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Longitudinal Assessment of Spectral Ripple Discrimination and Speech Perception:
Evolution in Cochlear Implant Users

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Introduction

Motivation
- **Spectral Ripple Discrimination** (SRD) correlates with speech perception outcomes in cochlear implant (CI) users [1-3].
- Limited knowledge of SRD evolution after implant switch on [3].
- Non-linguistic tests have been proposed as potential tools for evaluation of CI performance [2].

Research objectives
- To evaluate **longitudinally** the **evolution** of spectral ripple discrimination and speech perception in quiet and noise for CI users.
- To assess the **clinical applicability** of non-linguistic tests as predictors of speech perception outcomes in CI users.

Experimental measures
- **Speech Perception test**: AzBio sentence tests.
- **Psychoacoustic test**: Spectral Ripple Discrimination thresholds.

Methods

Participants

Subject	Gender	Age at Implantation	Aetiology	HL Type	Implant Manufacturer	Speech Processor Model	Speech Processing Strategy
1	Female	73yr, 8mo	Congenital	Progressive	Advance Bionics	Naida	HiRes Optima-S
2	Female	57yr, 9mo	Congenital	Progressive	Cochlear Ltd.	CP910	MP3000
3	Female	22yr, 2mo	Congenital	Progressive	Advance Bionics	Neptune	HiRes Optima-S
4	Male	34yr, 3mo	Congenital	Progressive	Cochlear Ltd.	CP910	ACE
5	Females	53yr, 6mo	Congenital	Progressive	Cochlear Ltd.	CP910	MP3000
6	Male	79yr, 1mo	Acquired	Progressive	Advance Bionics	Neptune	HiRes Optima-S
7	Female	72yr, 5mo	Acquired	Sudden	Advance Bionics	Naida	HiRes Optima-S
8	Male	73yr, 5mo	Acquired	Progressive	Cochlear Ltd.	CP910	MP3000
9	Male	30yr, 3mo	Congenital	Progressive	Advance Bionics	Naida	HiRes Optima-S
Mean		55 yr , 5mo (+/- 21yr)					

Study Design
- Participants attended seven testing sessions during the 1st year of post-implantation (see Fig.1A).
- SRD thresholds were acquired via psychoacoustics (see Fig.1B).
- Speech perception outcomes were measures via AzBio sentence lists (see Fig.1D).
- Stimuli were delivered via the direct connect input to the speech processor at the level in which participants were most comfortable.
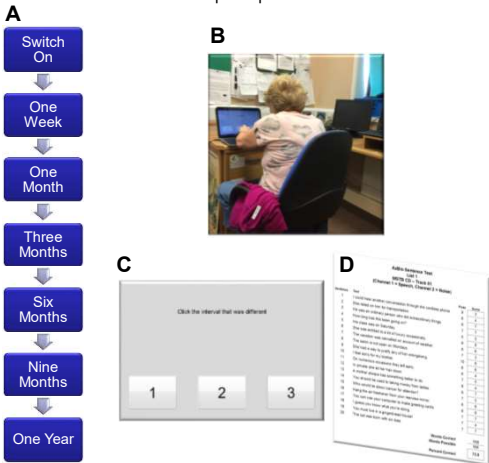

Fig.1: **A)** Timeline of data collection points; **B)** Participant performing psychoacoustic testing; **C)** Psychoacoustic test interface; **D)** AzBio sentence marking sheet.

Speech Perception test
- AzBio sentence lists with ten talker-babble noise.
- 3 SNR levels (Quiet, 10dB and 5dB) with respect to ten talker-babble noise.
- Percentage of correctly identified words was recorded as the speech perception score per SNR level (see Fig.1D)

SRD Stimuli and Procedure
- Spectrally rippled noise stimuli were created via a full-wave rectified sinusoidal spectral envelope on a log amplitude scale (see Fig.2). Stimuli had a bandwidth of 100–8,000 Hz and a peak to-valley ratio of 30 dB.
- A two-up/one-down three-alternative forced-choice task was implemented where the participant had to choose a standard sound out of the inverted sounds (see Fig.1C).
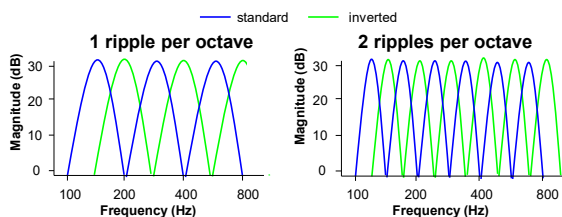

