

Syllable-based surprisal effects on voicing during closure in intersonorant German stops

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Speakers produce more reduced forms or shorter durations for predictable messages and conversely lengthen forms for less predictable ones [1, 2]. There are several measures to quantify predictability. One of them is surprisal, which is calculated as $S(\text{Unit}_i) = -\log_2 P(\text{Unit}_i|\text{Context})$. The predictability effect is well studied in multiple languages and linguistic levels [3]. However, it is still not clear how predictability effects are transmitted across different linguistic levels. Ibrahim et al. [4] found that syllable-based predictability affects the syllable's temporal dimension and this effect extends to the segmental level, e.g., voicing in German. In high surprisal syllables, closure duration was uniformly longer for both voiceless and voiced stops, but VOT was longer only for voiceless stops. This asymmetrical pattern of VOT could be related to German being considered an aspirating language, using [+spread glottis] for voiceless consonants and [-spread glottis] for their voiced counterparts [5]. However, phonetic voicing has also been reported in an intervocalic context for both voiceless and voiced consonants to varying extents. To further test whether the previously reported surprisal effect on VOT is driven by the phonological feature [spread glottis], the current study re-examined the downstream effect of syllable-based surprisal on segmental voicing in German stops by measuring the degree of voicing during closure (VDC) in an intersonorant context.

Method: In the data set collected for a separate research question in Ibrahim et al. [6], there were voiced vs. voiceless stops in CV syllables allowing us to explore the above-stated question. However, the data set contained an unbalanced set of voicing contrasts in different places of articulation /p k b d/. These stops in onset position are combined with one of the vowels /a: e: i: o: u:/ to form a syllable. Each of these lexically stressed syllables is part of a polysyllabic word and was produced in carrier sentences by 38 German speakers. The data in the current study contained voiceless vs. voiced initial stops in a low or high surprisal CV syllable. Surprisal was estimated by means of a syllable-level language model trained on DeWaC [7]. Closure duration (CD) and voicing during closure (VDC) were extracted using Praat scripts. Linear mixed-effects modeling was used to evaluate the effect(s) of surprisal and stop voicing status on CD and VDC, taking into consideration potential factors such as different places of articulation in different syllables.. The final model was: $\text{feature} \sim \text{Surprisal} + \text{Stop voicing status} + (1 | \text{Speaker}) + (1 | \text{Syllable}) + (1 | \text{PrevManner}) + (1 | \text{Sentence})$.

Results: We found that closure duration is longer in a high surprisal syllable, regardless of the voicing status of the stop (figure1). Since this durational cue is not directly connected to the phonological feature [spread glottis], one should observe a uniform downstream effect of syllable-based surprisal for voiceless and voiced stops in the same direction, in line with our expectation. As regards phonetic voicing, VDC is longer in a high surprisal syllable and this holds for both voiced and voiceless stops (figure 2). In addition, VDC is significantly shorter in voiceless than voiced stops. That shows the acoustic implementation of VDC is constrained by the voicing status of the target consonants. A phonologically specified voiceless stop naturally will have a shorter VDC interval than a phonologically specified voiced stop. Despite that, an additional effect of syllable surprisal was observed, with an increase in the VDC interval in a high surprisal syllable. This direction is consistent with syllable lengthening in a high surprisal syllable, suggesting a uniform downstream effect of surprisal on phonetic voicing of stop consonants. Our findings reveal that the syllable-based

surprisal effect can spread downstream to the segmental level and that the effect is uniformly affecting acoustic cues that are not directly tied to a phonological feature in German voicing (i.e., [spread glottis]).

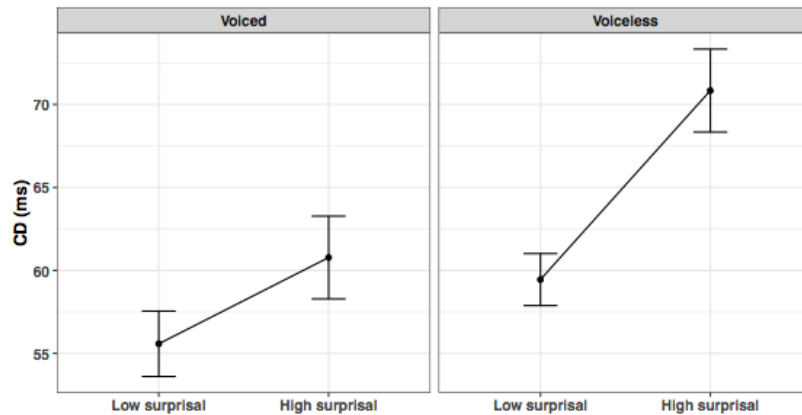


Figure 1: Mean closure duration as a function of surprisal and stop voicing status (with \pm SE)

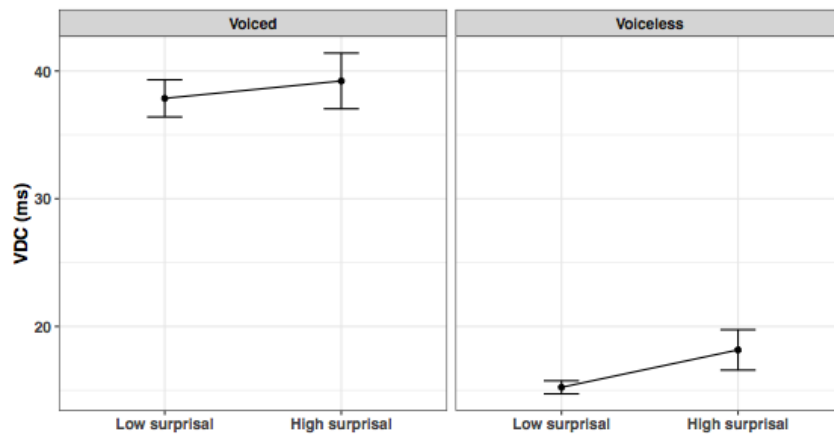


Figure 2: Mean duration of voicing during closure as a function of surprisal and stop voicing status (with \pm SE)

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