Recurrence analysis of head movements to explore the influence of hearing loss on group conversation dynamics

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There is growing interest in investigating the effect of hearing loss and the efficacy of hearing aids on conversation success in realistic situations. Improving the realism of laboratory assessments of hearing and communication skills requires developments on two fronts: developing more realistic experimental tasks and developing outcome measures that can be carried out without disrupting the tasks. One realistic task that has been receiving growing attention recently in the hearing research community is conversations (Hadley et al., 2019, 2021; Nicoras et al., 2022; Petersen et al., 2022; Smeds et al., 2021). One technology that can be used to develop outcome measures for conversations without interrupting them is motion sensor technology, specifically eye and head tracking (Hadley et al., 2019, 2021). However, adding eye or head tracking sensors to an experimental setup comes at the cost of some of the realism of the experimental situation. Here we will report on recent group conversation work carried out at ORCA Europe for which we leveraged accelerometers embedded into hearing aids to explore the movement dynamics of hearing-aid wearers during group conversations and to try to relate these dynamics to conversation success. Accelerometers do not offer positional data, which restricts what can be learned from them about movements, but recurrence analysis of accelerometer data has been suggested as a tool to investigate the movements of participants in conversations (Brick et al., 2018) as well as their inter-personal movement synchrony (Paxton & Dale, 2017). Hearing aids already have accelerometers embedded, but they are used for a different purpose. In this work, we set out to explore whether we could learn something from the accelerometer data about group conversation dynamics, without any a priori hypothesis.

We will present two exploration studies. In the first, groups of four participants (two normal-hearing and two hearing-impaired) carried out conversations in different scenarios, all common in everyday life but varying in terms of noise type and level and in informational content (dinner at home, party, business meeting, dining in public). The scenarios were implemented acoustically by presenting ambisonics recordings from the ARTE database (Weisser et al., 2019). Participants were either sitting across a table in a large meeting room or standing up in a kitchenette area. We used pictures and consensus questions (e.g., “Can you put together a menu with dishes that none of you like?”) as conversation sparkers. After each conversation, participants evaluated conversation success subjectively in questionnaires, following the success clusters from Nicoras et al. (2022). As normal-hearing participants do not wear hearing aids and the hearing-impaired participants already had their own, we collected acceleration data by attaching the body of a hearing aid with an embedded accelerometer to the nape of the participants’ neck. We used recurrence analysis to look for differences in the acceleration dynamics between normal-hearing and hearing-impaired participants and to relate these differences to differences in the subjective evaluations of conversation success. Recurrence analysis is a non-linear analysis method that provides insights into a system’s dynamics via a visualization of the phase space trajectories of the system’s states (a recurrence plot; Eckman et al., 1987) and via several quantification metrics that measure the large-scale and small-scale patterns exhibited by the recurrence plots (recurrence quantitative analysis; Webber Jr. & Zbilut, 1994). Recurrence analysis was performed with the CRQA R package (Coco & Dale, 2014). In the second study, we asked normal-hearing participants to carry group conversations while maintaining a pre-assigned level of body engagement: they were asked to either talk and move their head, talk but refrain from moving their head, listen and move their head, or listen and refrain from moving their head. We used recurrence analysis to identify recurrence patterns predictive of the four levels of engagement, and then looked for those recurrence patterns in the data of the first study, with the aim of relating differences in hearing and conversation success evaluation to differences in body engagement.

Index Terms: group conversations, head movements, recurrence analysis

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