Remote and lab measurement of facial expressions as a measure of emotional responses

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INTRODUCTION

- Emotions connect us to humanity and affect attention, memory, behavior, and our overall quality of life.
- Emotion recognition is adversely affected due to aging and hearing loss. However, less is known about emotional responses or responses of an individual to emotional stimuli.
- Existing studies in emotional responses show a reduced range of emotional responses in individuals with hearing loss[1]; and a relationship between emotional responses and feelings of social disconnectedness[2].
- Increased negative emotional responses or reduced positive emotional responses could deter individuals from participating in social situations. This is more important to consider in individuals with hearing loss who are already at risk for negative social and emotional consequences of hearing loss.
- We used facial expressions with an automatic facial expression recognition software to objectively measure emotional response. This method uses simple instrumentation, can help identify the emotion and its intensity, and can track the time course of the emotional response. Additionally, we used speech material which is more salient.

	Existing studies	Our study
Stimuli	Non-speech sounds	Sentences in noise
Outcome measures	Subjective ratings	Facial expressions (objective) with subjective ratings

- Our long-term goal is to measure emotional responses using facial expression recognition algorithms in the real-world in hearing device users. As a first step, in the current study, we determined emotional responses remotely under relatively controlled environments.
- Our aim was to explore how emotional responses obtained remotely correlate with that obtained in the lab setting. We hypothesize that the emotional responses obtained in the lab will be able to predict emotional responses in remote settings.

METHODS

- Participants: 33 young adults, aged 18 to 34 (Mean = 23, SD = 4) with normal hearing.
- Stimuli used: Speech perception testing using IEEE[3] sentences in quiet and noise (-1 dB signal-to-noise ratio (SNR) with reference to their individualized SNR-50).
- The facial expressions of individuals were recorded using a camera (Logitech HD Pro Webcam C920) in the lab and using participants' laptop camera remotely.
- Remote testing was done at participant-chosen quiet location using Zoom video conferencing. Stimuli were calibrated to participant's most comfortable level.
- Remote and lab videos were analyzed using the Emotient FACET software (v8.2; iMotions). The software detects the face, the different landmarks on the face, and monitors how much these landmarks move in response to the different stimuli. Movements of muscle or muscle groups (action units, or AU) are classified using the Facial Action Coding System developed by Ekman and Friesen[4]. Combinations of AUs are identified as facial expressions.
- The algorithm computes the evidence level, which is the probability of the presence of a given facial expression. We analyzed the expressions of confusion and frustration as these emotions are seen when individuals encounter cognitive disequilibrium or gaps in knowledge[5,6].
- Other outcome measures: Listening effort rating[7], subjective emotion rating.

