Neurodiagnostic ABR methods: Merging theory with clinical application

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INTRODUCTION

While the auditory brainstem response (ABR) is an established clinical tool, there are many aspects of ABR acquisition that one must consider for optimal recordings, such as the placement of electrodes and stimulus parameters. Theoretical assertions about the ABR along with animal and human studies have guided clinical practices. Here we aim to revisit theoretical assertions regarding electrode montage, click rate, and click polarity and provide data to support optimal recording parameters for clinical use.

METHODS

Participants

The following analysis includes 77 adults (6 males) between 21-34 years with normal hearing (≤25 dB HL 0.25-8kHz) in their test ear. Only 54 subjects (4 males) were included in analysis for click rate due to missing data.

Auditory Brainstem Response (ABR) Recordings

ABRs were recorded to a 100-µs broadband click at 80-85 dB nHL. Three separate recording sessions varied in either electrode montage, click rate, or stimulus polarity. Two repeatable traces (1024 sweeps each) were recorded per condition and averaged for analysis. Responses were collected and marked on the Intelligent Hearing Systems Duet SmartEP platform. All marked components were checked for accuracy by a certified and licensed audiologist.

Data Analysis

ABR waves I, III and V amplitudes and latencies were compared across recording conditions. ABR amplitude and latency differences between montages and polarities were compared using Wilcoxon matched pairs signed-ranks test, and across click rates using a Friedman analysis. All statistics were performed using GraphPad by Prism version 8.0.2.

CONCLUSION

From our review of theory and subsequent findings, we recommend recording neurodiagnostic ABRs in a vertical montage to a rarefaction click at 19.3/s for efficient acquisition of robust waveforms. Future directions should aim to determine if these trends persist in clinical populations.

WAVEFORMS

AMPLITUDE

LATENCY

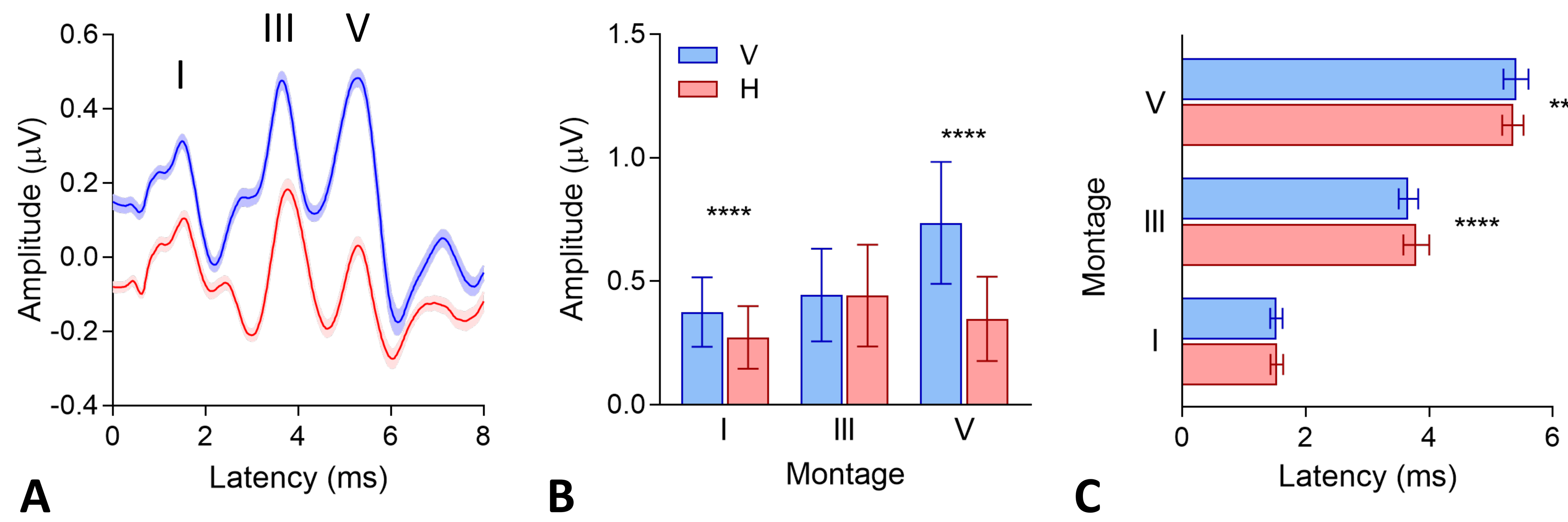

Figure 1. A) Grand average waveforms of a subset of participants (n = 36). Shaded region = SEM. **B)** Mean and standard deviations of peak-to-trough wave amplitudes. **C)** Mean and standard deviations of wave latencies. For all panels, Blue = vertical montage (A2-/Fz+); Red = horizontal montage (A2-/A1+).

