High pitch signals word onsets for German 9-month-olds:
evidence for a pitch segmentation strategy

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The metrical segmentation strategy [1] predicts that infants from stress-timed languages treat stressed syllables as word onsets. It has been demonstrated that by 9 months of age, infants are able to segment trochees from fluent speech [see 2, on American-English; 3, on German; 4, on Dutch]. It has previously been shown that German 9-month-olds only treated stressed syllables as word onsets when produced with high pitch (L+H* or H* accent), but not when stressed syllables were low-pitched (rising L*+H or falling H+L* accent) [5]. This is surprising, since (i) not every stressed syllable is accented and (ii) not every accented syllable is high-pitched. Instead, there are other – seemingly more stable – stress cues such as duration, intensity or spectral tilt (e.g., [6-9]). Here, we scrutinize the role high-pitched syllables play in the segmentation process by investigating whether high pitch itself is a sufficient cue to stress for German 9-month-olds.

We tested 48 German infants (mean age: 0;9.0 range: 0;8.19-0;9.17, 17 female) from monolingual German families in the head-turn preference paradigm. Infants were familiarized with two of four trisyllabic nonce words with final stress (weak-weak-strong (WWS) stress pattern), e.g., [linu'ʁoː] in sentence-contexts. The nonce words were presented in two naturally occurring intonation conditions: (i) in an early-peak condition in which the pitch peak preceded the stressed syllable or (ii) in a medial-peak condition in which the pitch peak was realized within the boundaries of the stressed syllable, manipulated between subjects, see Figure 1 for exemplar contours. Test items were the last two syllables of the WWS carrier word, but with the reverse stress pattern (SW, e.g., ['nuːʁo], for WWS [linu'ʁoː]); these test items were familiarized or novel (counter-balanced across infants). They were recorded 15 times with varied intonation (five x rising, five x falling and five x flat) and concatenated with an ISI of 800ms.

Looking times to the four test lists were measured online and averaged for novel and familiar items for each infant. Infants looked on average 8.6s (sd=2.2s) to familiar and 7.4s (sd=2.2s) to novel test lists in the early-peak condition and 8.7s (sd=2.4s) to familiar and 8.6s (sd=2.4s) to novel test lists in the medial-peak condition, see Figure 2. Results of a repeated measures ANOVA with *intonation condition* as between-subject factor and *familiarity status* as within-subject factor showed a significant interaction between the two factors ($F(1,46)=4.52$, $p=0.04$). Post-hoc pairwise t-tests showed a statistically significant difference between looking times to familiar test lists and novel ones in the early-peak condition ($t(23)=3.34$, $p=0.003$), but not in the medial-peak condition ($p=0.78$).

Our results suggest that the position of high pitch is a sufficient cue to word onsets for German 9-month-olds: they treated high-pitched syllables as word onsets even though they were unstressed. We see three explanations why infants may rely on high pitch for segmentation. First, high-pitched syllables are salient and infants show a high sensitivity to this acoustic parameter from early on (e.g., [10, 11, 12]). Second, in infant-directed speech high-pitched syllables are more frequent than low-pitched syllables [13], which might strengthen the association between stress and high pitch. Third, our findings could be interpreted in the framework of the iambic-trochaic law, which shows that infants group syllable strings that alternate in pitch height into trochaic units, starting from high-pitched syllables (high-low, cf. [14]). Taken together, our findings offer a novel perspective to account for early speech segmentation, suggesting that pitch might be the driving force in this process, at least in German.

Figure 1. *Exemplar WWS-carrier word in sentence-context; smoothed f0 contours, sound pressure wave and spectrogram are shown for the early-peak condition* (a) *and the medial-peak condition* (b).

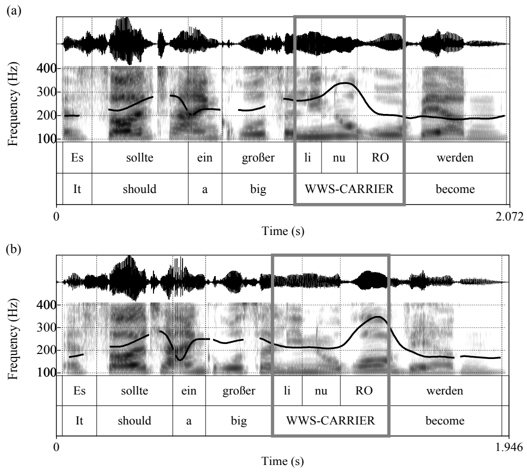
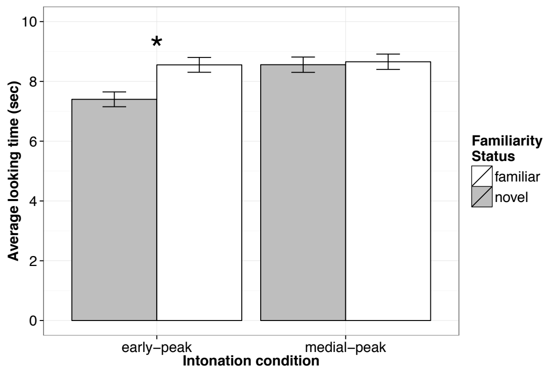


Figure 2. *Average looking times to test lists split by familiarity status and intonation condition (whiskers represent ±1 SE of the mean).*



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