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Waxy business: the impact of ear cerumen on in-ear electrophysiological recordings

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Physiologically steered hearing aid devices rely on the principle of utilizing bio-electrical signals, recorded from a contact point close or inside the ear, aiming to extract relevant information that can be used to manipulate settings or parameters of the hearing device. For this reason, it is important to know to what extent the environmental conditions, to which the recording electrodes will be exposed, can impact the quality of the bio-electrical signals of interest.

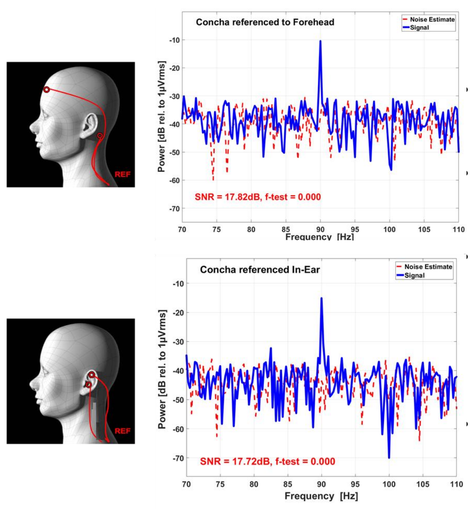

Figure 1. (top) exemplary ASSR response acquired from and in-ear electrode referenced to the forehead; (bottom) exemplary ASSR response acquired from an in-ear electrode referenced to another in-ear electrode in the same ear.

Background & Hypothesis

Auditory Steady State Responses (**ASSR**) can be **measured by placing recording electrodes inside the ear cavity** [1-3]

Extensive ear preparation of lab-based in-ear recordings **is incompatible with realistic** long-term **recordings**.

The use of **dry-contact electrodes is a potential platform towards real life applications** of electrophysiologically steered devices [5], but little is known about **the impact of an uncleaned or unprepared ear on the quality of in-ear recordings**

We hypothesised that presence and production of cerumen inside the ear would have a negative impact in the quality of ASSRs recorded from the ear.

Methods

Four **Auditory Steady State Responses** and two **Resting State Noise-floors** from 8 participants were recorded with **dry-contact electrodes** [5]. Recordings were done both, before and after cleaning and preparing the ears, with a **replicate 3 weeks later** to allow for cerumen recovery. The amount of cerumen present in the ear was evaluated visually with an otoscopic camera before both recording sessions and rated by 3 clinical experts.

Figure 2. Graphical overview of the study design.

Figure 3. Single examples of otoscopic inspections of ear cavities with varying degrees of cerumen from none to high (left to right).

Procedures

ASSR
- **Duration**: 5 minutes
- **Stimulus**: Diotic White Noise
- **Modulation Freq**: 40Hz
- **Reference**: Forehead
- **In-Ear electrode**: 1 in concha; 1 in canal

Resting State
- **Duration**: 5 minutes
- **Stimulus**: Silence
- **Reference**: Forehead
- **In-Ear electrode**: 1 in concha; 1 in canal

Otoscopic Inspection
Visually via an OTOcam. Photos of the ear cavity recorded for ranking.

Ear Cleaning
1. Cotton swab wax removal
2. NuPrep abrasive cleaning
3. Alcochol swab cleaning
4. Cotton Swab water rinse
5. Drying

Data Analysis
- **3X4 repeated Measures ANOVA** to assess ASSR responses (forehead referenced and in-ear re-referenced)
- **3X4 repeated measures ANOVA** to assess resting state noise floor (forehead referenced and in-ear re-referenced)
- **Spearman's rank correlation** to assess the amount of cerumen vs ASSR amplitude

Information

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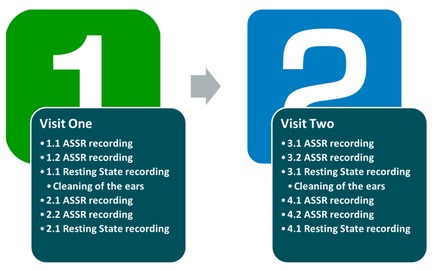
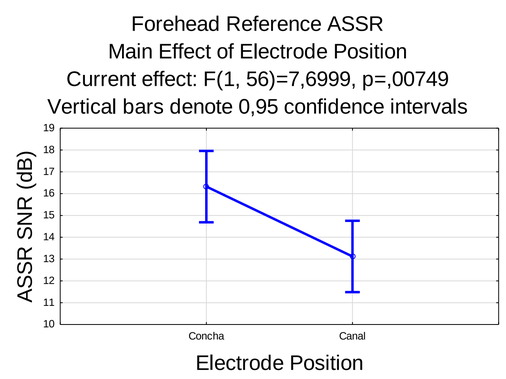
Results