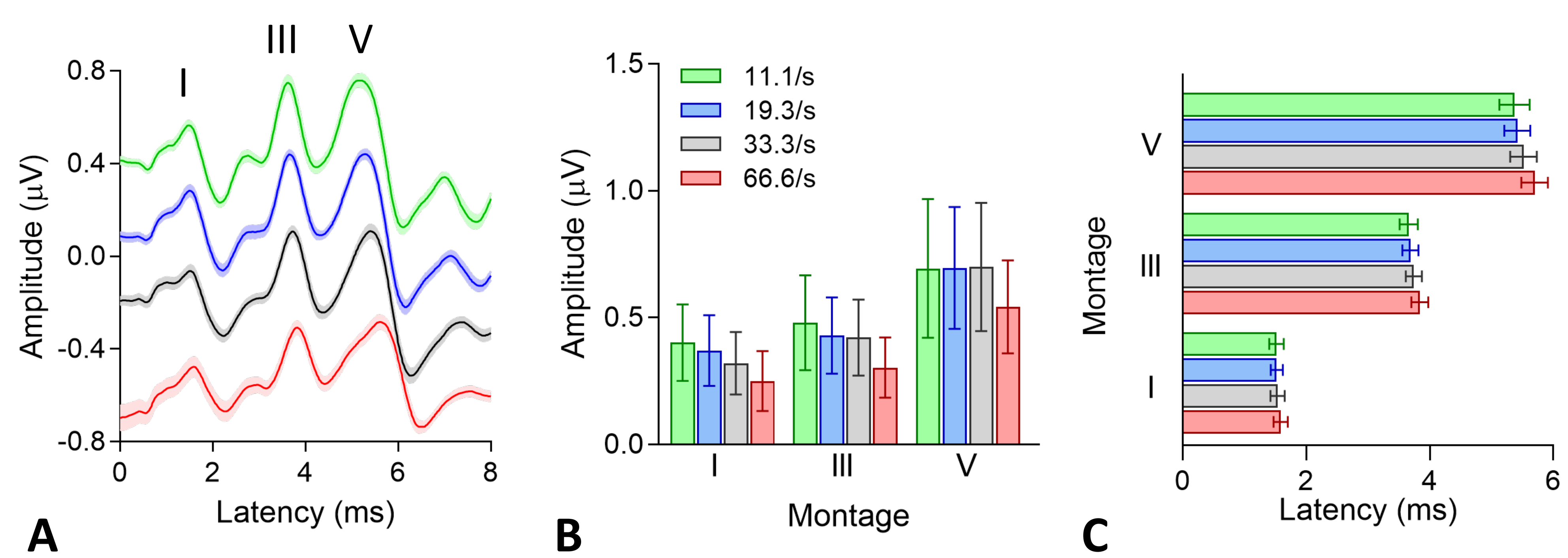

Figure 2. A) Grand average waveforms of a subset of participants (n = 36). Shaded region = SEM. **B)** Mean and standard deviations of peak-to-trough wave amplitudes. **C)** Mean and standard deviations of wave latencies. Green = 11.1/s; Blue = 19.3/s; Black = 33.3/s, Red = 66.6/s.

