version. The same schema was followed for the pseudo-words. Thus in the target block, 16 consisted of the repetition of pseudo-words used in the prime block with the same accentual pattern, 16 consisted in the repetition of pseudo-words used in the prime block but with a different accentual pattern, and 16 were unrelated. The experimental conditions are illustrated in Table 2.

Because each target word was paired with three different primes (match, mismatch, control) and no participant was presented with the same target twice, three experimental lists

were created. The three lists were then divided into two sub-lists so that each stimulus of the prime and target blocks was heard in its accented and unaccented version.

Procedure: The participants were tested individually in a sound attenuated booth, and stimuli were presented over headphones at a comfortable sound level. The presentation of the stimuli was controlled by a computer thanks to the software E-Prime. In both the prime and the target blocks, participants were asked to make a lexical decision as quickly and accurately as possible with “word” responses using their dominant hand on a button-box that was placed in front of them. Response times (RTs) were recorded from the onset of stimuli. Within each block, the stimuli were presented randomly. An inter-trial of 2000ms elapsed between the participant's response and presentation of the next stimulus. During the prime block, the stimuli were binaurally presented. During the target block, half of the participants heard the stimuli in the right ear and the other half in the left ear. Simultaneously with the targets, the participants were presented with the noise in the opposite ear. The participants were tested on only one experimental list and the experiment began with 12 practice trials.

Results

Statistical analyses were performed on the target words. Two items that gave rise to an error rate of more than 40% were removed from the analyses. The mean RT and percentage of correct responses in each condition are presented in Figure 2. RTs (available at <https://osf.io/x2trp/>) were analyzed using linear mixed effects models with participants and items as crossed random factors, using R software (R Development Core Team, 2020) and the lme4

package (Baayen et al., 2008; Bates & Sarkar, 2007). The RT analysis was performed on correct responses, thus removing 459 data points out of 3312 (13.86%). Following Baayen and Milin (2010)'s recommendations, the model was applied to the complete set of correct RTs. Also, following Baayen and Milin (2010), for the model to meet the assumptions of normally-distributed residuals and homogeneity of variance, a log transformation was applied to the RTs prior to running the model. The model was run on 2853 data points and included the variable Prime Type (match, mismatch, control), Ear of Presentation (left, right) and their interaction as fixed effects. The model failed to converge when random slopes for the within-factor Prime Type for both participants and items and the within-factor Ear of Presentation for items were included (see Barr et al., 2013). Therefore, the final model included only random intercepts for participants and items.

The reference was the performance in the left ear for the match condition. The model revealed shorter RTs in the match than in the mismatch condition ($\beta = .0855$, $SE = .0135$, $t = 6.35$; $p < .001$). RTs were also shorter in the match than in the control condition ($\beta = .1191$, $SE = .0139$, $t = 8.57$; $p < .001$). The effect of Ear of Presentation was not significant ($\beta = -.0332$, $SE = .0397$, $t = -0.84$; $p > .20$). Crucially, the model revealed that the difference between the match and mismatch conditions significantly interacted with the Ear of Presentation ($\beta = -.0795$, $SE = .0191$, $t = -4.17$; $p < .001$). Also, the difference between the match and control conditions significantly interacted with the Ear of Presentation ($\beta = -.0582$, $SE = .0196$, $t = -2.97$; $p < .01$).

To understand the interactions, the model was relevelled such as the performance in the right ear for the match condition was now the reference. No significant difference was observed

between the match and mismatch conditions ($\beta = .0060$, $SE = .0135$, $t = 0.44$; $p > .20$). The difference between the match and control conditions was again significant ($\beta = .0609$, $SE = .0138$, $t = 4.41$; $p < .001$).

The percentage of correct responses was analyzed using a mixed-effects logit model (Jaeger, 2008) following the same procedure as for RTs. The reference was the performance in the left ear for the match condition. Only the difference between the match and control conditions was significant ($\beta = -.9427$, $SE = .1839$, $z = -5.13$; $p < .001$), with more correct responses in the match condition.

General Discussion

The results are clear-cut. When target words are presented in the right ear, repetition primes that mismatch the targets on accentual information are equally effective as repetition primes that match the targets on accentual information in facilitating the processing of the targets. In contrast, when target words are presented in the left ear, repetition primes that mismatch the targets on accentual information are less effective than repetition primes that match the targets on accentual information in facilitating the processing of the targets. Our results are thus perfectly in line with González and McLennan (2007)'s observation, and showed that hemispheric differences also exist in the representation and processing of word accentual pattern in French. Hence, in the same way as a right hemispheric advantage has been reported in the management of talker-specific information, here, we show that, at least in French, the right hemisphere is more efficient than the left hemisphere in managing word accentual information.

