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

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Introduction

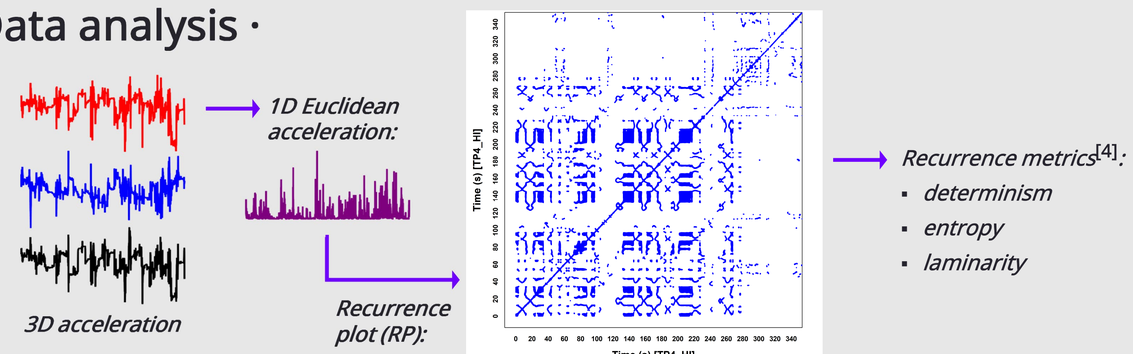
There is growing interest in investigating the effect of hearing loss and the efficacy of hearing aids on conversation success in realistic situations. Accelerometers embedded in hearing aids provide a potential way to monitor behaviour without disrupting activities. Accelerometers have been used in conjunction with recurrence quantification analysis to investigate the movements of participants in conversations[1] as well as their inter-personal movement synchrony[2]. We recorded accelerometer data from hearing aids during group conversations and we explored whether we could learn something about group conversation dynamics by using recurrence analysis.

Spontaneous head movements

Data collection ·

- 4 conversation scenarios (6 minutes each) for 5 groups of 4 participants (2 older normal-hearing [NH] / 2 older hearing-impaired [HI])
- Conversation scenarios: dinner at home, party, business meeting, dinner in public
- For “party” scenario: participants standing up in kitchen area / for other scenarios: participants seated around a table in a meeting room
- Conversation sparkers: consensus questions (for business meeting), pictures[3] (other scenarios)
- Ratings scales after each conversation: scenario realism, listening ease, engagement, talking ease, flow, conversation success
- Accelerometer recordings and video recordings

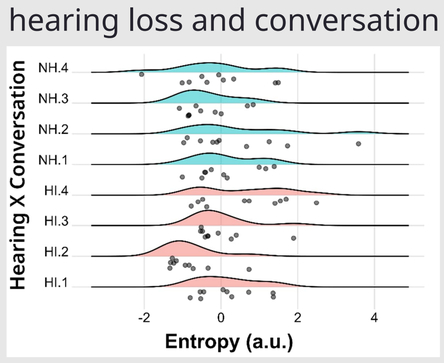
Data analysis ·



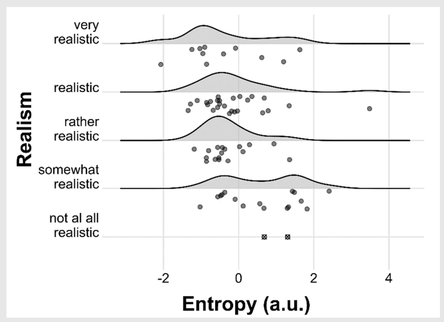
- For a trajectory $\{\vec{x}_i\}_{i=1}^{N}$, the RP plots the $\mathbf{R}_{i,j} = \begin{cases} 1 \text{ if } \|\vec{x}_i - \vec{x}_j\| \leq \epsilon \\ 0 \text{ otherwise} \end{cases}$
- Linear mixed models built to fit recurrence metrics with hearing loss, conversation scenarios, and rating scales
- Visual help from videos to interpret differences between RPs

Results ·

- No recurrence metric (or a combination of them) let us separate NH and HI participants, and we found no association with conversation success ratings
- Entropy was the metric most sensitive to experimental factors
- The best linear mixed model for entropy included a significant interaction of hearing loss and conversation scenarios and a main effect of scenario realism



HI: hearing impaired
NH: normal hearing
1: dinner at home
2: party
3: business meeting
4: dinner in public



- The Hearing loss x Conversation interaction was driven by the hearing impaired having lower entropy in the “party” situation (participants standing)
- Lower entropy was associated with the scenario reported as more realistic
- Some individual videos suggested a potential association between lower entropy and being more consistently engaged in the conversation

Discussion ·

- Systematic differences in the pattern of movements of HIs and NHs during group conversations may not exist: some HI listeners may withdraw from the conversation and others monopolize it to avoid having to listen **[5]**
- The lack of knowledge about associations between specific recurrence patterns and specific movement patterns made it hard to make hypotheses about the recurrence metrics
- A second exploratory study sought to gather data on associations between recurrence metrics and specific movement patterns reflecting different degrees of engagement in the conversation, such as listening passively, talking, or talking in an animated way (with head movements)