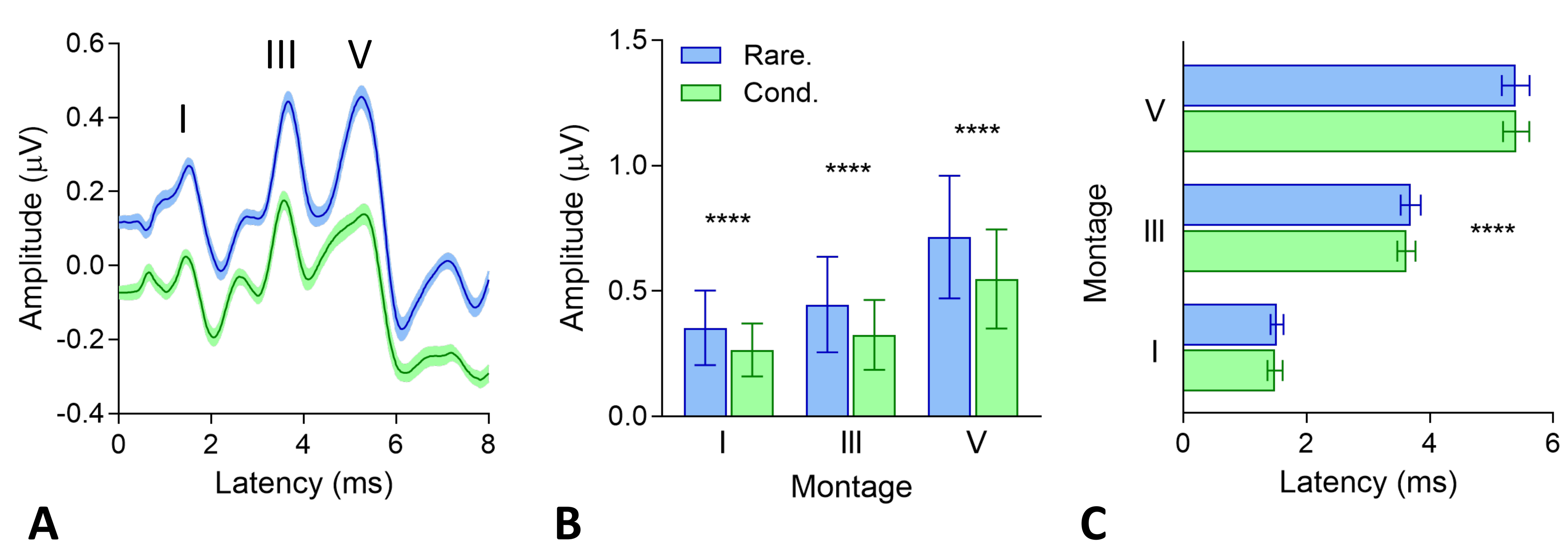

Figure 3. A) Grand average waveforms of a subset of participants (n = 36). Shaded region = SEM. **B)** Mean and standard deviations of peak-to-trough wave amplitudes. **C)** Mean and standard deviations of wave latencies. Blue = rarefaction; Green = condensation.

MONTAGE

We found significantly larger amplitudes for waves I and V in the vertical electrode montage recordings compared to the horizontal montage recordings (I and V: $p < 0.0001$). On average, wave I amplitude was 28.9% larger and wave V amplitude was 52.7% larger using the vertical electrode montage compared to the horizontal montage. The vertical montage produced significant latency differences for waves III and V (III: $p < 0.0001$, V: $p = 0.0017$). Albeit statistically significant, wave V latency was only 0.9% slower (an average difference of 0.05 ms) using the vertical electrode montage compared to the horizontal electrode montage.

CLICK RATE

No amplitude or latency differences were found between 11.1/s and 19.3/s (Amplitude – waves I, III, and V: $p > 0.9999$; Latency – waves I and V: $p > 0.9999$, wave III: $p = 0.2213$). 33.3/s produced a significantly smaller wave I amplitude than 11.1/s and 19.3/s ($p = 0.0003$; $p = 0.0081$) and significantly later latencies than 11.1/s (III and V: $p < 0.0001$) and 19.3/s (III: $p = 0.0071$, V: $p = 0.0021$). Smaller amplitudes and later latencies 66.6/s produced significantly smaller amplitudes than 11.1/s (I, III, and V: $p < 0.0001$), 19.3/s (I, III, and V: $p < 0.0001$), and 33.3/s (III and V: $p < 0.0001$). Lastly, 66.6/s produced significantly later latencies than 11.1/s (I, III, and V: $p < 0.0001$), 19.3/s (I: $p = 0.0001$, III and V: $p<0.0001$) and 33.3/s (I: $p= 0.0135$, III: $p = 0.0002$, V: $p < 0.0001$).

STIMULUS POLARITY

Latency differences between click polarities were only significantly different for wave III, where rarefaction produced a later latency (I: $p = 0.058$, III: $p < 0.0001$, V: $p = 0.86$). Albeit statistically significant, the average wave III latency was only 1.9% faster (an average difference of 0.07 ms) using the condensation polarity compared to the rarefaction polarity. Additionally, we found the rarefaction polarity produced significantly larger wave amplitudes compared to the condensation responses for all three waveforms analyzed (I, III and V all $p<0.0001$). The average percent increase in amplitude across all waveforms was ~34%, increasing by an average of 0.12 µV.