Comparison of Commercially Available Auditory Brainstem Response Stimuli at Threshold Intensity Levels

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Background

The auditory brainstem response (ABR) is an objective measure of hearing sensitivity used for young or difficult-to-test populations. To estimate hearing sensitivity, the broadband click stimulus has been traditionally used in clinical populations. It is assumed to elicit a highly-synchronized neural response but this assumption is challenged by the natural characteristics of the travelling wave, which stimulates high-frequency regions along basilar membrane before low-frequency areas. To overcome this, the broadband chirp stimulus is theorized to evoke a more synchronized response of auditory nerve fibers due to frequency composition of the stimulus. Greater synchronized recruitment of auditory nerve fibers is likely to result in better waveform morphology, including a more robust wave V amplitude near "true" behavioral threshold. Thus, the chirp stimulus holds promise as an alternative to the standard click for use in better estimating overall hearing sensitivity in clinically relevant populations.

Objective: Assess ABRs in young, normal-hearing listeners to determine the stimulus (click or chirp) that evokes repeatable and reliable ABR threshold estimation that are most comparable to behavioral thresholds.

Prediction: We predict that the chirp will result in more reliable and robust ABR waveforms near threshold when compared to the click stimulus.

Methods

38 young adults (18-30 years, M=24.2) with normal hearing (≤20 dB HL, 0.25 – 8 kHz; present DPOAEs 0.5 – 8kHz) completed ABR testing at the Northwestern University Center for Audiology, Speech, Language, and Learning. Testing for both behavioral and objective measures was completed in the right ear only using ER-3A insert earphones.

Stimulus	Broadband Click	Broadband iChirp
Duration	100 µs	3.5 ms
Epoch	12 ms	20 ms
Level	70 dB nHL to threshold	
Polarity	Rarefaction	
Sweeps	1024 (2048 at threshold)	
Rate	19.3/s	
Filter	100-3000 Hz	
Amplification	100,000X	
Montage	Active (Fz), Reference (A2), Ground (A1)	

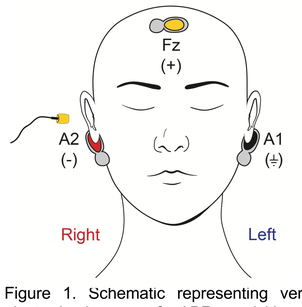

Figure 1. Schematic representing vertical electrode placement for ABR acquisition.

Summary / Discussion

Although the click ABR is still used routinely in clinical settings to estimate overall hearing sensitivity, evidence from our study suggests:

- ***Both click and iChirp underestimated true behavioral sensitivity, although iChirp mean threshold was closer to mean overall PTA.***
- ***The iChirp stimulus produced repeatable waveforms with robust wave V amplitudes near threshold compared to click. Thus, iChirp can aid in ease of waveform interpretation and threshold estimation.***
- ***The iChirp stimulus may be a better alternative to click as part of a clinical ABR test battery to estimate overall hearing sensitivity.***

Characteristics of Click and iChirp ABRs

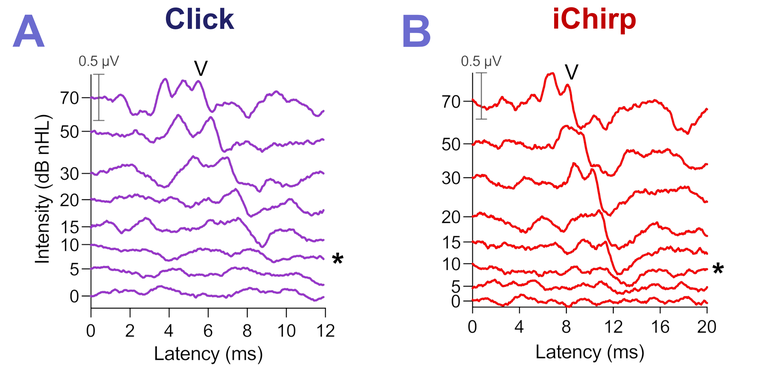

Figure 2. **A.** Representative click-evoked ABR traces for one participant. **B.** iChirp-evoked averaged ABR traces for the same participant. Threshold was estimated at 10 dB nHL for both stimuli (noted above by *).

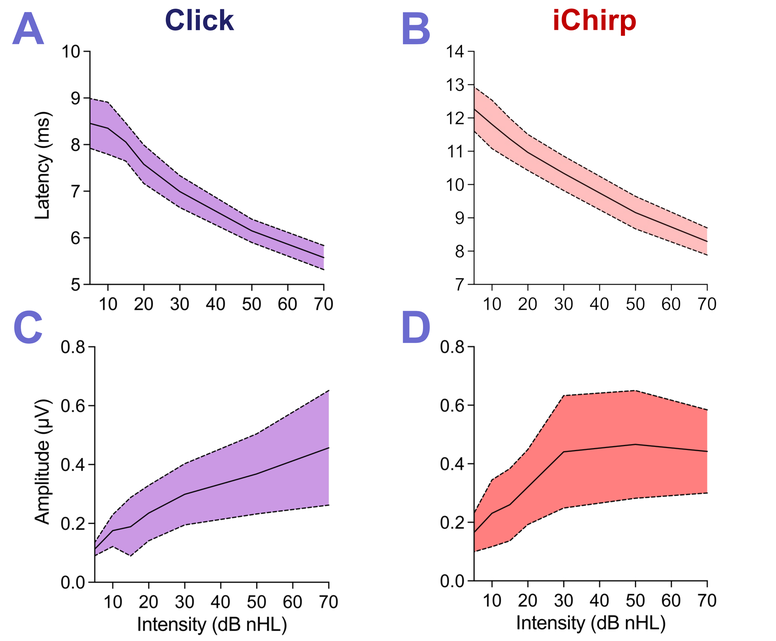

Figure 3. Latency-intensity functions plotted for **A.** click and **B.** iChirp. Amplitude-intensity functions plotted for **C.** click and **D.** iChirp. The solid line indicates mean, and shaded regions represent ± 1 standard deviation.

