"TURN AN EAR TO HEAR": THE BENEFIT OF HEAD ORIENTATION TO SPEECH INTELLIGIBILITY IN COMPLEX ACOUSTIC ENVIRONMENTS

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ABSTRACT

Spatial release from masking (SRM) is traditionally studied with listeners facing the target talker, because such attitude has long been assumed to be most natural or required, either for optimal lip-reading performance or to benefit from the directionality of prostheses microphones. In the laboratory, with a single interferer in the rear hemifield, we showed that a modest, 30^{O} head orientation away from directly facing the target benefited normal-hearing listeners and cochlear implant users by as much as 4.5 dB. The lip-reading benefit was unaffected by head orientation, both benefits being cumulative. With a sensitivity pattern rotated by 30-45^{O} by the acoustic head-shadow, head-orientation benefit (HOB) persisted with directional microphones.

To confirm the robustness of HOB in complex acoustic environments, an advanced simulation of a real restaurant was developed. Binaural room impulse responses measured with a head and torso simulator moved across the restaurant enabled simulation over headphones of a listener attending to a talker sat across one of six tables, either facing the talker or with a 30^{O} head turn either side. Multiple spatially distributed interferers were either continuous speech-shaped noise or speech. With normal-hearing (NH) listeners, mild-moderately hearing-impaired (HI) listeners or simulated cochlear implant (CI) users, 1-2 dB HOB was found at the best predicted 30^{O} head orientation, regardless of table position in the restaurant. This confirmed the robustness of HOB with the diffuse interference and reverberation typically found in social settings.

1. NH BASELINE

Kock [1] had found a large HOB from orienting the head away from a target talker, benefit also predicted by the Jelfs et al. model of SRM [2]. Grange & Culling [3] set out to acquire a NH audio-only baseline to confirm Kock's findings and establish whether NH listeners spontaneously made use of head-orientation to spatially release speech from masking. NH listeners showed as much as 8 dB HOB with a single speech-shaped noise interferer in the rear hemifield, in a sound-treated room, most of which could be obtained from a modest, 30^{O} head turn.

NH listeners were found to spontaneously make use of head orientation only 56% of the time in a challenging listening task with gradually diminishing signal-to-noise ratio. Listeners rarely reached the optimal head orientation and when repeating the experiment after being made aware of a potential HOB, although the amount of head turns increased, performance did not significantly. One could consider this outcome as an indication that NH listeners had not developed a head-orientation strategy simply because they rarely needed one.

2. COCHLEAR IMPLANT USERS

One would have thought that if HI listeners more critically needed HOB than NH listeners in noisy settings, they would have naturally developed a head-orientation strategy. CI users being the most challenged listeners in noise, Grange & Culling [4] set out to test CI users for HOB and head-orientation behavior. Knowing that CI users are most reliant on lip-reading, the Grange & Culling study [3] was repeated in audio and in audio-visual modalities, focusing on measuring HOB for 30^{O} head turn because it had previously been confirmed with NH listeners that such orientation provided the bulk of attainable HOB and it was believed that a sidelong look at the target talker would not be uncomfortable at that angle, including for users of glasses. Unilateral CI users were found to obtain the same HOB as age-matched NH listeners (4.5 dB) and bilateral CI users obtained somewhat less (2 dB), due to the squelch benefit of a second ear they already benefited from. It was also confirmed that all listeners' lip-reading benefit did not suffer from a 30^{O} head orientation, such that lip-reading and HOB are effectively cumulative. Interestingly, even with a directional microphone setting, HOB remained high, because the directional sensitivity pattern of a directional microphone is tilted 30-40^{O} by the head shadow once the microphone is placed on the side of the head.

For the behavioral task, we had hypothesized that CI users would make more spontaneous use of head orientation, given that HOB is so important to their accessibility to noisy settings and expecting them to have learned that strategy over time. It turned out that CI users made even less spontaneous use of head turns than young NH listeners. As hypothesized, the talker being visible inhibited head movements, and more so for CI users. Once informed that they could benefit from a head orientation, CI users, especially unilateral CI users demonstrated a much higher ability to exploit HOB than NH listeners. Upon quizzing CI users about reasons why they did not spontaneously use head turns in the first experiment, many reported that they had been advised to face the target talker head-on by clinicians. Surveys of 98 CI users and 37 UK clinicians confirmed that erroneous advice was provided ~80% of the time, mostly because of misconceptions about the need to face a talker head-on to optimally lip-read them and about directional

microphones being most sensitive in front of the listener. The same rate of erroneous advice was found when scanning the world-wide web for listening-tactics advice available to the HI. This highlighted the importance of informing clinical advice with our scientific findings.

3. COMPLEX ENVIRONMENTS

It remained to be showed that in noisy and reverberant social settings, HOB persisted. Impulse responses were acquired from a Cardiff restaurant, at 18 tables and with a head-and-torso simulator either facing the source across each table or with a 30^{O} head orientation either way. A subset of impulse responses from 6 tables were used to simulate and measure HOB over headphones with NH, HI and simulated CI users (using the SPIRAL CI simulator from Grange et al. [5]) attending to IEEE sentences, while speech-shaped noise or speech interferers were spread across another 9 tables. The NH baseline was reported in Grange & Culling [4], and HI and simulated CI user data in Grange et al. [6]. At the head orientation predicted as best by our model of SRM [2] and in steady noise, NH listeners obtained 1.7 dB HOB and HI and simulated CI users showed a 1.2 and 1.7 dB HOB, respectively. All SRTs were significantly higher for speech than noise interference for HI listeners (by 1 dB) and for simulated CI users (by 4 dB), as a result of broader auditory filters in the HI and highly degraded spectral resolution in CI users. The challenge simulated CI users faced with babble interference was significantly helped by a much higher HOB (3-4 dB) than in diffuse-noise interference. Such an interaction was not found in NH and HI listeners, and is yet to be explained.

4. CONCLUSION

In sum, making use of a simple head-turn strategy while looking sidelong at a target talker provides a speech intelligibility benefit to all listeners. While this simple listening tactic is instinctive, it was found to have been erroneously suppressed by clinical advice, hence the importance of gathering the scientific evidence to help improve guidance provided by professionals. Furthermore, HOB was found to be robust in a typical, noisy and reverberant social setting. Our findings demonstrate that the "Turn and Ear to Hear" strategy can help improve accessibility to noisy social settings by the hearing impaired, and hence, improving their quality of life.

5. REFERENCES

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