Brain indices for processing rising and falling pitch: An MMN study

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Attention towards a sound source is fundamentally important not only for survival but also for communication. We investigate whether rises in pitch are special in attention orienting. The idea originates from (neuro)cognitive studies attesting an attentional bias towards sounds with rising as opposed to falling acoustic properties; for example, a sudden increase in loudness or pitch of a sound is experienced by the listener as an approaching sound source, referred to as the auditory looming effect [e.g. 1].

The current study investigates whether this looming effect is triggered by rises in pitch attributable to accents and edge tones in speech. We conducted an EEG study (32 native German speakers: 28f, 4m; mean age 24.5) using the classic oddball paradigm in passive recordings: a sequence of standard repetitive auditory stimulation occasionally interspersed with a deviant sound. Of particular interest are the mismatch negativity (MMN) and a positivity around 300ms (P3) as they are claimed to index activation of pre-attentive and conscious attentional mechanisms respectively [2;3]. To simulate a more natural speech context, participants were presented with rising/falling pitch realised either on the stressed syllable or on the final syllable (see Fig. 1a) of four real CV.**CV**.CV German words (*Banane* "banana", *Limone* "lime", *Marone* "chestnut", *Melone* "melon"), alternating as standards/deviants across four oddball sequences: 1) deviant accentual fall/standard accentual rise, 2) deviant accentual rise/standard accentual fall, 3) deviant boundary fall/standard boundary rise, 4) deviant boundary rise/standard boundary fall. We hypothesize that if the processing of speech is purely signal-based, rising deviants should attract more attention by virtue of their being acoustically more prominent than falling ones. By contrast, if it is more linguistic, falling ones might attract more attention because linguistic processing is highly affected by language-specific expectations [4]. Since each sequence of standard stimuli resembles a list, which in German typically involves rises on non-final items in the list followed by a fall on the final item [e.g. 5;6], the rising sequence might be more natural than a sequence of falls. Listeners might thus habituate better to a sequence of rises, triggering a stronger reaction to falling deviants.

Separate Bayesian hierarchical models (weakly informative priors) were fitted per oddball sequence; Event related potential amplitude (in microvolt) was modelled as a function of condition (standard/deviant) from 0-to-700ms after stimulus onset, in steps of 100ms. Random effects for subjects included full variance-covariance matrices [7]. The results (see Fig. 1b for ERP waves; Fig. 1c for the posterior distributions of the estimated effects for the difference between standard and deviant) show that all deviants evoke an MMN activity relative to their corresponding standard stimulation with an onset in the 200-300ms time window. For all deviants except the accentual fall, the MMN activity lasts for two successive time windows (200-400ms), with the accentual rise exhibiting the most pronounced effect. MMN to falling deviants is followed by an additional P3, at the 400-500ms time window for the accentual falls, and at a later time window (500-600ms) for boundary falls.

Overall, all deviant contour types elicit an MMN activity, indexing an activation of pre-attentive mechanisms detecting regularity violations in the acoustic signal. Accentual rises evoke the largest MMN, indicating that they lead to a greater attraction of preconscious attention. Falling deviants engender a subsequent P3, indicating the use of additional conscious attentional resources. This is due to the naturalness of the standard sequence of rises which led to greater habituation and thus oriented conscious attention towards the deviant. In sum, deviant rises, being acoustically prominent, engender an auditory looming effect at the pre-attentive level, whereas in the case of deviant falls, the processing is affected by the linguistic context of the list, activating conscious attentional mechanisms.

