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Are word-initial sibilant-sonorant clusters *e*special? Behavioural and neural correlates differentiate sonority-conforming #FR and #SR clusters in English

Introduction When considering the pair *blick*-*nbick*, languages with word-initial consonant clusters can be divided into those that will allow for *nbick* as a possible word and those that will not (Chomsky & Halle, 1968). For the latter group, the sequence #/nb/ in *nbick* is ill-formed: there exists a sonority restriction in the grammaticality of initial clusters in languages such as English and French due to the Sonority Principle (C&H, 1968 *inter alia*). Languages with sonority-restricted word-initial consonant clusters specifically limit the combinations of permitted consonants to obstruent-sonorant (or obstruent-liquid) sequences (Clements, 1990; Scheer, 2012). For ease of exposition we will refer to these languages as #TR languages, where T is short for obstruent and R for sonorant (Scheer, 2012).

When empirically investigating the role of sonority in the contribution to initial cluster well-formedness in #TR languages, one potential experimental confound relates to the documented phenomenon of perceptual deafness to unattested and sonority-violating sequences (Dupoux *et al*., 1999). Because of this, existing experiments investigating the neural response of initial #nonTR clusters in #TR languages have only been indirect: the only existing electroencephalography (EEG) event-related potential (ERP) study on #nonTR relied on eliciting differential responses to sequences with and without an epenthetic vowel (Wagner *et al*., 2012). This indirect inference method does not address the grammatical status of initial clusters beyond the success rate of specific-token perception.

This paper focuses specifically on the comparison of word-initial nonsibilant fricative-sonorant (henceforth #FR) and sibilant-sonorant (#SR) clusters in English (*Table 1*). We include glides, liquids and nasals as sonorants: hence canonically "unperceivable" cluster sequences (/fn/) can also be tokens. Methodologically, we address aforementioned challenges by presenting two novel paradigms to facilitate investigations of all types of word-initial clusters in #TR languages: a dichotic listening study and an EEG study. Topically we explore behavioural and neurophysiological correlates to sonority sequencing in initial cluster perception *and processing*. Preliminary pilot results (n=9 behavioural, n=4 neural; data collection in progress) indicate a differential processing response between #FR and #SR clusters despite their shared rising sonority slope.

Table 1. Main clusters tested in our experiments

Cluster type	Attestedness	
	Attested	Unattested
Nonsibilant fricative-sonorant (#FR)	**fl** fɹ θw	(fm) **fn** **fw** vl vɹ vw
Sibilant-sonorant (#SR)	ʃɹ **sm** **sn** **sw** (sl) (sj)	**ʃl** ʃm ʃn **ʃw** zɹ

Key: (dichotic listening study only); **both experiments**

Dichotic listening study We adapt an existing dichotic listening paradigm originally designed to test segment sequencing of #TR and #RT (sonorant-obstruent) clusters in Czech, a language with no initial sonority restrictions (Dumercy *et al.,* 2014). Monolingual British English subjects were binaurally presented simplex onsets in a /C-VVn/ template which differed in both ears. One ear was presented with a fricative onset token that is either nonsibilant (/f/, *e.g.* /fɔɪn/) or sibilant (/s, ʃ/); simultaneously, the other ear received an obstruent (/p t b d g/) or sonorant onset token (/j, l, m, n, w/). Although token delivery was always binaural, one ear may receive a delayed input of up to 50*ms* to probe sequencing biases. Oral responses of percepts were taken between consecutive token delivery. Results considering fusion rate indicate the lack of fusion between all input pairs which presented fricatives with obstruents (0% of total responses across all subjects): there were no #FT/#TF or #ST/#TS clusters perceived. However, fusion was achieved when certain fricatives were presented with sonorants: there were percepts of #/fl/ (25%), #/fw/ (25%), #/ʃl/ (19%) and #/ʃw/ (36%), all consistently sequenced as #fricative-R (*i.e.* no #R-fricative). Crucially, there was a 0% fusion rate specifically in /s/-R input pairs. Combined with findings from a previous study where only #TR clusters are possible fused percepts in English (citation suppressed), our results indicate that although fusion is constrained by sonority, #sR displays exceptional fusion resistance despite its rising sonority profile. We follow this up using EEG.

EEG study Our experimental set-up allows for successfully tapping into an English speaker's response even in auditory presentation of *illicit* clusters due to pre-EEG familiarisation which presented tokens both auditorily and visually (with spelling). Attested and unattested #FR and #SR clusters were given in a CCVC template (*e.g. floon*, *zrip)* with other #TR, #TT, #RR and #RT tokens. EEG recordings were acquired in a passive listening paradigm to the same auditory-only tokens. Two goodness rating tasks (pre-EEG with audio-visual presentation, post-EEG with audio-only presentation) doubled as a confirmatory procedure – Daland *et al.*, 2011 document correlating rating responses with sonority: as long as the correlation holds in goodness rating within auditory-only presentation, we know perceptual deafness has been overcome. Our main finding reveals a P400 response which categorically divides attested and unattested #FR from attested #SR (no P400), while unattested #SR displays a lower yet existent P400 (*Fig. 1*). This ERP may index sonority assessment using initial acoustic processing similar to a P3a ERP (Wagner *et al.*, 2012) that is later overridden by grammatical factors (such as conflicting syllabification) which generates an ERP-cancelling N400 in attested #SR. This is consistent with theoretical accounts which posit that not only #sT clusters have an atypical syllabification in English, but all #sC including #sR are coda-onset (Kaye, 1992). Also, #ʃR form largely the unattested #SR group in the EEG experiment, while #sR are the majority of attested #SRs. Only factors additional to surface level derivations of sonority can account for the separation of all #FR together with unattested #SR (#ʃR), from attested #SR (#sR). #sR exceptionality in the dichotic study may be explained by this P400 grammatical markedness; in contrast, #ʃR has yet to be lexicalised as atypical and can fuse. In conclusion, both behavioural and EEG results highlight exceptionality in sibilant-sonorant initial clusters (#sR) compared to #FR. Furthermore, our findings of differential responses of #sR *vs.* #ʃR in the dichotic experiment warrant further research, since many languages typologically group /s/ and /ʃ/ as a class of sibilant fricatives.

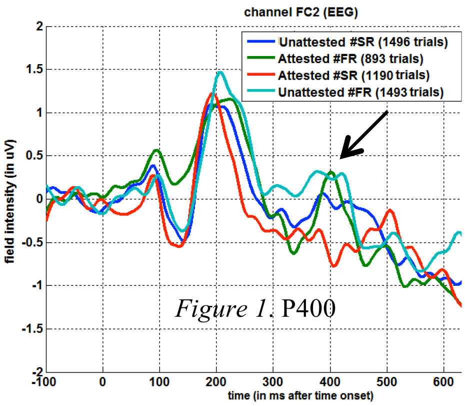

Figure 1. P400

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