

Mismatch Negativity Measures of Gap Detection

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Introduction

This paper examines the feasibility of using Event Related Potentials to measure temporal resolution in adults. Measures of temporal resolution have recently become interesting to language acquisition researchers because of claims that certain kinds of language impairment may result from an underlying lack of temporal resolution (e.g., Lowe & Campbell, 1965; Tallal et al., 1985; Tallal et al., 1993). Many of the features distinguishing speech sounds, such as voice onset time, rely on timing differences of a few milliseconds. A child diagnosed with poor temporal resolution also presumably had poor temporal resolution in infancy. Currently, children with language impairment are not usually diagnosed until at least 3 or 4 years of age. Thus, if temporal resolution could be measured in prelinguistic infants, it could be used to identify infants at risk for later language impairment.

Gap detection is the most common way of measuring temporal resolution. We used Gaussian-enveloped sine wave tones rather than broad band noise as markers for the silent gap as we are interested in gap detection at particular frequencies in the absence of adaptation effects. Gaussian envelopes were used as they minimize the spectral splatter that occurs when a sound is turned on or off and the degree of spectral splatter is independent of the size of the gap (see Schneider et al., 1994). No-gap standard stimuli were constructed as in Schneider et al. (1994) to match the gap stimuli in duration and energy, and to approximate them in spectral content.

The purpose of the present study is to find a measure that does not require attention or a behavioural response. The mismatch negativity (MMN) appears to be ideally suited to this purpose. When an infrequent stimulus (e.g., a tone with an embedded silent gap) occurs in a series of frequent stimuli (e.g., a tone with no gap), the electrical activity recorded at the scalp is more negative for the infrequent than for the frequent stimuli between about 100-300 ms after the onset of the stimulus. MMN appears to be a rather pure measure of sensory processing, as it is affected very little by attention (Näätänen, 1992).

In the present study, we attempted to measure adults' gap detection thresholds using MMN.

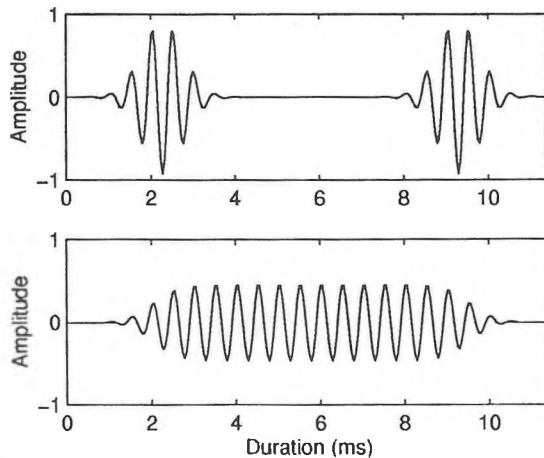


Figure 1. The gap (upper panel) and no-gap (lower panel) stimuli for gap size 7.

Method

Participants

Eight adults (age range = 21 to 24 years; 4 female, 4 male) were tested with all gap sizes. The data for one condition (gap size 8 ms, see *Stimuli*) was unusable for one participant.

Stimuli

In each of 5 conditions, gap stimuli were constructed with two 2000 Hz Gaussian-enveloped tone pip markers (standard deviations of .5 ms) whose peak amplitudes were separated by 4, 5, 6, 7, or 8 ms (see Figure 1). The matching no-gap stimuli were created as in Schneider et al. (1994) to match the gap stimuli in duration and energy, and roughly in spectral content (see Figure 1).

Apparatus

The sounds were generated with inhouse software running on a Comptech pentium computer with a sound card. They were presented with a Denon PMA 480R amplifier and a Grason Stadler speaker. The EEG was recorded with NeuroScan 4.0 software, using 32-channel Synamps, and electrocaps with Ag/AgCL electrodes in a shielded room.

Procedure

A target-nontarget oddball methodology was used. In each gap condition (4, 5, 6, 7, 8 ms) 400 trials were presented, of which 80% were no-gap trials and 20% were gap trials. In order to mimic the infant procedure, adults were tested in a passive listening paradigm, whereby they were simply instructed to watch a screen saver.

Recordings

Recordings were made from the following 27 sites (see Figure 3): Fpz, Fp1, Fp2, Fz, F3, F4, F7, F8, FC1, FC2, FC5, FC6, Cz, C3, C4, T3, T4, T5, T6, PC5, PC6, Pz, P3, P4, Oz, O1, O2. The sampling rate was 500 Hz, and the bandpass was set between .15 and 30 Hz. Impedance levels were maintained below 5 kOhms. Cz was used as a reference during recording, although a common average reference was used for the analyses.

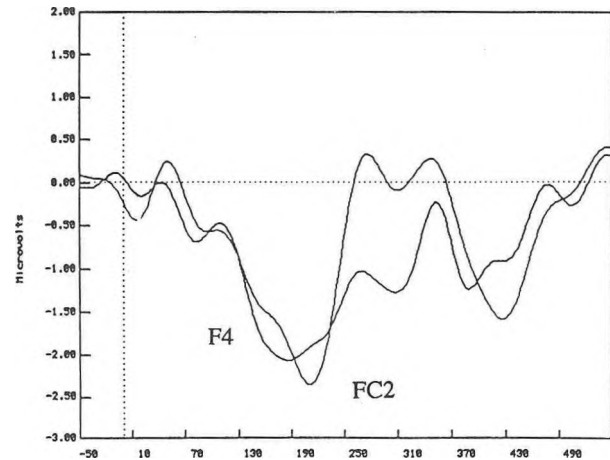


Figure 2. Difference waves (oddball minus standard) for gap size 7 at F4 (upper panel) and FC2 (lower panel).

