Are rises special in attention orienting? Some evidence from boundary tones in German

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The question of how attention orientation is conditioned by intrinsic auditory warning cues, such as rising sound intensity or fundamental frequency (f0), has inspired processing studies for many years investigating this relation in the domain of auditory looming. Such studies [e.g. 1; 2] have reported that rises in sound intensity or f0 evoke looming effects, attracting thus more attention than intensity or f0 falls. Yet, previous research on neurophysiological correlates of the link between acoustic properties of sounds and attention orienting have focused on non-linguistic stimuli only.

This study is concerned with the link between intonation (conveying linguistic meaning) and attention orienting during online processing using event related potentials (ERPs). We recorded electroencephalographic data from 32 Ag/AgCl electrodes from 32 native German speakers (28f, 4m; mean age 24.5, sd 3.5) while they were presented with the classic oddball paradigm, that is a sequence of repetitive sounds (standards) occasionally interspersed with rare sounds (deviants), in passive recordings. We are particularly interested in two brain responses: the mismatch negativity effect (MMN) which is assumed to index an automatic, pre-attentive detection of regularity-violation changes [e.g. 3] and the P3a component (early and late positivity) which is claimed to reflect a conscious attention orienting to novel or salient stimuli [e.g. 4]. The auditory oddball stimulation uses rising and falling f0 contours, realised at the boundary, i.e. on the final syllable, of four different items (CV.'CV.CV nouns), alternating as standard/deviant sounds across two conditions (deviant rise vs standard fall; deviant fall vs standard rise). Linguistic research reports that f0 rises demand more attentional resources than f0 falls [5; 6]. Our main aim is thus to assess the differential processing of rises and falls, and how far language specific expectations play a role. We expect that if auditory looming is purely signal-based, deviants with rising contours should evoke a more pronounced MMN/P3a effect than deviants with falling contours (rises > falls).

Modelling and visual inspection of the signal reveal that negative and positive deflections are modulated by the deviant contour type (Figure 1). Our results show (time-locked to stimulus onset) that rising deviants (left panel) elicit an MMN activity relative to falling standards with an onset around 300ms, succeeded by a pronounced anterior negativity at a later time window (500-700ms), followed by a late positivity (700-800ms). Similarly, falling deviants (middle panel) evoke an MMN relative to rising standards which however is shorter than the MMN caused by rising deviants (around 300ms). MMN activity evoked by falling deviants is followed by a positivity with onset around 450ms and a subsequent anterior negativity at a later time window (around 600-800ms). The right panel displays the difference plots.

Overall, we find that both deviant contour types elicit an MMN activity relative to their corresponding standard stimulation, indexing a pre-attentive detection of regularity violations in the acoustic signal, with rising deviants evoking greater MMN, and thus attracting more attention than falling ones. Surprisingly, the subsequent responses to deviants differ based on the contour type. These results could potentially indicate different neurocognitive processing of speech rises and falls, both because speech sounds are more complex and because the stimuli are interpreted linguistically. Crucially, the presentation of the stimuli in the oddball paradigm resembles a list, which typically entails rises on non-final elements and falls on final elements [e.g., 8; 9]. A sequence of rises with an occasional fall is therefore more natural than a sequence of falls with an occasional rise, leading to a difference in processing. The violation of linguistic expectations (in terms of list intonation) in the deviant rise/standard fall condition appears to cause additional processing costs, reflected in a later negativity (500-700ms).

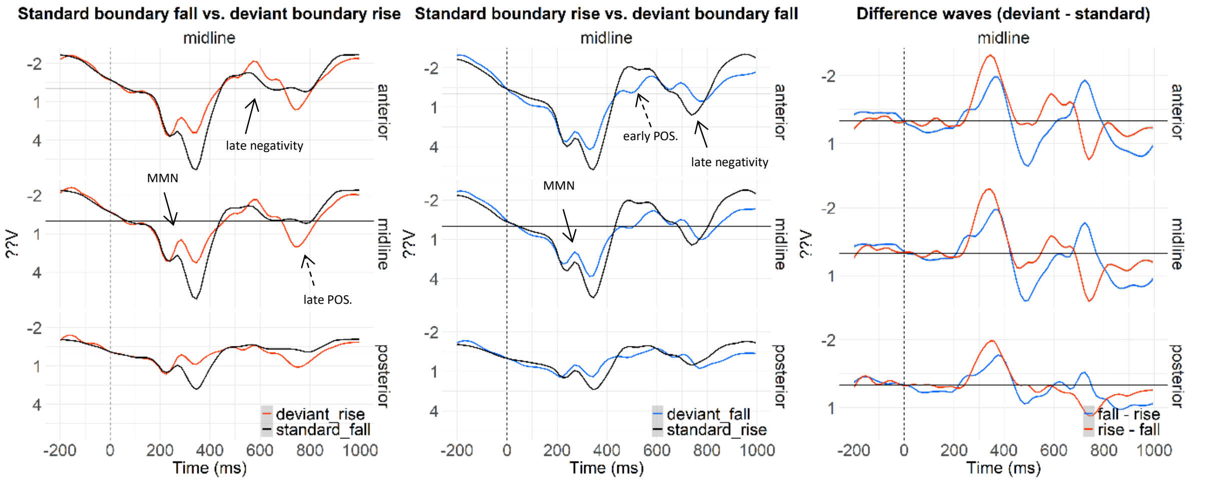

Figure 1: Grand-average ERPs recorded to the onset of stimulus (illustrated by the vertical line) over time (x-axis) at midline electrodes (Fz, FCz, Cz, CPz, Pz, POz, Oz). For plotting purposes, the continuous topographic variables were grouped into ROIs based on two-dimensional coordinates: midline (vertical panels) and sagittality (horizontal panels). Negative voltage (y-axis) is plotted upwards. Deviant rising stimuli are illustrated in red, deviant falling stimuli in blue, and standard stimuli in black across conditions (left panels: deviant rise vs standard fall; middle panels: deviant rise vs standard fall). The right panels depict the difference waves (in red lines: deviant rise – standard fall; in blue lines: deviant fall – standard rise).

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