Poster 5aSC24

Analysis of Physiological Measures Around Conversational State Changes

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Introduction

Pupil Dilation Response

- Task evoked pupil response has been found to be an indicator of within-task cognitive effort, with systematic changes in pupil response occurring based on task demands [1]
- Conversation can be viewed as a homogenous mixture of tasks, likely with overlapping cognitive efforts from each participant needing to simultaneously listen, plan their speech, and produce their speech
- This work attempts to extend the analysis methods of task-evoked pupillary response to conversation by defining discrete points in time around which we can analyze and de-mix physiological changes

Conversational State Changes and Turn-Taking Behavior

- Here, we define our stimulus signal as the state-changes in conversation, i.e., the points at which turn-taking occurs, which can be modeled for dyadic conversation as a set of 4 impulse trains
- These points in time will inherently be linked to some mixture of listening, planning, and speaking, and related to both the Floor-transfer Offsets (FTO) and Interpausal Units (IPU)

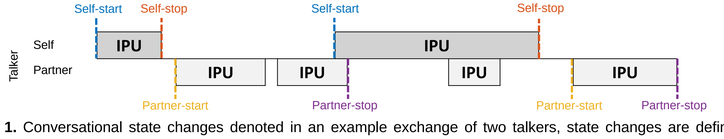

Figure 1. Conversational state changes denoted in an example exchange of two talkers, state changes are defined relative to Talker 1.

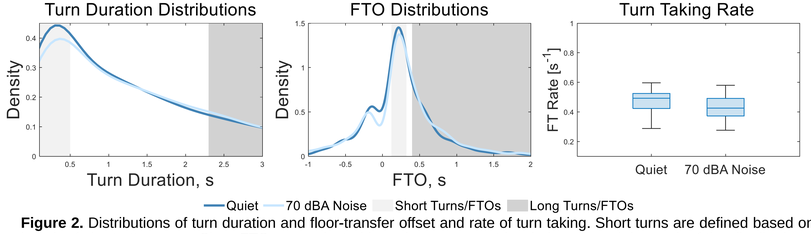

Figure 2. Distributions of turn duration and floor-transfer offset and rate of turn taking. Short turns are defined based on length of short utterances. Short FTOs are selected based on a symmetric window around the peak of the distributions. Long turns and FTOs are defined to match the number of occurrences as short turns and FTOs, respectively. Floor-transfer rate is computed as number of floor-transfers divided by the length of conversation.

Measuring Pupil Response in Interactive Conversation

Experimental Design

- 12 pairs of normal hearing Danish talkers
- Performed 2 replicates of DiapixUK [2] tasks (with modified Danish signage) in 4 conditions
  - Quiet
  - Simulated Conductive Hearing Loss
  - 60 dBA background noise
  - 70 dBA background noise
- Quiet and Noise70 suspected to be the easiest and most difficult and selected for analysis [3]
- Eye tracking data recorded with Tobii Pro 3

Pupil Data Pre-Processing

- Eye with the least missing data selected
- De-blinked response signals by statistical outliers
- Trials with more than 30% missing excluded
- Missing values interpolated through with cubic spline
- Response signals filtered between .1-1 Hz to isolate turn-taking rate eye response
- Responses standardized for each person across conversations