Fig.2: Examples of spectral ripple envelopes at 1 and 2 ripples per octave

Results

Speech Perception results
(Fig. 3)
- Two-way repeated measures ANOVA revealed a significant effect of time ($F_{(2.14,17.1)}$=7.5, $p<0.01$) and SNR ($F_{(1.1,8.5)}$=14.84, $p<0.01$), as well as a significant interaction of time and SNR ($F_{(2.54,20.28)}$=8.37, $p<0.01$).
- Planned comparisons at Switch On, Six Months and One Year, showed significant differences in all SNR levels ($p<0.05$). Significant differences in time were only observed with respect of Switch On ($p<0.05$).
- The interaction plot clearly depicts the different evolution profiles of speech perception at the different SNR levels over time.
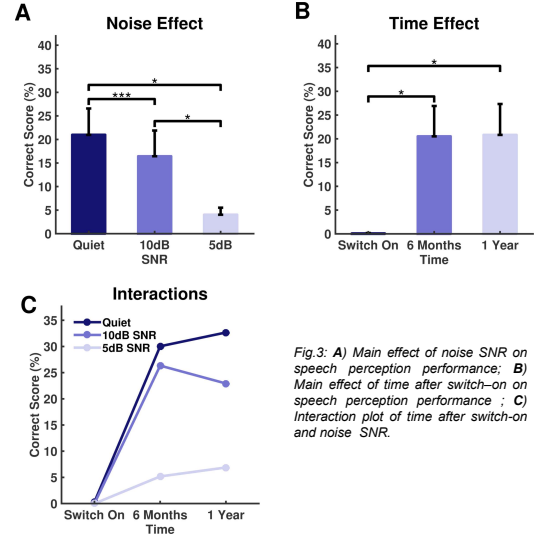

Fig.3: **A)** Main effect of noise SNR on speech perception performance; **B)** Main effect of time after switch–on on speech perception performance ; **C)** Interaction plot of time after switch-on and noise SNR.
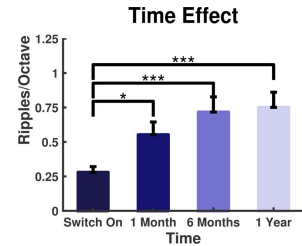

Fig.4: Main effect of time after switch-on on SRD

Spectral Ripple Discrimination results
(Fig.4)
- One-way ANOVA revealed significant changes in spectral ripple discrimination abilities over time ($F_{(6,48)}$=7.66, $p<0.005$).
- Pairwise comparison of SRD thresholds at different time points showed a significant difference between Switch On and every time point from One Month onwards.
- Planned comparisons at Switch On, One Month, Six Months and One Year, showed a significant increase in SRD from Switch On onwards. Although, there is an increase in SRD from One Month onwards. This increase did not reach statistical significance.

Correlation results
(Fig.5)
- SRD thresholds at Switch On correlate reasonably well with speech perception at Six Months at all three SNR levels (Quiet r²=0.6, $p<0.05$; 10dB r²=0.47, $p<0.05$; 5dB r²=0.41, $p=0.065$).
- SRD thresholds at One Month correlate reasonably well with speech perception at Six Months in Quiet r²=0.45, $p<0.05$, though a trending correlation exists at 10dB and 5dB.
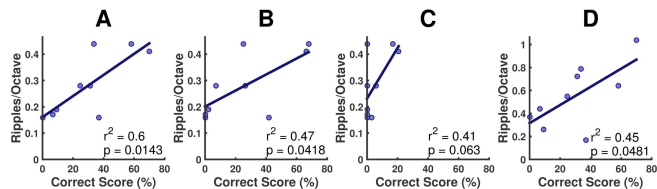

Fig.5:**A)** Correlation between SRD at switch-on and AzBio scores in quiet at 6 months; **B)** Correlation between SRD at switch-on and AzBio scores in noise 10dB SNR at 6 months ; **C)** Correlation between SRD at switch-on and AzBio scores in noise 5dB SNR at 6 months ; **D)** Correlation between SRD at 6 months and AzBio scores in quiet at 6 months.

Discussion

Speech Perception Evolution
- Speech perception evolution after switch one, stabilizes after six months. However, the significant interaction found with the SNR levels indicates that speech perception evolves differently depending on the testing condition.
- **Speech Perception in noise develops at a slower rate than speech perception in quiet, and the same is true for different levels of Noise SNR.**
- Speech perception may continue to improve in CI users beyond the one year follow-up in this study.

Spectral Ripple Discrimination Evolution
- SRD evolution stabilizes after one month of switch on.
- **SRD improvements can be observed earlier than speech perception improvements within one year after implant switch on.**

Correlation between Speech Perception and Spectral Ripple Discrimination
- SRD thresholds correlate reasonably well with speech perception outcomes as early as switch on date.
- SRD and speech correlate better in the quiet condition. This effect may be attributed to the fact that speech perception in noise develops at a slower rate.
- **Non-linguistic SRD may be used in clinic as an indicator of speech perception performance outcome in newly implanted CI users from switch on.**
- This opens the possibility to explore objective non-linguistic tools for evaluation of CI performance is younger populations, where psychoacoustics may be unreliable

References
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