Data Analysis

The recordings were low pass filtered at 18 Hz. Baseline was defined as the mean amplitude for the 50 ms preceding the onset of the stimulus. Epochs were defined as 550 ms beginning from the onset of the stimulus. FP1, FP2, F7, and F8 were used to rejected trials contaminated by eye movement artifact.

For each participant in each condition, the waveforms on the standard (no-gap) trial epochs were averaged together, as were the waveforms on the oddball (gap) trial epochs. Then the averaged standard waveform was subtracted from the averaged oddball waveform to create a difference wave. T-tests were employed to determine the portions of the difference wave between 100 and 300 ms that were significantly less than 0 across participants.

Results

The difference wave was significantly below 0 ($p < .05$) at a number of sites in the region expected for MMN for gaps of 8, 7, 6, and 5 ms. At 4 ms, there was significance only for very brief portions of the waveform at only 3 sites. From this, we can conclude that the gap threshold with these stimuli as measured by MMN is in the neighbourhood of 4 ms. Figure 2 shows difference waves for a gap of 7 ms.

In detail, for 8 ms gaps, significance was found at FC2 (186-234 ms), Cz (170-194 ms), C4 (194-248 ms), and Pz (144-192 ms). For 7 ms gaps, significance was found at Fz (152-256 ms), F3 (178-216 ms), F4 (146-252 ms), FC2 (138-244 ms), FC6 (174-208 ms), C4 (176-222 ms), and CP6 (216-242 ms). For 6 ms gaps, significance was found at F4 (160-258 ms), Cz (166-232 ms), C4 (210-218 ms), and CP6 (194-206 ms). For 5 ms gaps, significance was found at Fz (166-196 and 218-236 ms), FC1 (152-240 ms), FC2 (126-248 ms), FC6 (224-264 ms), Cz (148-244 ms), C4 (210-250 ms), T4 (236-292 ms), CP6 (206-274 ms), and T6 (248-300 ms). For 4 ms gaps, significance was found at F8 (180-196 ms), FC6 (174-192 ms), and T4 (162-186 ms).

Figure 3 shows the distribution of sites showing significant MMN. It can be seen that the locus of the effect is predominantly right frontal.

Discussion

The threshold measured by MMN of around 4 ms is in agreement with the behavioural literature. Schneider et al. (1994) found that practiced young adults had thresholds in the

neighbourhood of 2 to 3 ms with these stimuli. Philips et al. (1998) found that gap thresholds with broadband markers with similar leading-marker durations to those of the present study were between 4 and 6 ms for inexperienced listeners. Thus the MMN appears to be a good tool for measuring gap detection thresholds.

The MMN in the current study had a right frontal locus. According to Näätänen (1992), the MMN has two underlying generators, one located bilaterally in auditory cortex and one located in the right frontal hemisphere. As the stimuli were presented in the sound field (i.e., binaurally), it appears that we are primarily measuring the effects of the latter generator.

Although our task was a passive listening one, we did not follow the usual practice of having adults read a book or engage in problem solving tasks in order to eliminate all attention to the auditory channel. Our data actually shows evidence of a P3a following the MMN, perhaps indicating inadvertent capture of attention. However, even under these conditions, we could measure a clear MMN, which suggests that this methodology may be a good one for measuring thresholds in nonlinguistic infants. A study is currently underway to determine gap thresholds in infants using MMN.

References

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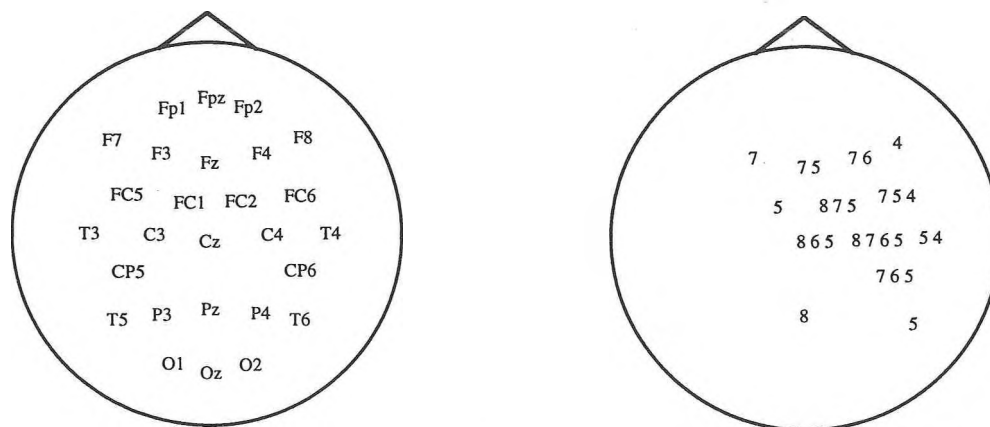


Figure 3. Left panel: The 27 recording sites. Right panel: Numbers represent where significant MMN was found for that gap size.