Results

State Change Pupil Response Curves

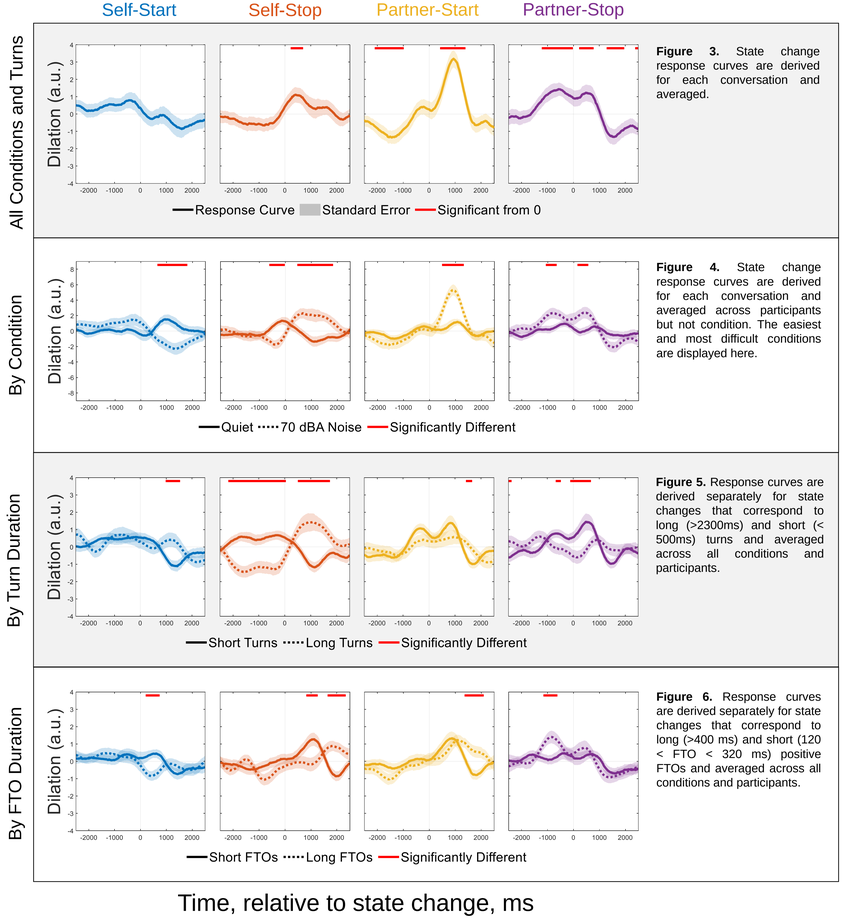

Figure 3. State change response curves are derived for each conversation and averaged.

Figure 4. State change response curves are derived for each conversation and averaged across participants but not condition. The easiest and most difficult conditions are displayed here.

Figure 5. Response curves are derived separately for state changes that correspond to long (>2300ms) and short (< 500ms) turns and averaged across all conditions and participants.

Figure 6. Response curves are derived separately for state changes that correspond to long (>400 ms) and short (120 < FTO < 320 ms) positive FTOs and averaged across all conditions and participants.

Time, relative to state change, ms

Results, cont.

Turn-Taking Probability Over Time

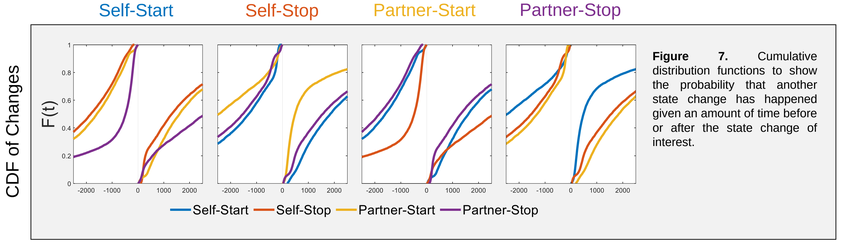

Figure 7. Cumulative distribution functions to show the probability that another state change has happened given an amount of time before or after the state change of interest.

Processing Details

- We define the State Change Response (SCR) function as the solution of the ridge-regression between a time-lagged multivariate stimulus matrix of the state changes and the pupil response
- Curves are fit on each conversation using the mTRF Toolbox [4], with the minimum and maximum time lags determined a priori ($\tau = \pm 2.5\ s$)
- To select regularization value, 10-fold cross validation is performed for each conversation, and the best regularization parameter is selected as the value yielding the highest average validation correlation

Discussion

Questions

- Can we develop a set of tools to identify response patterns around the conversational state changes?
  - If so, can these responses be used to infer effort and/or predict turn-taking?

Our findings reveal systematic and significant effects in pupil response time-aligned to turn-taking

- Reactionary and anticipatory effects are especially observable around self-start and partner-start
- We also find differences between state-changes corresponding to different types of turns or conversations, such as by condition, turn-duration, or FTO duration
- Interpretation must consider that pupil response is indicative not only of cognitive effort due to the task, speaking, and listening, but also of arousal and changes in luminance
  - We hypothesize that effects unrelated to cognitive demands will be temporally uncorrelated to the state-changes, and therefore that systematic changes observed here will be minimally affected

Follow up

- Experimental designs to control for luminance, and to isolate cognitive effort related to speaking from listening/task completion effort

References

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3. Aliakbaryhosseinabadi, S., Keidser, G., May, T., Dau, T., Skoglund, M. A., & Rotger-Griful, S. (2023). Measuring communication difficulty with eye-gaze behavior when speaking and listening. 912-915. Paper presented at 49. Jahrestagung für Akustik, Hamburg, Germany.
4. Crosse, M. J., Di Liberto, G. M., Bednar, A., and Lalor, E. C. (2016). The Multivariate Temporal Response Function (mTRF) Toolbox: A MATLAB Toolbox for Relating Neural Signals to Continuous Stimuli. Frontiers in Human Neuroscience, 10.

Acknowledgements

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