Event-related potential responses to morphophonological violations

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This study focuses on the morphophonological processing of the English plural suffix *-s*, which is conditioned by the stem ending. The plural marker is typically /z/ (e.g., *shoe-s* /ʃu-z/), but it surfaces as /s/ after a voiceless sound (e.g., *cat-s* /kʰæt-s/) and /ɪz/ after sibilants (e.g., *wish-es* /wɪʃ-ɪz/). One possibility for representations and processing of phonological variations is that the complex word is stored and retrieved as a whole. Alternatively, the suffix could have a separate abstract representation, possibly along with all the potential phonological forms. To test these hypotheses, we compared event-related potentials (ERPs) evoked by nouns that take the canonical /z/ form of the plural suffix (e.g., *shoe-s* /ʃu-z/) to those evoked when the canonical /z/ is replaced by the wrong allomorph /s/ (e.g., /ʃu-s/) or by an unrelated phoneme /v/ (e.g., /ʃu-v/). Differences in the ERPs between the wrong allomorph /s/ and the unrelated phoneme /v/ would indicate that the abstract representation of the suffix, presumably with all its allomorphs, is accessed during speech perception rather than a representation of the whole word.

The second goal of this study is to determine the effects of phonotactic status and congruency of phonetic cues. The auditory stimuli included naturally spoken and cross-spliced items. For one set of spliced stimuli, a stem ending with a voiced obstruent was spliced to form phonotactically legal (e.g., bag-/z/) and illegal coda consonant clusters (bag-/s/ and bag-/v/; /gs/ and /gv/ are unattested). For another set, stems ending with a vowel or an approximant were used (e.g., *shoe* /ʃu/). The resulting suffixed forms are all phonotactically legal, but the segment preceding /s/ becomes unnaturally long compared to the naturally spoken items. Because the duration of the preceding vowel is a cue to obstruent voicing [1], we hypothesized that splicing causes incongruent phonetic cues. Both phonotactic status and congruency of phonetic cues may lead to different ERP response patterns.

Method: Eight native English listeners (of a planned 30) listened to noun phrases and rated the acceptability of the pronunciation in an ERP experiment. Each noun phrase began with *the*, *one*, or *two*. The noun was either singular or plural after *the*, always singular after *one*, and always plural after *two*. As summarized in Table 1, we manipulated the phonotactic legality and phonetic cue congruency in Spoken, Spliced & Legal, Spliced & Illegal conditions. We also presented nouns that end with /z, s, v/ to control for the acoustic differences between these sounds in a Control condition. Electroencephalography was time-locked to the onset of the fricatives /z, s, v/ and extracted from -100 to 500 ms. At least 23 artifact-free epochs contributed to the averaged ERP for each condition and participant. Mean amplitudes in 140-240 ms from left central electrodes (FC1, FC3, C1, C3) and 360-500 ms from central posterior electrodes (CPz, Pz, P1, P2, POz) were analyzed. These time windows and regions of interest were selected according to a previous study on violations of French voicing assimilation [2].

Results: Figure 1 illustrates the grand average ERPs when the determiner is *the*. Negative deflections appeared in the early time window for /s/ and /v/ violations in the Spoken condition. Also, a late positivity was evident at posterior sites in all conditions. We subtracted the mean amplitudes in the Control condition from the other conditions in subsequent comparisons.

Although the mean amplitude in the early time window for the /s/ violation was numerically more negative than for the /v/ violation or the canonical /z/, these differences were not statistically significant ($F(2, 14) = 3.09$, $p = .08$). The numerical differences in the late positivity were also not significant ($F(2, 14) = 3.05$, $p = .08$). In the Spliced & Legal condition, significant differences in both the early negativity ($F(2, 14) = 5.58$, $p = .02$) and late positivity ($F(2, 14) = 4.72$, $p = .03$) were observed. Post hoc single-step tests using the R package multcomp showed that the early negativity was smaller for /s/ than /z/ ($p < .01$) and /v/ ($p < .01$). The late positivity for /v/ was larger than for /z/ ($p = .29$). No other pairwise comparison was significant. As for the Spliced &

Illegal condition, the mean amplitudes were different in the late ($F(2, 14) = 5.61$, $p = .02$) but not the early time window ($F(2, 14) = 1.87$, $p = .19$). Post hoc tests showed a larger late positivity for /v/ than /z/ ($p < .01$) and /s/ ($p = .03$), but ERPs elicited by allomorphs /z/ and /s/ did not differ ($p = .77$).

