The auditory system is capable of following acoustic stimuli presented at very high repetition rates – rates that fall outside those normally studied by those interested in attentional processing. Yet an important aspect of the attentional system that of non-salient stimuli, which must be identified by the nervous system in order to allocate appropriate neural resources and behavioral responses to auditory inputs important to the organism's survival. We have recorded transient auditory evoked responses to non-salient, unchanging auditory stimuli delivered at rates of 20-90 Hz. We propose that such stimulus trains may enable us to examine auditory processing of responses to temporally rich data that represent a background barrage of noncritical auditory information.

This study investigated the response to tone pip stimuli delivered at a rate of 40 Hz under conditions in which both sensory load and attentional focus were experimentally manipulated. If these non-salient responses were pre-attentively blocked under conditions in which sensory processing was challenged, we anticipated that the recorded waveforms would be reduced in number or amplitude or both.

Methods. Twenty healthy human subjects (14 male, 6 female) with normal hearing were recruited for these studies. Subjects ranged in age from 20-33. All subjects participated in full knowledge of all procedures, having read and signed an informed consent agreement. All protocols were approved by our institutional IRB committee and subjects were reimbursed for participation. Subjects were fitted with gel-based surface electrodes applied using a commercially available 10-20 electrode array (recorded channels were C4-A1, C3-A2, F3-P4 and F4-P3). Electrode pairs were impedence matched to improve common mode rejection. During recording, subjects were seated comfortably in a sound insulated chamber. Auditory stimuli (2 kHz, 8 msec, Blackman-windowed tone-pips) were delivered binaurally at a 40 Hz repetition rate (run duration/trial was 7.5 min) from a centrally located loudspeaker placed about 1 meter in front of the subject. Sound intensity was about 70 dBSL. Under conditions in which additional auditory stimuli were introduced, they were delivered from an eccentrically located loudspeaker placed about 30 degrees off the midline (approximately 45 degrees horizontally and 24 degrees vertically). Visual stimuli were projected into the chamber and displayed directly in front of the subject. Seven experimental conditions were tested (see Table 1). All experimental trials included two runs of each stimulus condition. Data were collected from each of 4 independent channels (16-bit A/D accuracy, 48 kHz per channel), averaged and analyzed off-line using WAAD (Wrap-Around Average Deconvolution) and filtered 30-150 Hz. For display and analysis, each channel waveform was the average of two trials. For display and statistical analysis purposes, averaged waveforms were summed across channels to produce a quad vector. For each quad vector, peak amplitudes and latencies were measured using an automated IGOR analysis program developed in-house. These data were tabulated for each condition and analyzed using the Wilcoxian matched-pairs signed-rank test for statistical significance.

Paradigm	**Experimental condition**	**Attentional focus**
A	Control (auditory stimulus alone)	Control Stimulus
B	Control + visual display	Visual display
C	Control + music	Music
D	Control + visual and music	Music in visual display
E	Control + visual and music	Control stimulus

Results. Despite overlapping of recorded waveforms in the primary data, the WAAD technique enabled us to recover a transient middle latency responses that represent the neural response to each stimulus in the train (Figure 1). Figure 1 illustrates the response on a single channel (C3-A1) to paradigm A.

