Neural processing of high-rate auditory stimulation under conditions of increased sensory load. L.J. Larson-Prior[1,2] and D.L. Jewett[2], [1]Touro Univ. COM, Vallejo, CA 94595, [2]Abratech Corp, Sausalito, CA

The neural attentional system is tasked with allocating limited processing capacity to incoming sensory stimuli. An open question concerns where in the processing stream selection of stimuli takes place. Auditory stimuli presented at high repetition rates result in middle latency responses (G-waves) that appear to be pre-attentive and sensitive to auditory, but not polymodal, sensory loads. Thus, G-waves represent a response that may provide information on where in the sensory processing stream attentional selection occurs.

Methods. With informed consent, twenty-three healthy human subjects (11 male, 12 female, 18-40) with normal hearing were fitted with tin-tin electrodes. Auditory stimuli were delivered from a centrally located speaker (70 dBSL), with distracter stimuli delivered from an eccentrically located speaker. Auditory evoked potentials were recorded from four bipolar channels (16-bit A/D accuracy, 48 kHz per channel), averaged, and G-waves recovered using Abratech's proprietary QSD method. Resultant data was filtered (30-150 Hz), averaged over two trials, and summed to produce a quad vector. For each quad vector, peak amplitudes and latencies were measured using an automated analysis program developed in-house. Statistical significance was assessed using the Wilcoxian matched-pairs signed-rank test.

To test G-wave responses to changes in load, we recorded subjects under conditions where the degree of load on the auditory system was varied as follows (see Figure 1):

1. Control: 2 kHz Blackman-windowed tone pip at 40/sec
2. CDFS: stimulus 1 + music CD with no filtering
3. CDBR: stimulus1 + music CD filtered to remove frequencies from 1-3 kHz
4. CDBP: stimulus 1 + music CD filtered to include only frequencies from 1-3 kHz
5. WNFS: stimulus 1 + full spectrum white noise
6. WNBR: stimulus 1 + white noise filtered to remove frequencies from 1-3 kHz
7. WNBP: stimulus 1 + white noise filtered to include only frequencies from 1-3 kHz

Subjects were asked to attend to the control stimulus in all conditions.

A Krohn-Hite analogue filter (set for 24 dB/octave roll-off) was set to match the primary frequency band of the delivered tone-pip stimuli. The presence of competing auditory stimuli, if sufficient to "overload" the attentional processing system, should reduce the amplitude of recorded G-waves. We hypothesized that introduction of the music CD distracter, regardless of the filtering, would produce a greater interference with the processing of high-repetition-rate auditory stimuli than would any white noise distracter.