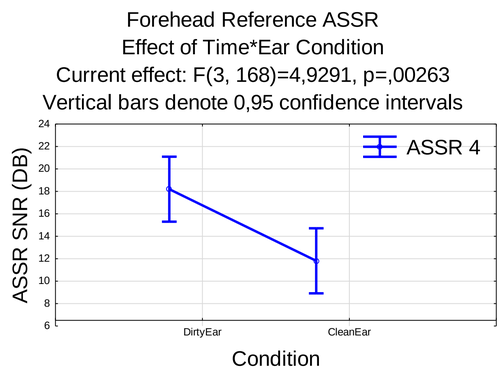
Test re-test reliability

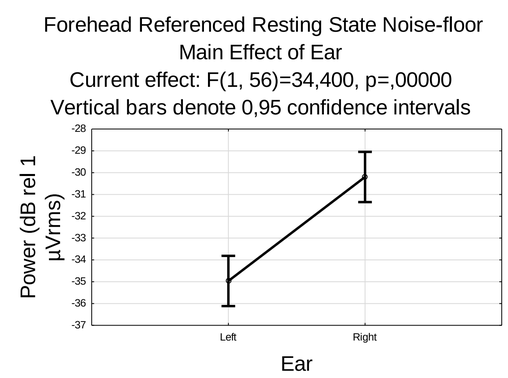
Test-Retest comparisons	Intra-class correlation coefficient
1.1 *vs* 1.2	0.894
2.1 *vs* 2.2	0.898
3.1 *vs* 3.2	0.958
4.1 *vs* 4.2	0.756

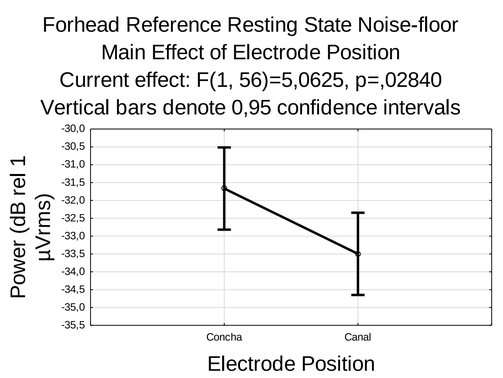


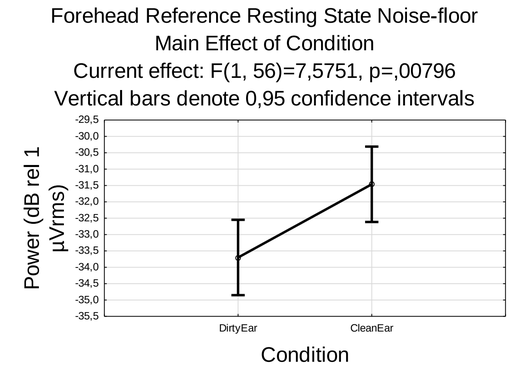
Repeated Measures ANOVAs

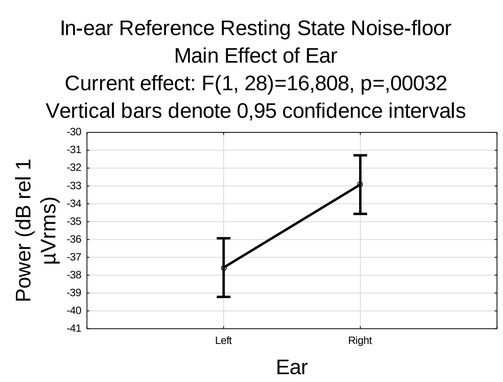












Spearman's Rank Correlations

Spearman's rank-order correlation p-values			
Measurement	**Electrode**	**Left Ear**	**Right Ear**
ASSR	Concha	$p = 0.094$	$p = 0.115$
ASSR	Canal	$p = 0.486$	$p = 0.447$
Resting state	Concha	$p = 0.270$	$p = 0.585$
Resting state	Canal	$p = 0.229$	$p = 0.052$

Discussions & Conclusions

We hypothesised that presence and production of cerumen inside the ear would have a negative impact in the quality of ASSRs recorded from the ear.

Repeated measures ANOVAs on forehead reference ASSRs showed the opposite effect, i.e. Cleaning the ears had a detrimental impact on the ASSR SNR. This effect was present only after the 3 week build up period.

ASSR responses were significantly larger when measured from an electrode placed in the concha than in the ear canal.

Presence of cerumen in the ear had a positive impact, lowering the power of the resting state noise-floor, which increases the probability of capturing smaller ASSR responses.

No significant correlation was found with respect of the amount of earwax present before the recordings and the ASSR SNR nor the noise-floor level.

With this small cohort of participants, there is no evidence to support the need for ear preparation before in-ear electrophysiological recordings with dry-contact electrodes in the ear.

This is a positive finding towards the realization of physiologically steered hearing devices.

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