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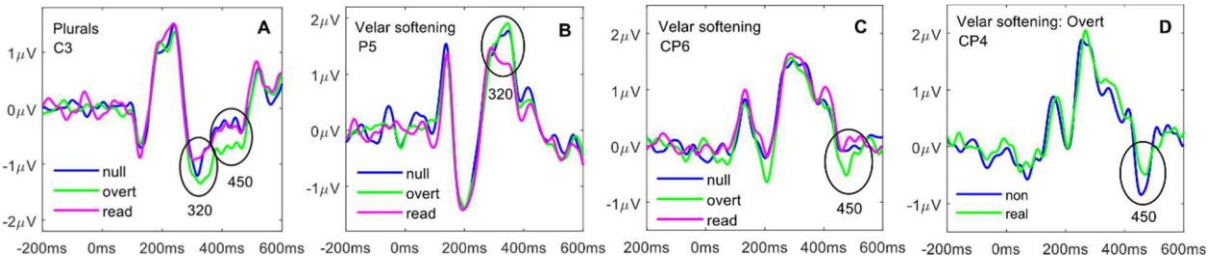
Velar softening is phonological: EEG-based evidence

Problem and relevance. Despite substantial efforts made in the 70s and 80s (evaluation measure, overview by Bermúdez-Otero & McMahon 2006: 383ff), to date phonologists are unable to determine whether phonological computation is or is not involved in the production of a given alternation. To take an especially contentious example, is the alternation between k and s in *electri]k] - electri[s]-ity* (velar softening) an instance of suppletion (*electricity* stored as one single lexical item), allomorphy (*electri[k]-* and *electri[s]-* stored, selected by the affix) or phonological computation (only *electri[k]-* stored, then k → s / _i)? On the syntactic side, the issue of how many different lexical entries a morphologically complex word represents (and what kind of computation is involved in their management) is known as lexicalism (e.g. Williams 2007). In this situation, the popperian competition among phonological theories is impossible: the set of phenomena that fall under the purview of phonology (the Gordian knot of the discipline, say Bermúdez-Otero & McMahon 2006: 389) wildly diverges according to intuitive, conceptual or theory-specific inclinations. Hence phonologists are currently in a position of, say, geologists who aim to make a theory of the characteristics of stone, but are unable to distinguish stone from plastic. They thus collect samples on which they build their theory, some of which contain 10% of plastic, others 30%, still others 60% etc. Unsurprisingly enough, competing theories built on these wildly varying sets significantly diverge – not because of the theorizing but because of the plastic. The issue is fundamental for phonological theory in two ways: on the one hand phonologists do not know whether phonological computation is involved in known alternations – but on the other hand their take on what a possible phonological computation is (UG) also wildly diverges. The latter issue is at the heart of the debate regarding substance-free phonology (Hale & Reiss 2000) that has recently gained velocity as it transcends individual theories: representatives of OT (Uffmann 2019), Government Phonology (Scheer 2019, Chabot 2019) and rule-based phonology (Odden 2019) follow the idea that the computational system of phonology does not impose any constraints on the processes that are carried out (so-called Crazy Rules may look phonetically crazy for the analyst, but phonologically speaking they are not any more crazy than, say, voice assimilation).

Unprecedented EEG-based evidence. Since the issue could not be settled for over 50 years and advances based on available evidence are unlikely to occur, we have adapted an EEG-based experiment that is able to detect phonological activity. Sahin et al. (2009) presented evidence from patients with intracranial electrodes showing that lexical access, morpho-syntactic processing, and phonological processing can in principle be separated in time and space based on characteristic electrophysiological responses at 200 ms, 320 ms, and 450 ms respectively. In the current study, we aimed 1) to replicate these findings in surface EEG with healthy adults producing English plurals to confirm the sensitivity of the paradigm, and 2) to apply the paradigm to investigate the processes involved in English velar softening. For the replication with plurals, 80 words matched on frequency and phonological properties were used. In the Read condition, only the repetition of the word is required (all responses in the experiment are silent pronunciations that participants carry out in their head), eliciting lexical access but no further processing: *Repeat: + rock = rock*. In the Null condition, the cue requires appropriately inflecting the word, but the result is a null (i.e. unpronounced) inflection: *This is the _ + rock = rock*, eliciting lexical access and morpho-syntactic processing but no phonological computation. In the Overt condition, the cue induces overt (i.e. pronounced) inflection of the word (*Those are the _ + rock = rocks*), requiring all stages of processing including progressive voice assimilation at the phonological processing stage:

the plural morpheme /-z/ is lexically voiced (*tree-[z]*) but devoices if preceded by a voiceless obstruent (*rock-[s]*). To elicit velar softening, 43 real words (*electric*, *critic*) and 37 nonwords (*nectic*, *glyphic*) were used with the cues *Repeat:* for Read, *This is really* _ for Null, and the cues *They talk about* _ (eliciting *electricity*, *necticity*) or *You need to* _ (eliciting *criticise*, *glyphicise*) for Overt.

Results. The EEG from 13 participants (20 planned) was recorded from 64 scalp electrodes during silent pronunciation tasks involving either pluralisation (i.e. voice assimilation) or velar softening in the Overt conditions. All participants were monolingually raised right-handed native speakers of Standard Southern British English without neurological or language impairment. In the pluralisation task, the response at 320 ms had a different distribution than the response at 450 ms (as in Sahin et al. 2009), overlapping at electrode C3. Panel A shows the ERP (Event-Related Potential) for the Null and Overt conditions patterning together at 320 ms, while at 450 ms the Overt ERP diverges from the rest, mirroring Sahin et al. (2009). In the velar softening task, with different stimuli and different



presumed morpho-phonological processes than the pluralisation task, the distributions of the responses at 320 ms (panel B) and 450 ms (panel C) do not overlap, but again show the same basic pattern: divergence of Read at 320 ms, divergence of Overt at 450. Crucially, nonwords elicit stronger responses in the Overt condition at 450 ms (panel D) compared to real words.

Discussion. These results show that the basic paradigm developed by Sahin et al. (2009) carries over to surface EEG in healthy adults, and is differentially sensitive to morpho-syntactic concatenation (at 320 ms) and phonological processing (at 450 ms). Moreover, this sensitivity is not restricted to inflectional processes, but extends to a derivational process like velar softening. This means our results can give evidence to the nature of the process of velar softening (suppletion, allomorphy, phon. computation). For nonwords, the derivation necessarily involves online computation: suppletion and allomorphy rely on the root being present in the lexicon, which is excluded for nonwords. The average ERP indexing phonological processing in the Overt condition is larger for nonwords than the average ERP for real words. Our interpretation of this fact is that speakers have no other choice than to use online phonological computation when confronted with nonwords, supporting the idea that velar softening is part of their phonological competence. On the other hand, at least some real words may not always undergo phonological processing but rely on suppletion or allomorphy instead, resulting in less activity at 450 ms. There is substantial experimental evidence to support that the more frequent a morphologically complex word, the higher chance it stands to be lexicalized as one single chunk (Caramazza et al. 1998, Schreuder & Baayen 1995). Finally, suppletion and allomorphy being excluded, speakers could use analogy for deriving, say, *necticity* from *nectic*. If it is the case that the 450 ms ERP represents phonological and no other activity, this option can also be excluded since nonword derivation produces significant activity at 450 ms – but performing analogy does not involve any phonological activity.

The contribution of our study to phonological theory, then, is its support for the presence of velar softening in the phonological competence of speakers, documented for both real and nonwords. Beyond this result concerning an individual process in a particular language, the experimental setup may be suited to referee any contentious alternation to see whether it is

phonological in kind, and also to find out whether Crazy Rules can be managed by phonology. That is, whether phonology is substance-free and what UG constraints, if any, really constrain phonological computation.