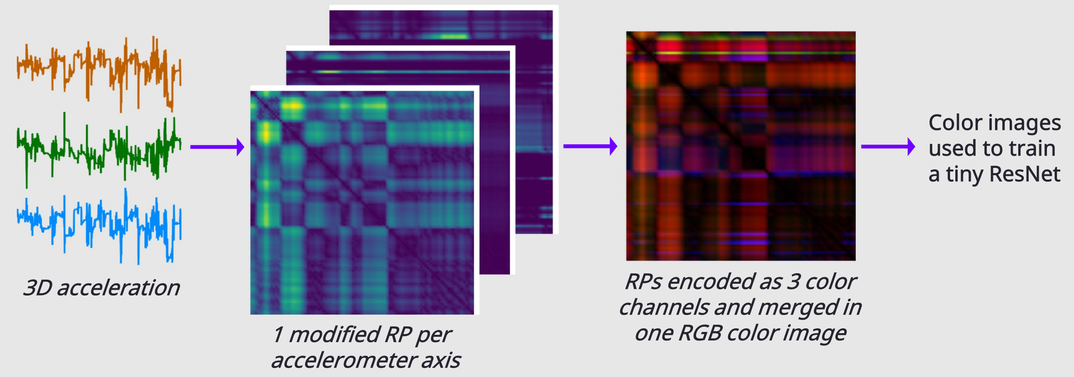
Acted head movements (role-play)

Data collection ·

- 4 participants sitting in circle role-playing four attitudes during group conversations (2 minutes each): talking with head movements, talking without head movements, listening with head movements, listening without head movements
- 4 conversations in quiet, changing role every 30 seconds
- Accelerometer recordings and video recordings

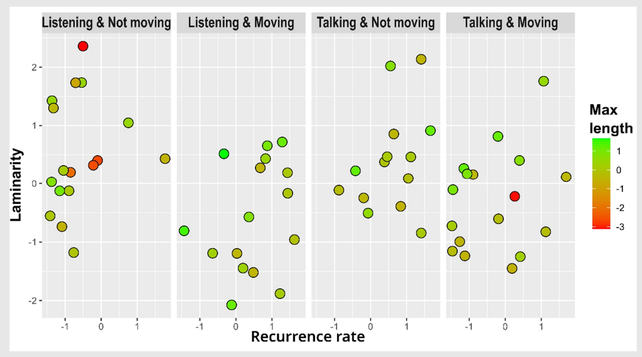
Data analysis ·

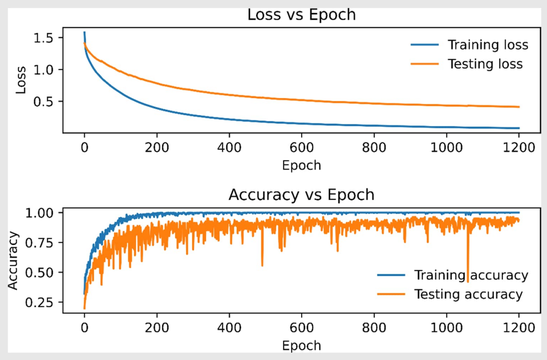
- Multinomial logistic regressions to fit attitudes with recurrence metrics
- Classification of *modified* RPs with a residual neural network, as in **[6]**:



Results & Discussion ·

- The best logistic regression model combined the laminarity, the recurrence rate, and the length of the longest diagonal line segment
- Some degree of clustering visible, maybe a deep-learning model would do better?
- **[6]**: movements classified were walking, standing up, sitting, etc..., but code available





- Training model of **[6]** on the attitudes resulted in some success, but model may need tailoring (cf. testing loss)
- Data augmentation and/or learning-rate tuning failed to improve model
- Still an open question whether attitudes in conversation can be classified in the way of larger movements such as the ones in **[6]**

General discussion

- We did not find an obvious way to use accelerometer data and recurrence analysis to learn about group conversation dynamics
- Accelerometers might still be useful as one input among others (acoustic, linguistic, physiological) in a multidimensional recurrence analysis of group conversation dynamics
- Embedded accelerometers might be more useful for measuring hearing-aid efficacy by focusing on long-term changes in movement patterns after hearing-aid intervention
- Further progress on this work would probably require an extensive manual annotation of the video recordings

[1] **Brick, Gray, Staples (2018).** Recurrence quantification for the analysis of coupled processes in aging. *J Gerontol B Psychol Sci Soc Sci, 73*(1), 134–147.
[2] **Paxton, Dale (2017).** Interpersonal movement synchrony responds to high-and low-level conversational constraints. *Front Psychol, 8*, 1135.
[3] **Smeds, Larsson, Dahlquist, Wolters, Herrlin (2021).** Live evaluation of auditory preference, a laboratory test for evaluating auditory preference. *J Am Acad Audiol, 32*(08), 487-500.
[4] **Coco, Dale (2014).** Cross-recurrence quantification analysis of categorical and continuous time series: an R package. *Front Psychol, 27*, 5-510.
[5] **Stephens, Zhao (1996).** Hearing Impairment: Special Needs of the Elderly. *Folia Phoniatr Logop, 48*(3), 137–142.
[6] **Lu, Tong (2019).** Robust single accelerometer-based activity recognition using modified recurrence plot. *IEEE Sensors Journal, 19*(15), 6317-24.