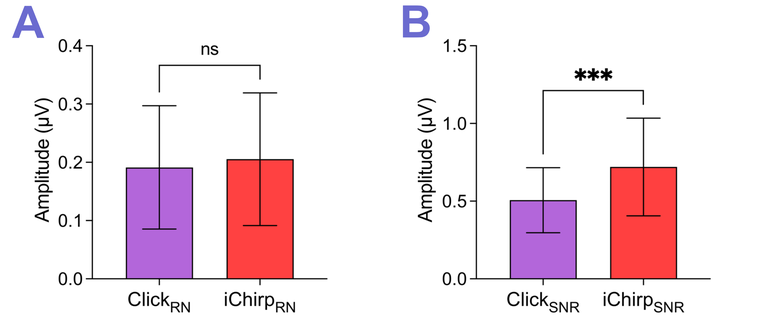

Figure 4. **A.** Average residual noise (RN) and **B.** signal-to-noise ratio (SNR), at threshold. Error bars represent one standard deviation. No significant difference was found for RN between stimuli. A significant difference was found between stimuli for SNR, iChirp SNR greater than click (SNR; paired $t(37)=3.6$, $p=0.0009$).

Comparative Analysis

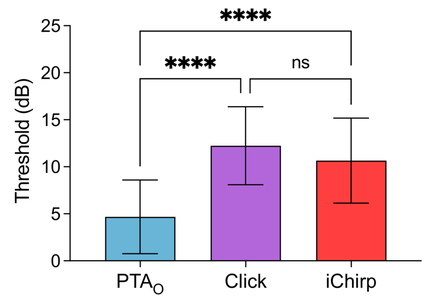

Figure 5. There was a significant effect of overall PTA (PTA_O, 0.25 – 8kHz) on ABR threshold for both stimuli at $p<.05$ level, indicating that ABR thresholds underestimated behavioral thresholds ($F(2, 37)=47.29$, $p=<0.0001$). Post hoc comparisons using Tukey HSD test showed the mean score for PTA_O (M=4.67, SD=3.92) was significantly different from ABR thresholds (click; M=12.24, SD=4.14) (iChirp; M=10.66, SD=4.53).

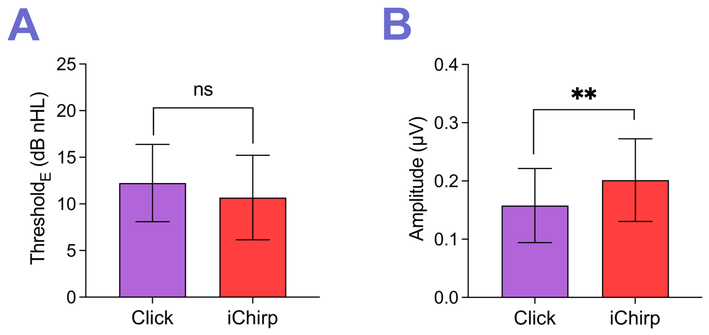

Figure 6. **A.** Average estimated ABR threshold ($Threshold_E$) for both stimuli. **B**. Average peak-to-trough amplitude for both stimuli at threshold. Error bars represent one standard deviation. No significant difference was found comparing ABR thresholds for click and iChirp**,** although mean click threshold (M=12.24, SD=4.14) was higher than iChirp threshold (M=10.66, SD=4.53). iChirp amplitude at threshold (M=0.2, SD=0.07) was significantly more robust than click amplitude at threshold (M=0.16, SD=0.01) (paired $t(37)=3.14$, $p=0.003$).

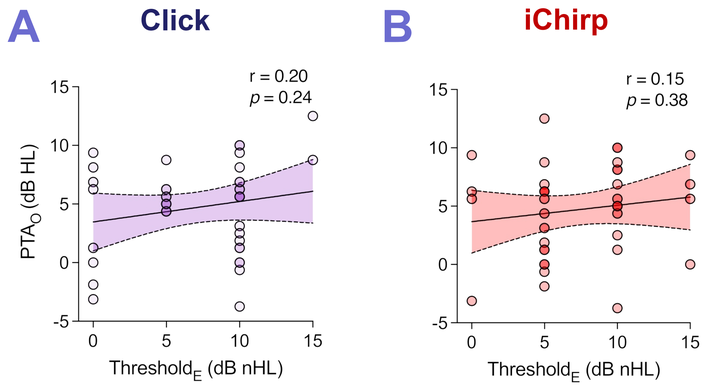

Figure 7. **A.** Relationship of overall PTA (PTA_O, 0.25 – 8kHz) with estimated ABR threshold ($Threshold_E$), for click and **B.** relationship of overall PTA_O with $Threshold_E$ for iChirp. This indicates that both stimuli evoke a response that is not strongly associated with PTA_O in young, normal-hearing listeners.

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