Discussion and conclusion: In the Spoken condition, the ERP elicited by the wrong allomorph /s/ appeared to differ from the unrelated phoneme /v/ and the canonical /z/. The ERPs to /s/ also differed from /v/ in the Spliced & Illegal condition. Taken together, these findings provide some tentative evidence for the abstract representation of the plural suffix being accessed during speech perception. Our data also suggest that phonotactic status and phonetic cue congruency modulate the ERPs elicited by morphophonological violations. The early negativity to the phonetically incongruent /s/ was reduced in the Spliced & Legal condition, suggesting that providing a primary cue consistent with /z/ was sufficient to eliminate the differences in ERPs elicited by the /z/ and /s/ forms of the suffix. Meanwhile, the difference between conditions in the late positivity was enhanced in the Spliced & Illegal condition. Thus, our preliminary data suggest that abstract morphological representations of the English plural suffix, the congruency of acoustic cues with morphophonological forms, and phonotactic constraints all influence the processing of clear speech.

Table 1 Experimental conditions and examples of stimuli.

Condition	Phonotactic legality	Phonetic cue congruency	Example
Spoken	legal	congruent	*shoes* /ʃu-z/, /ʃu-s/, /ʃu-v/
Spliced & Legal	legal	incongruent	*shoes* /ʃu-z/, /ʃu-s/, /ʃu-v/
Spliced & Illegal	illegal	N/A	*bags* /bag-z/, /bag-s/, /bag-v/
Control	legal	congruent	*maze* /meɪz/, *bus* /bʌs/, dive /daɪv/

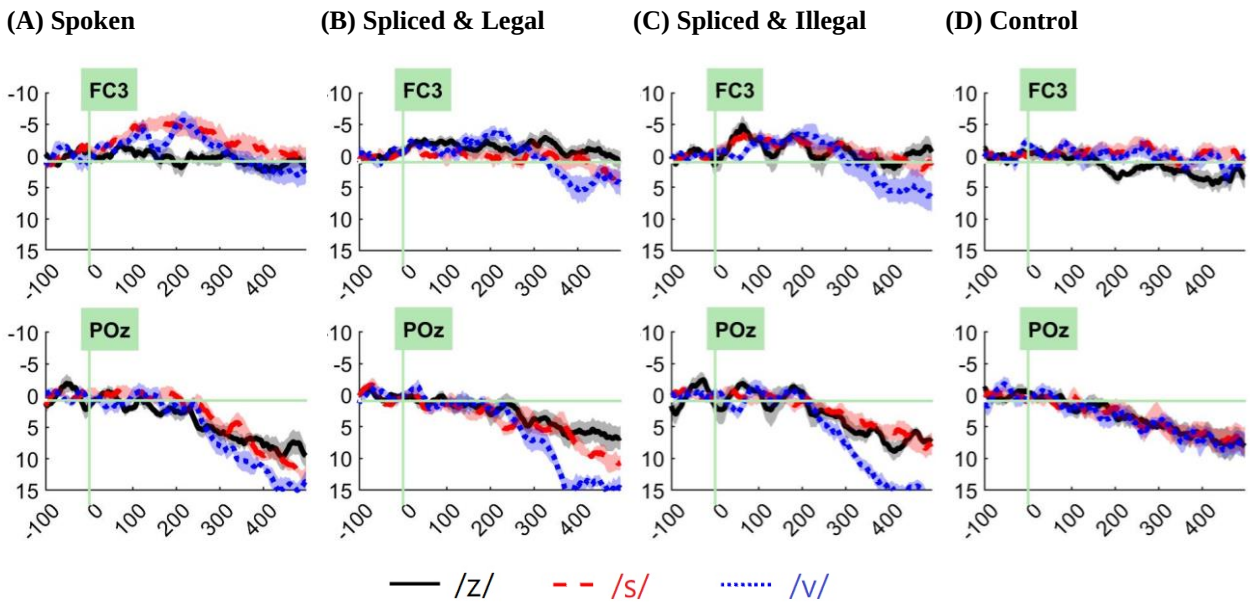

Fig.1 Grand average ERPs evoked by /z/ (solid black), /s/ (dashed red), and /v/ (dotted blue) from two representative electrodes FC3 and POz. Shaded areas indicate one standard error.

References

[1] Denes, P. (1955). Effect of duration on the perception of voicing. *The Journal of the Acoustical Society of America*, *27*(4), 761-764.

[2] Sun, Y., Giavazzi, M., Adda-Decker, M., Barbosa, L. S., Kouider, S., Bachoud-Lévi, A. C., ... & Peperkamp, S. (2015). Complex linguistic rules modulate early auditory brain responses. *Brain and Language*, *149*, 55-65.