Substance-free phonology in the brain: evidence from event-related potentials

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While most phonological alternations are grounded in phonetics, some are not. Moreover, even phonetically grounded alternations can contain aspects that are unexpected from a phonetic point of view. For instance, French has regressive voice assimilation in obstruent clusters, by which, say, the final voiceless /s/ of *bus* ("bus") can become voiced in the sequence *bus vert* ("green bus"). Crucially, the same change cannot take place in *bus marron* ("brown bus"), where the second consonant is a sonorant. While the voicing change before voiced obstruents is phonetically motivated (leftward spreading of the feature voice), its absence before (voiced) sonorants has no phonetic basis. French listeners have been shown to recognize the word *bus* in *bu[z] vert* but not in *bu[z] marron*; thus, they rely on their phonological grammar to perceptually compensate for assimilation (Darcy et al., 2009). Here, we provide neurophysiological evidence concerning the processing of voice assimilation in the brain, showing an early impact of phonological - as opposed to phonetic - knowledge during speech perception.

We used electroencephalography to record event-related potentials (ERPs). Twenty-five French participants performed a mismatch detection task. In each trial, a series of four identical precursor stimuli with the structure $V_1C_1C_2V_2$ was followed by a test stimulus that was either identical to the precursors or differed from them in the voicing of C_1. In the *viable* condition, the precursor stimuli presented the context for assimilation (precursors: [asvi]; test: [azvi]); in the *unviable* condition, it did not (precursors: [asmi]; test: [azmi]) (Table 1). All stimuli were created by means of cross-splicing, such that clusters that disagreed in voicing consisted of one completely voiceless segment followed by one completely voiced one (e.g. [asvi] was created by combining the first and second syllable, respectively, of naturally produced tokens of [asfi] and [azvi]). If compensation for voice assimilation is driven by phonology rather than by phonetics, French listeners should have more difficulty detecting the voicing change in the viable than in the unviable condition. This prediction was borne out by both the behavioral and electrophysiological results: The behavioral results show a difficulty in the detection of a voicing change in the viable but not in the unviable condition (Figure 1). Likewise, the electrophysiological results show an early mismatch response related to the detection of a voicing change in the unviable condition only (Figure 2). This response is similar in both latency and topography to the Mismatch Negativity, an ERP that reflects automatic detection of perceptual deviance (Näätänen et al., 1997).

Our results show that compensation for French voice assimilation relies on early automatic mechanisms during speech perception. They are in accordance with previous research showing early compensation of other types of assimilation (Mitterer & Blomert, 2003, Mitterer et al., 2006). Crucially, compensation reflects listeners' implicit knowledge about the distinction between viable and unviable contexts for assimilation, which - unlike in previously studied cases - lacks an intrinsic phonetic basis in French voice assimilation. Thus, this study is the first to provide evidence for an early role of abstract phonological knowledge during speech perception. While more research is needed, especially on the processing of alternations that completely lack a phonetic motivation, our results suggest that there might be no neurological basis for the distinction between substance-free and phonetically-grounded phonology.

References:

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Näätänen, R., Lehtokoski, A., Lennes, M., Cheour, M., Huotilainen, M., Iivonen, A., et al. (1997). Language-specific phoneme representations revealed by electric and magnetic brain responses. *Nature* 385, 432–434.

Table 1: Experimental design and predictions

Condition	Precursor (×4)	Test	Expected response
Viable	[asvi]	[asvi]	Same
		[azvi]	**Same**
Unviable	[asmi]	[asmi]	Same
		[azmi]	**Different**