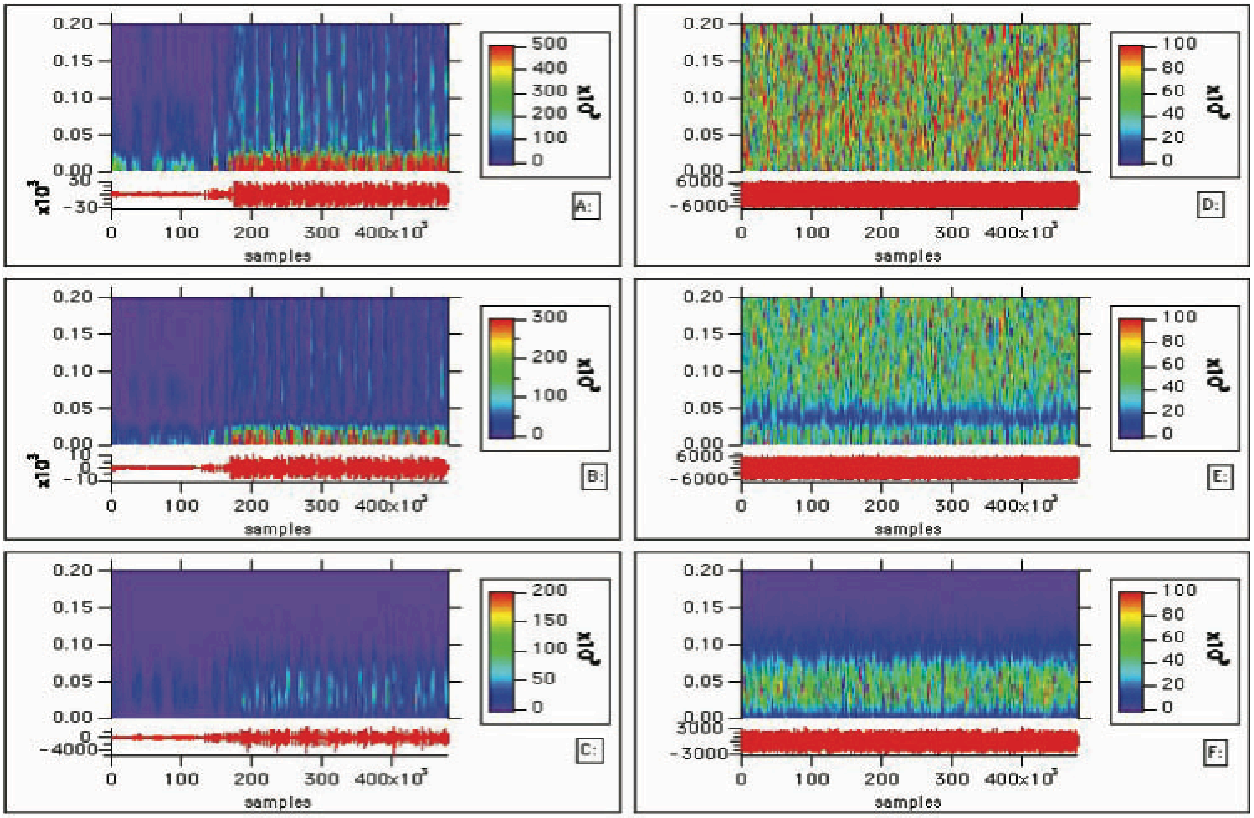
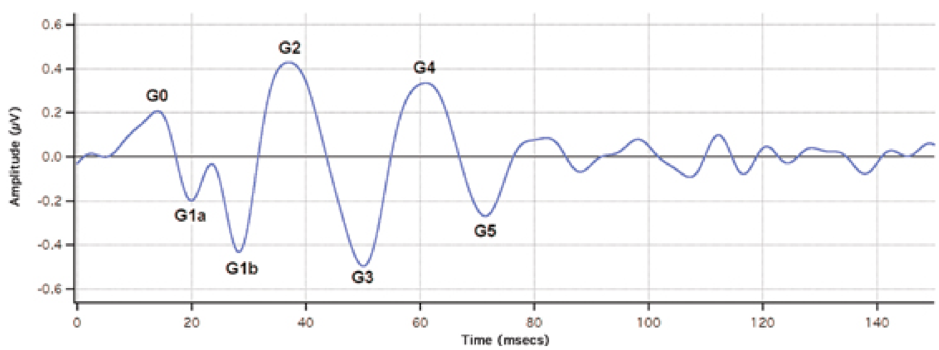


Figure 1 Sonorgram Data Showing A: Full Spectrum CD; B: Band Reject(1Kh-3Khz) CD
C: Band Pass(1Kh-3Khz) CD; D: Full Spectrum White Noise; E: Band Reject (1Kh-3Khz)White Noise
F: Band Pass(1Kh-3Khz) White Noise

Results. The typical response to a single auditory stimulus in a train played at 40/sec is presented in Figure 2. Data were analyzed to evaluate peak amplitude and latency to

Figure 2. G-waves recorded from a single channel, illustrating waveform shape and number.



peak of waves G0-G3. Our data show that G0 is a filtered representation of the ABR, giving us an indicator of early auditory responses. The latency-to-peak of each G-wave was consistent from subject to subject (G0; 18±0.34 msec [mean±SEM, *n* = 23] from stimulus presentation, G1A; 24±0.3 msec [*n* = 22], G1B; 31±0.29 msec [*n* = 22], G2; 40±0.31 msec [*n* = 23] G3; 53±0.55 msec [*n* = 23]).

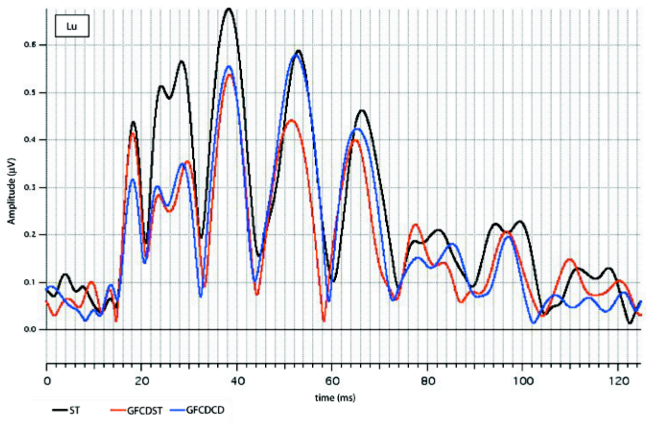


Figure 3. Reduction in G-wave amplitude in the presence of both an auditory (CD) and a visual (G-force) distracter stimulus. Control, attend to stimulus in presence of both distracters, attend to music in presence of both distracters.

