

An MMN study on auditory processing of rising and falling f0 in speech

Maria Lialiou, Martine Grice, Christine Röhr, Petra Schumacher

Modern cognitive neuroscience has been concerned with the division of auditory perception into preconscious and conscious processes, exploring the brain mechanisms that contribute to this division. Mismatch negativity (MMN), peaking between 100-300ms, is a principal index of central sound representation (Näätänen, 2001; Näätänen et al., 2011), reflecting automatic, preconscious attention processes to any discriminable change in a repetitive sound sequence (Näätänen et al., 2019), while conscious attention processes to novel or salient stimuli is indexed by the P3 (early/late positivity) component (Polich, 2007). Processing studies in the auditory looming domain (e.g. Bach et al., 2008; Macdonald et al., 2011) report that sudden increments in the properties of the acoustic signal, e.g. increases in sound intensity, duration or fundamental frequency (f0), evoke a larger MMN than sudden decreases. Accordingly, a rising sound, by virtue of it being an intrinsic warning cue, attracts more attention than a falling one.

Our study extends this line of research to f0 rises and falls in speech, to assess the differential processing of rises and falls, and how far language specific expectations play a role. We are particularly interested in the MMN/P3 brain responses, thus we recorded electroencephalographic data (32 Ag/AgCl electrodes) from 32 native German participants (28f, 4m; mean age 24.5, sd 3.5) using the classic auditory oddball paradigm in passive recordings, consisting of rising and falling f0 movement on the stressed syllable of four items (CV.CV.CV nouns), alternating as standards/deviants across two conditions (deviant fall/standard rise; deviant rise/standard fall). Linguistic research reports that f0 rises are more prominent (e.g. Grice et al., 2005; Baumann et al., 2015) and demand more attentional resources than f0 falls (e.g. Hsu et al., 2015; Röhr et al., 2021). Thus, we expect that, if auditory looming is purely signal-based, deviants representing rises should evoke a more pronounced MMN/P3 effect than falls.

Our results (time-locked to stimulus onset) show that both rising and falling deviants elicit an MMN (starting around 200-250ms) relative to their corresponding standard stimulation, indexing a preconscious detection of a change in the acoustic signal. Surprisingly, falling deviants evoke greater MMN than rising ones. Moreover, MMN to *falling* deviants is followed by an early positivity (400-500ms), succeeded by a late anterior negativity (500-700ms). Contrarily, MMN to *rising* deviants is followed by additional negativity in between 300-500ms and a pronounced posterior late positivity (500-700ms). These results 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. Baumann et al., 2001; Peters, 2018). 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 (300-500ms).