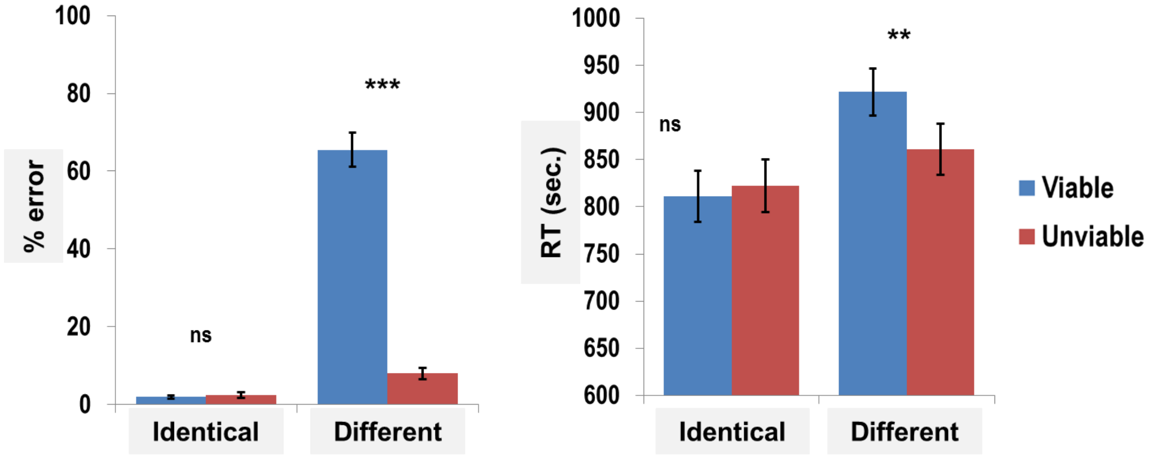

Figure 1: Behavioral results. Error rates (left panel) and reaction times (right panel).

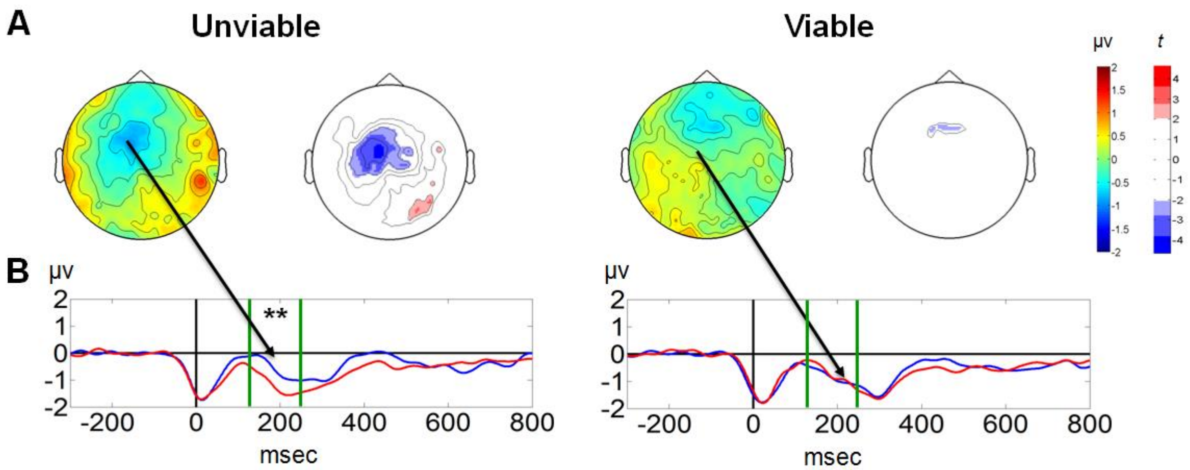

Figure 2: Electrophysiological results. ERP response within the 140–240 ms post-deviance time window. (***A***) Scalp map of time-averaged voltage (left) and t-value (right) of deviant-minus-control subtraction in the unviable (left) and viable (right) contexts. (***B***) Averaged ERPs of sensors in the cluster for which the Context x Condition interaction is significant Monte-Carlo $p < 0.05$; blue line: averaged ERPs for identical trials; red line: averaged ERPs of deviant trials).