In the presence of a second auditory stimulus (music CD), whether accompanied by a visual co-stimulus (G-Force) or not, G-wave amplitude was significantly reduced (p<0.01) and the latency-to-peak of waves G3 and G4 was reduced (p<0.0001; see Figure 3). Table I illustrates the results of experiments in which subjects were asked to attend to a rapid sequence (40/sec) of tone-pip stimuli in the presence of a softly playing music CD.

Table I	**Peak Amplitude Values (μV, mean ± SEM)**				
G-wave	G0	G1A	G1B	G2	G3
Control	0.21 ± 0.25	0.23 ± 0.03	0.3 ± 0.07	0.53 ± 0.07	0.42 ± 0.07
Auditory Distractor	0.17 ± 0.02‡	0.2 ± 0.03*	0.19 ± 0.03‡	0.45 ± 0.05†	0.31 ± 0.04‡
*p ≤ 0.5, †p ≤ 0.01, ‡p ≤ 0.001	n=11				

To further examine the effect of auditory distracter stimuli, we tested subjects using variously filtered music or white noise. Under these conditions, reductions in peak amplitude were noted earlier for white noise stimuli, regardless of the filtering, than for music CD distracters.

Table I	**Peak Amplitude Values (μV, mean ± SEM)**				
G-wave	G0	G1A	G1B	G2	G3
Control	0.33 ± 0.13	0.42 ± 0.3	0.43 ± 0.2	0.67 ± 0.3	0.62 ± 0.3
CDBP	0.35 ± 0.1	0.3 ± 0.3*	0.41 ± 0.2	0.57 ± 0.2*	0.57 ± 0.3
CDBR	0.35 ± 0.1	0.28 ± 0.11	0.46 ± 0.3	0.55 ± 0.2*	0.52 ± 0.3*
WNBP	0.31 ± 0.1	0.3 ± 0.3	0.37 ± 0.2	0.6 ± 0.3*	0.58 ± 0.3
WNBR	0.25 ± 0.1	0.32 ± 0.3	0.27 ± 0.2‡	0.55 ± 0.2‡	0.53 ± 0.3*
*p ≤ 0.05, †p ≤ 0.01, ‡p ≤ 0.001	n=11				

A general increase was noted in G0 to the music CD, but not to the white noise stimulus and the band-reject condition was more effective than full-band stimuli in reducing G-wave amplitudes. These data are presented in Table II and representative recordings are shown in Figures 4 and 5.

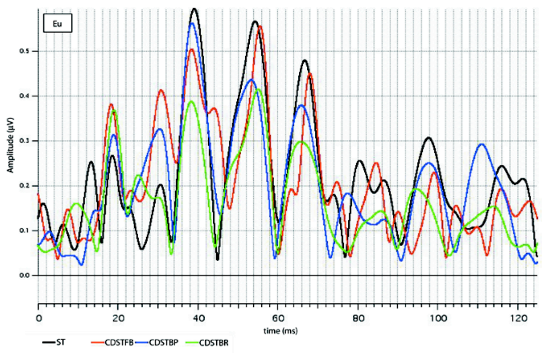


Figure 4. G-wave quad vector data for one typical subject under music CD auditory distracter conditions: **control**, **full band**, **band pass**, and **band reject**.

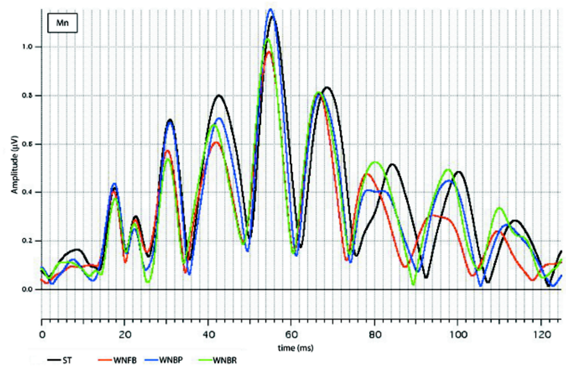


Figure 5. G-wave quad vector data for one typical subject under white noise distracter conditions: **control**, **full band**, **band pass**, and **band reject**. Note reduction in "jitter" in these responses compared with those to music CD.

Conclusions. The hypothesis that the music CD distracters would create a greater load on the auditory attentional system was not upheld. Interestingly, the data suggest that band reject stimuli, regardless of salience, are rejected earlier in the processing stream and that selection process are enacted at levels beyond brainstem auditory centers.