We also observed that the repetition priming effect in case of an exact match between the prime and the target (i.e. the matched prime condition in comparison to the control condition) is stronger when words were presented in the left than in the right ear, and thus when processing is constrained in the right hemisphere. We believe that we have captured a general and well-known phenomenon that participants benefit more from an exact match between the repeated primes and targets in difficult conditions than in easy conditions. As the right hemisphere is known to be less efficient than the left hemisphere in visual word processing (see Dundas et al., 2014 for a review), the auditory lexical decision is also likely more difficult to perform when processing is constrained in the right hemisphere. As a result, it is the right hemisphere that benefits more from an exact repetition, and thus a greater priming effect is observed in this case.

The present study combined with that of González & McLennan (2007) suggests that during spoken word recognition tasks, the right hemisphere relies on fine-grained acoustic representations, while the left hemisphere relies on abstract representations. Consequently the results of both studies are compatible with hybrid models of spoken word recognition that combine the two types of representations, namely abstract and detailed representations (e.g., MINERVA, Goldinger, 1998; ART, Grossberg & Myers, 2000; see also, Pierrehumbert, 2001). In a more general way and in accordance with a growing body of researches (Bowers, 2000; Hanique et al., 2013; Nijveld et al., 2016; Marsolek, 2004), our study plaid for the existence of two memory systems, the one retaining words in an abstract format, and the other retaining words in their various forms. The former makes it possible to account for abstract priming effect, and thus for the fact that variation in word pronunciation does not systematically affect the magnitude of the priming effect (e.g., Dufour & Nguyen, 2014; González & McLennan, 2007;

McLennan & Luce, 2005). The latter, in contrast, offers an interesting account for acoustic priming effect, and thus for the fact that under some circumstances priming effect is greater in the case of a perfect acoustic match between the primes and the targets. Note however, that in more natural listening situations—with a binaural presentation of stimuli—evidence in favor of acoustic detailed representations is generally found only under specific conditions, especially when processing is slow and effortful (see Dufour & Nguyen, 2014; Luce and McLennan, 2005). This is perfectly in line with our observations that “acoustic” effects are more likely to occur in the right hemisphere, since when processing is pushed in this hemisphere RTs were in average longer than when processing is pushed in the left hemisphere (i.e. main global effect of hemisphere; $F=4.29$; $p<.05$). Hence, although detailed representations coexist with abstract representations, spoken word recognition processes seem to rely predominantly on abstract representations.

To sum-up, we started this paper by a summary of studies indicating that non-linguistic information such that information related to the voice or identity of the talker is supported by the right hemisphere (e.g., Belin et al., 2004; González & McLennan, 2007; Van Lancker & Canter, 1982; Von Kriegstein et al., 2003), while linguistic information such as phonemic and semantic information is supported either by the left hemisphere or by both hemispheres (see Ries et al., 2016; Vigneau et al., 2011 for reviews). Our study shows that in French, accentual pattern of words is supported by the right hemisphere, which leads us to the conclusion that in French word accentual information is processed as non-linguistic information. This is likely related to the fact that in this language, accent has not a lexically contrastive function and thus whether words are accented or not has no consequence on their meanings. Consequently, in the same way as

hemispheric differences have been reported in the representation and processing of talker-specific variation, here, we reported hemispheric differences in the representation and processing of word accentual variation with an advantage of the right hemisphere in managing this kind of information.

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Table 1: Acoustic properties of the words in their accented and unaccented versions.

		Acoustic properties of the 1 st syllable				Acoustic properties of the 2 nd syllable			
		Duration (ms)	f0 min (Hz)	f0 max (Hz)	f0 rise (%)	Duration (ms)	f0 min (Hz)	f0 max (Hz)	f0 rise (%)
Accented (e.g., /b̃b̃/)	Target words	128	181	180	-1	227	173	453	162
	Controls	129	184	184	0	228	175	473	170
Unaccented (e.g., /b̂b̂/)	Target words	133	191	190	-1	132	182	181	-1
	Controls	129	204	204	0	134	189	188	-1

Table 2: Summary of the experimental conditions with examples of the prime and target words.

Condition	Prime	Target
Match		
Unaccented prime – Unaccented target	/bɔ̃bɔ̃/	/bɔ̃bɔ̃/
Accented prime – Accented target	/bɔ̃' bɔ̃ /	/bɔ̃' bɔ̃ /
Mismatch		
Accented prime – Unaccented target	/bɔ̃' bɔ̃ /	/bɔ̃bɔ̃/
Unaccented prime – Accented target	/bɔ̃bɔ̃/	/bɔ̃' bɔ̃ /
Control		
Unrelated prime – Unaccented target	/la' ma /	/bɔ̃bɔ̃/
Unrelated prime – Accented target	/lama/	/bɔ̃' bɔ̃ /

Figure captions

Figure 1: Accentual profile of the target word /bɔ̃bɔ̃/ “candy” in its accented (A) and unaccented (B) versions.

Figure 2: Mean Reaction Times (in ms) in each priming condition and for each ear of presentation. Percentages of correct responses are shown at the bottom of the graph. Error bars represent 95% confidence intervals.