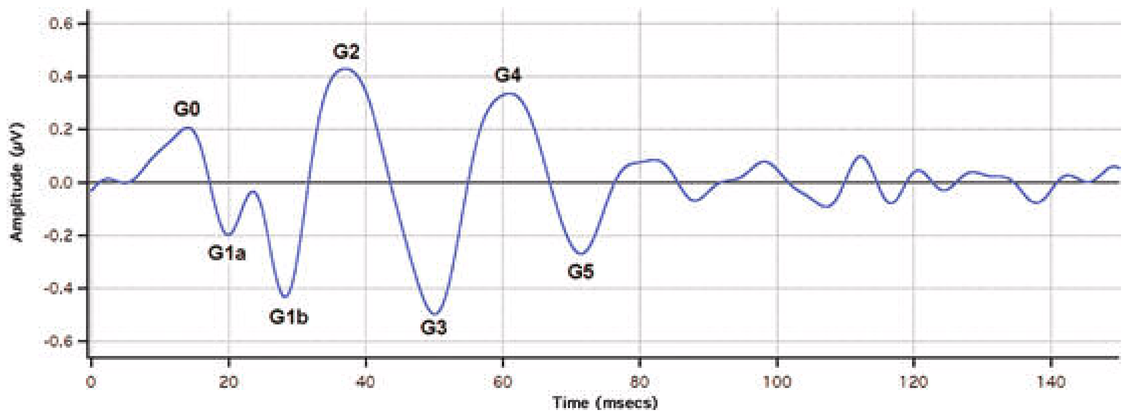

Figure 1. Representative response recorded from channel pair C3-A2. Note temporal sequence from G0-G5 of auditory evoked response.

Evoked G-wave responses were collected under four experimental paradigms (A-D) to determine the effect of both same and cross modal sensory load when subjects were asked to volitionally attend to either the control stimulus (A) or a sensory distractor (B & C). Subjects reported attentional focus as a percentage score. On average, subjects reported that they were able to maintain attention to the required stimulus (range 50-100%, 84 ± 2.05%). G-Waves evoked by the control stimulus were reduced in amplitude and latency when subjects attend to a visual display that changed in synchrony with the beat of a softly playing music CD (paradigm D, Figure 2). All G-waves were significantly reduced in amplitude under these conditions (G0 at $p<0.01$, all other at $p<0.005$, $N=20$) while later wave peaks exhibited a leftward shift in latency

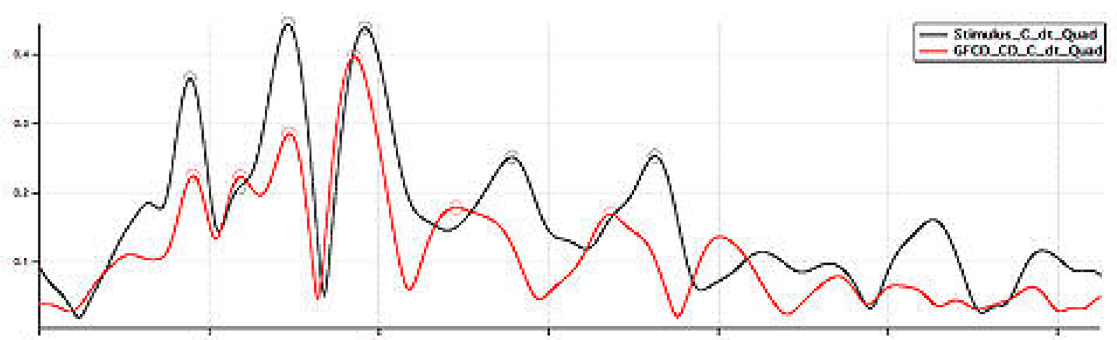

Figure 2. Representative response, processed as described in Methods, to experimental paradigm D. In this subject only waves G0-G4 are clearly present. Note the shifts in latency of the later waves (G3, G4) and the overall reduction in waveform amplitude.

(G2 and G3 at $p<0.005$). Interestingly, G0 actually showed a rightward shift in latency ($p<0.01$). Some subjects (4/20) dropped late G-waves (G5-G11) under paradigm D. However, the median number of G-waves recorded from our subject population was 6, and this was not changed with condition. When tested under paradigm B, subjects (N=9) exhibited no significant changes in G-wave waveform amplitude or latency. Paradigm C, which utilized a same modality distractor, produced significant changes only in the later G-waves (at p=0.05 level for G2 in amplitude and latency, at p=0.05 level for G3 in latency only, N=11). These data indicated that directed attention to a single stimulus, while slightly affected under conditions in which both stimuli were of the same modality, was insufficient to change the neural response to each auditory stimulus of the train. We further tested the effects of attentional focus alone using paradigms D and E (N=20). In this condition, no significant change in waveform amplitude, latency or number was seen.

Conclusion. Under conditions of increased sensory load, we verified our hypothesis that G-wave response amplitudes would be reduced. Furthermore, neural responses to non-salient, high rate auditory stimuli were unaffected by volitional attention, suggesting that they do belong to a pre-attentive processing stream. These data show that increasing the amount and type of sensory information to be processed, while affecting auditory processing, do not prevent the cortical processing of high-rate non-salient auditory information.