Ear-EEG as a novel technology for wearable brain wave monitoring

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Electroencephalography (EEG) enables assessment of the neural activity in the brain, which has been used in neuroscience research and clinical applications for decades. However, usability of the technology is still limited by relatively expensive and non-portable devices. Here we present a future technology with wearable and unobtrusive EEG devices.

Background

Electroencephalography (EEG) has traditionally been used in neuroscience research and clinical applications. Current technologies are characterized by recording systems with high sampling rate and multiple sensors over the scalp, to obtain excellent temporal and spatial resolution.

Although such technologies are valuable, the limitations are price, non-portable devices, and highly visible EEG caps. Hence, current technologies are not appropriate for everyday use to record the continuous brain activity for diagnosis, monitoring intervention or brain-computer-interfaces.

Therefore, cheaper, portable and unobtrusive EEG devices are warranted. Previous studies have shown, that the potentials recordable at the scalp, are also conducted to the ear canal by volume conduction [1]. Hence, sensors in the ear canal may provide a solution that would fulfill the requirements by recording the so called »Ear-EEG«.

Aims of the present study

- Develop Ear-EEG devices to record potentials comparable to scalp EEG potentials.
- Investigate which reference configuration of Ear-EEG is most sensitive to record the neural response to discrete auditory stimuli in a concurrent dichotic oddball paradigm.
- Investigate the sensitivity of Ear-EEG to capture the neural response in a concurrent diotic audiobook paradigm.

Methods

Participants

- Eight normal hearing subjects (4 males, mean age 34.6, range 23 to 49 years) with individual fittet Ear-EEG devices were enrolled in the study.
- All subjects participated in a dichotic oddball paradigm with discrete stimuli (Figure 1A).
- Five of the participants were native danish speakers, and participated in a continuous diotic audiobook paradigm with selective attention to one of the stories (Figure 1B).

Test paradigm and EEG recording

- The dichotic oddball paradigm consisted of two streams with differences in presentation rates and pitch. On average, 15% of the tones were oddballs. Participants were asked to either attend to the stream in the right or left ear and press a button when they heard an oddball in the attended stream.
- The diotic audiobook paradigm consisted of two stories read by a male and female speaker. Participants were instructed to attend either to the female or male voice, in alternating order. A total of 60 minutes of EEG data were recorded.
- EEG was recorded using BioSemi Active Two amplifier (BioSemi, Amsterdam, Netherlands), with 64 scalp electrodes and 3 Ear-EEG electrodes in each ear (Figure 2).

Figure 1. Listening paradigms for dichotic oddballs (A) and diotic audiobooks (B). Modified version of the broad-band temporal envelope (C), and syllable onset (D).

Figure 2. Development of Ear-EEG devices from individual ear impressions (top) to various devices with different numbers of electrodes and electrode positions.

Results

- Correlation between average Ear-EEG potentials from each ear canal and all 64 scalp potentials.

Figure 3. Comparison between average Ear-EEG potentials and scalp EEG potentials.

Comparison between Ear-EEG and conventional scalp EEG

- Ear-EEG are highly correlated to ear-near potentials.

Figure 4. Event related potentials recorded from scalp EEG re-referenced to Ear-EEG channels. Remote channels (A) reveal typical components of auditory evoked potentials, which can also be found at adjacent channels (B). Similar courses can be derived by cross-correlation of the modified broad-band temporal envelope and the EEG response (C), which is also applicable to continuous stimuli like speech (D). Horizontal bars below the EEG traces indicate intervals significantly differing from zero across participants.

Assessment of Ear-EEG potentials

- Event related potentials observed at scalp channels, can also be observed in a pure Ear-EEG configuration.
- Ear-adjacent scalp EEG channels might capture the potential differences originating from rather (fronto-) central sources.
- Qualitatively similar findings were observed by cross-correlation between audio features and EEG responses for both dichotic oddballs and diotic audiobook presentation.

Discussion

- Feasibility to record relevant neural responses from Ear-EEG has been demonstrated.
- The position of the reference electrode plays a role in recording the most discriminative potentials for both dichotic oddballs and diotic audiobooks.
- Ear-EEG is sensitive to capture neural responses in a concurrent diotic audiobook paradigm.

Conclusion

Ear-EEG is able to capture brain activity comparable to potentials recorded by conventional scalp EEG. Furthermore, the results obtained in this pilot study, serve as a fruitful first indicator of the feasibility to use Ear-EEG in future BCI systems for hearing aids [2].

REFERENCES
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