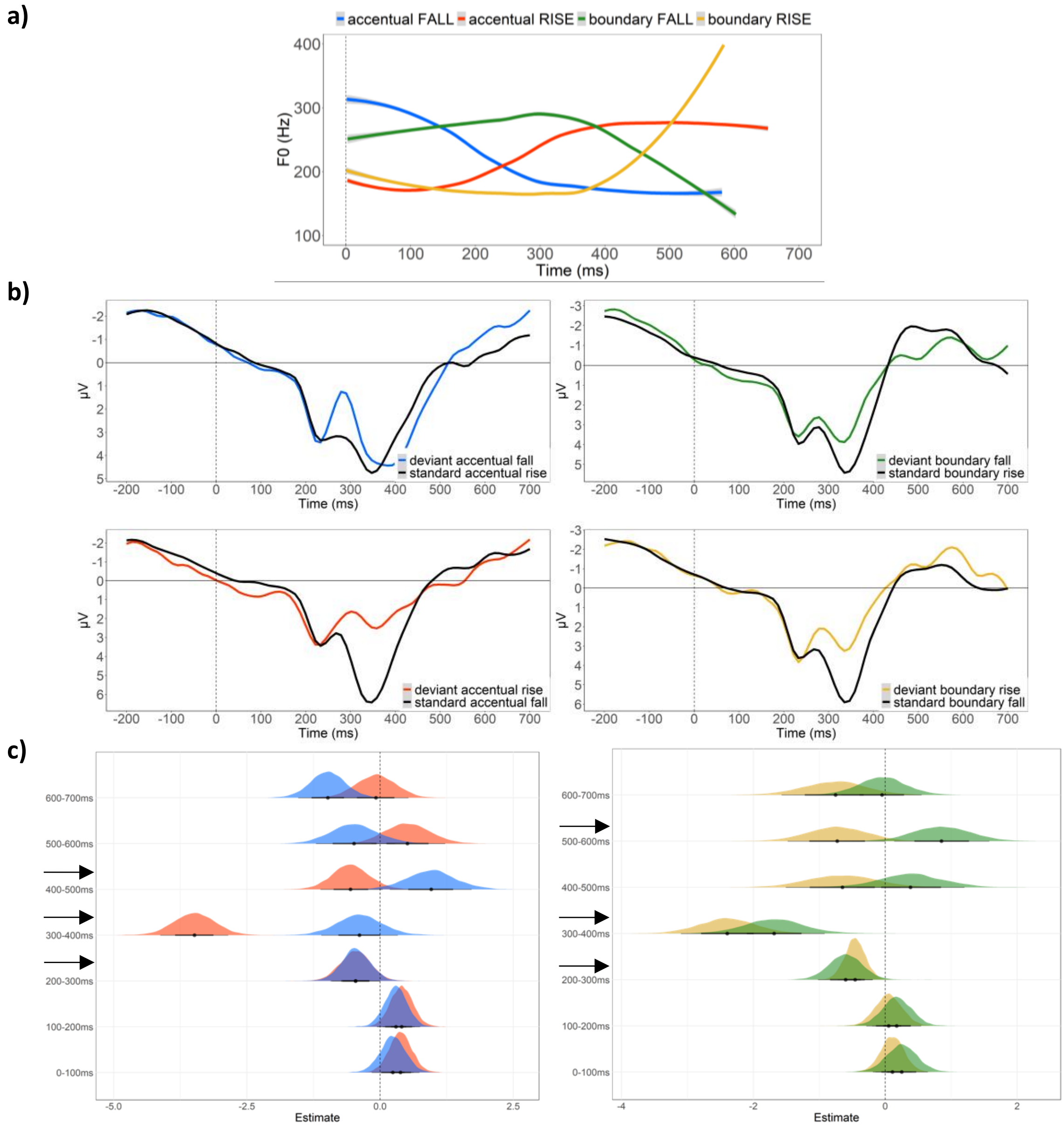

Figure 1. *Top panel (a) depicts the mean f0 contours of the oddball auditory stimulation. Middle panels (b) illustrate the grand average ERPs (per oddball sequence) recorded to the onset of stimulus (illustrated by the vertical dashed line) over time (x-axis) at the AF3, AF4, F3, Fz, F4, FC1, FCz, FC2, Cz electrode sites. Negative voltage is plotted upwards. Bottom panels (c) show the posterior distributions of the estimated effects for the difference between standard and deviant per oddball sequence (red: deviant accentual rise – standard accentual fall; blue: the deviant accentual fall – standard accentual rise; yellow: deviant boundary rise – standard boundary fall; green: deviant boundary fall – standard boundary rise). Error bars around the posterior means represent 66% (thick) and 90% credible intervals. Arrows highlight time windows of interest.*

References

[1] Bach, D., Schachinger, H., Neuhoff, J., Esposito, F., Salle, F., Lehmann, C., Herdener, M., Scheffler, K., & Seifritz, E. 2022. Rising Sound Intensity: An Intrinsic Warning Cue Activating the Amygdala. *Cerebral Cortex*, *18*(1), 145-150. [2] Näätänen, R. 1992. *Attention and brain function.* Lawrence Erlbaum Associates, Inc. [3] Polich J. 2007. Updating P300: an integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128-2148. [4] Grice, M., Ritter, S., Niemann, H., & Roettger, T. B. 2017. Integrating the discreteness and continuity of intonational categories. *Journal of Phonetics*, *64*(2), 90–107. [5] Baumann, S., & Trouvain, J. 2001. On the Prosody of German Telephone Numbers. Proceedings *7th Conference on Speech Communication and Technology*, 557-560. [6] Peters, J. 2018. Phonological and Semantic Aspects of German Intonation. *Linguistik Online*, *88*(1). [7] Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. 2013. Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278.