The effect of increasing acoustic and linguistic complexity on auditory processing: an EEG study

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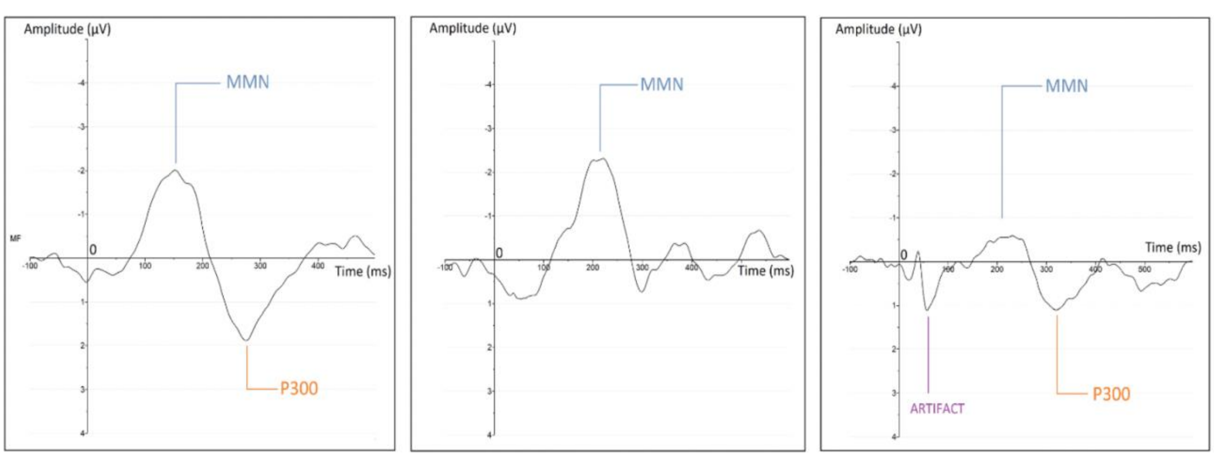
The mismatch negativity (MMN) is a neurophysiological marker of pre-attentive processing that is elicited when a rare, deviant stimulus is presented in a stream of more frequent, standard stimuli (oddball paradigm). Recorded using electroencephalography (EEG), the MMN is sensitive to acoustic differences between oncoming stimuli. In linguistic research, MMN has often been used to investigate individuals' perceptual boundaries of phonemes, or to study phoneme learning. MMNs have been elicited by syllables as well, showing a larger response to contexts that form words as opposed to those that form pseudowords. Previous work has compared speech and non-speech sounds and investigated how the MMN response differs. However, the results are not conclusive. Some studies have shown a larger response to speech compared to complex waves, but smaller in comparison to simple tones (e.g. Sorokin et al., 2010). Other works comparing non-speech stimuli have shown complex waves to elicit an MMN that is larger compared to those elicited by simple tones (e.g. Tervaniemi et al., 2000). The current study investigated pre-attentive processing of stimuli with a systematic (stepwise) increase in acoustic (and linguistic) complexity. Three different types of acoustic stimuli were presented in an oddball paradigm where deviants differed in pitch only: simple (pure sine wave) tones, complex harmonic waves, and artificially produced syllables generated with an articulatory synthesizer. The syllables had consonant- vowel (CV) structure, beginning with voiceless stops. The simple tones had a frequency of 1000 Hz (deviants: 1200 Hz). The complex waves were generated with a fundamental frequency of 100 Hz (deviants: 120 Hz), and their intensity envelopes were matched to those of the syllables. Finally, syllables with no semantic content (/ti tu tə ka/; fundamental frequency 100 Hz) were generated using VocalTractLab (Birkholz et al., 2019), a software that allows highly controllable manipulation of vocal tract and laryngeal parameters and configurations to generate natural-sounding artificial speech. Thus, complex waves and artificial syllables were acoustically very comparable, the main difference being the presence versus absence of both vocal tract influences and laryngeal control (e.g. voiceless VOT phase with transient and noise elements driven by articulator interactions). We hypothesised that the pitch deviant for each stimulus type would evoke an MMN, and that the size of this response would differ depending on the nature of the stimuli (simple, complex wave, or syllable). Results supported our hypothesis. An MMN was elicited for all three types of stimuli (**Figure 1**). The largest response was evoked to simple tones, and the smallest to the syllables. The responses to the complex waves were more similar to those evoked to sine waves than to syllables. This suggests differences between how linguistic stimuli (syllables) are processed compared to non-linguistic stimuli (simple, complex waves). The results of this study demonstrate how incremental increases in acoustic complexity and resemblance to speech of auditory stimuli are reflected in the MMN response.

Figure 1. *The figures show the MMN response evoked to the frequency (pitch) deviant for the three stimulus types: simple tones (left-most), complex waves (middle), and syllables (right-most). Time ms is plotted on the x-axis, and amplitude in µV is plotted on the y-axis.*



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