

Impact of Prior Exposure to Acoustic Environment on Speech Intelligibility and Listening Effort in Vcoded Speech

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Background: Cochlear implants (CIs) are widely used to restore hearing in individuals with severe-to-profound hearing impairment. Despite these benefits, the detrimental effects of reverberation on speech perception are more pronounced for CI users than for normal-hearing (NH) listeners [1]. One mechanism that mitigates these challenges is adaptation to the acoustic environment. Prior exposure to a reverberant environment has been shown to improve speech intelligibility in CI users [2]. However, it remains unclear how prior listening exposure jointly impacts both speech intelligibility and listening effort under CI-simulated processing condition. To address this gap under controlled conditions, the present study uses vocoded speech to simulate CI processing in NH listeners and investigates the impact of prior exposure to an acoustic environment on speech intelligibility and listening effort.

Experiment Design: To examine the impact of prior listening exposure to a specific acoustic environment, a blocked listening test design was implemented. In the blocked condition, the acoustic environment was fixed within each block of trials, providing listeners with repeated exposure to the same reverberant environment over consecutive sentences. The order of acoustic environments was counterbalanced across participants. Speech intelligibility was quantified using word-correct scores. Listening effort was assessed using pupillometry, as pupil responses are known to reflect cognitive processing load, enabling assessment of effort changes across successive sentences under repeated exposure [3,4].

Stimuli: The speech materials were three-word English sentences from the simplified University of Canterbury Auditory-Visual Matrix Sentence Test (UCAMST-P) [5]. Two speech types were tested: non-vocoded speech and vocoded speech, with vocoded stimuli generated using an eight-channel noise vocoder [6]. To incorporate room acoustics, both speech types were convolved with room impulse responses measured in real rooms. Four reproduced room acoustic conditions were tested, comprising a seminar room and a chapel at source–receiver distances of 2 m and 5 m, with longer distances yielding lower speech clarity (C50) [7]. In addition, an anechoic condition was included to provide a baseline measure without the effect of room acoustics. The resulting stimuli were rendered using a 31-channel spherical harmonics-based spatial sound reproduction system [8] that recreated the sound field at the listening position corresponding to the original rooms (Fig. 1). Participants were seated at the centre of the loudspeaker array. On each trial, a sentence was presented once, and participants selected the perceived words using a graphical user interface displayed on a monitor located in front of them, while pupil diameter was continuously recorded. Each condition was repeated 10 times per participant using different audio files, resulting in a total of 100 stimulus trials per participant. Seventeen native New Zealand English speakers with no self-reported hearing problems (9 female, 8 male; age range: 18–35 years) took part in the experiment.

Result: Speech intelligibility and pupil dilation showed different responses to prior listening exposure to acoustic environments (Fig. 2). For non-vocoded speech, the speech intelligibility results are near ceiling, so changes in intelligibility provide limited information about ongoing listening adaptation. However, pupil dilation differences for non vocoded speech can be observed within a block of repeated exposure when comparing sentence 1 and sentence 10, most notably in the chapel 5m condition. For vocoded speech, the results show that prior listening exposure to a blocked presentation of acoustic environment can improve speech intelligibility, particularly in environments with lower speech clarity (chapel 2m, seminar 5m and chapel 5m). However, corresponding changes in pupil dilation were less systematic.

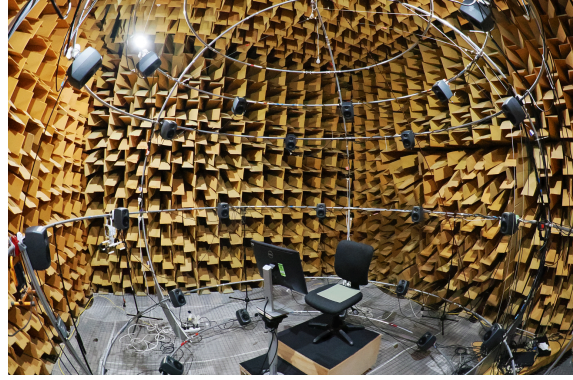


Fig. 1. Experiment setup of loudspeaker array in the anechoic chamber.

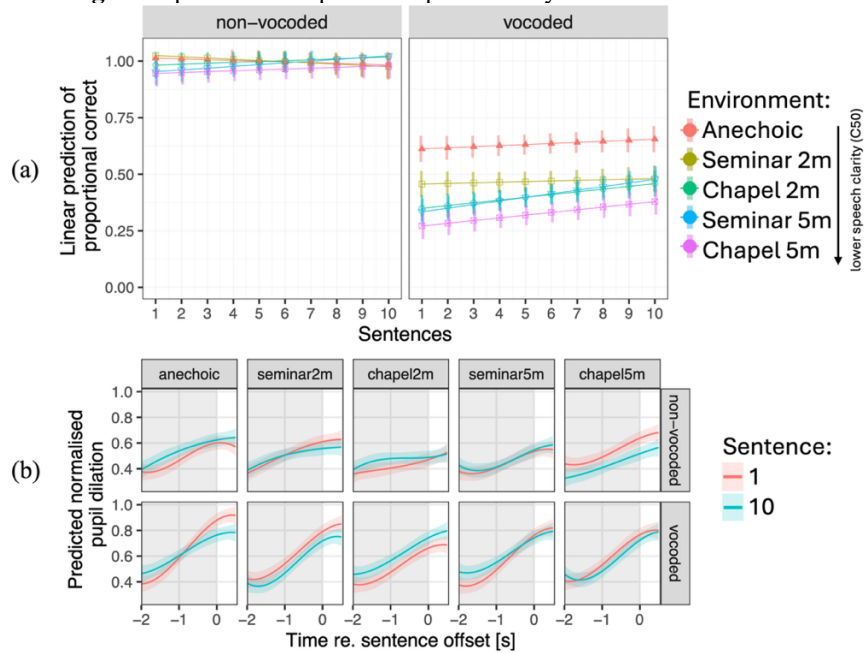


Fig. 2. Predicted speech intelligibility and pupil dilation as a function of prior listening exposure. (a) Top panels show predicted model of proportion correct across sentence position within a block for non-vocoded (left) and vocoded (right) speech across acoustic environments. (b) Bottom panels show predicted model of pupil dilation responses for sentence 1 and sentence 10 within each block across acoustic environments. Shaded regions indicate the stimulus presentation window.

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