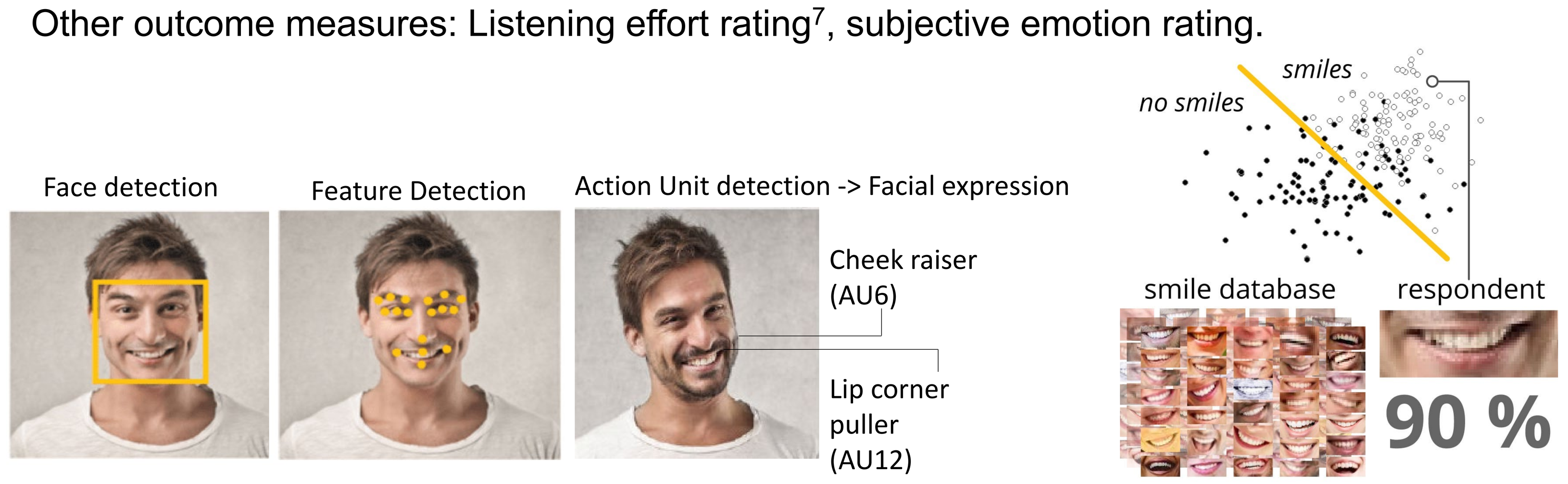

Figure 1: Working of the facial expression detection algorithm, AU6+AU12 indicate a high probability of the facial expression of joy.

RESULTS

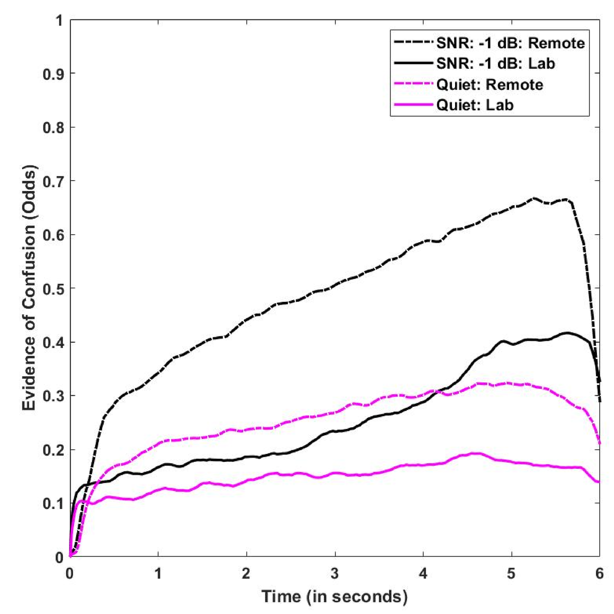

Figure 2. Mean time course of confusion

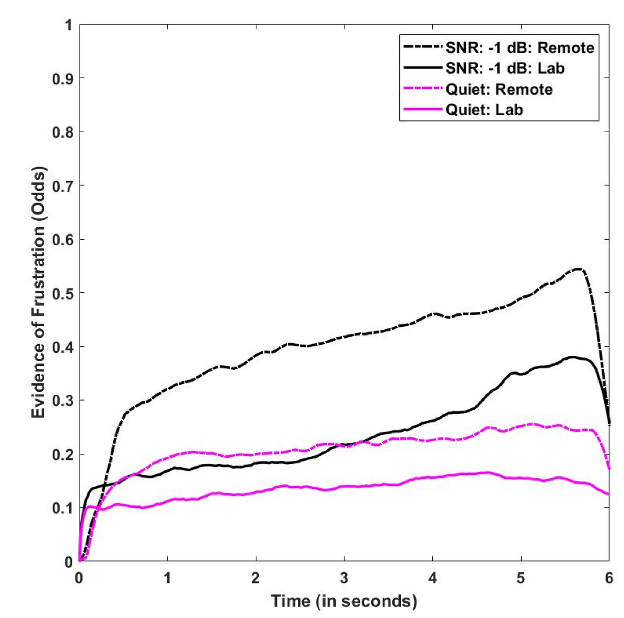

Figure 3: Mean time course of frustration

0 to 4 seconds: Sentence + Noise 4 to 6 seconds: Retention period. Confusion and frustration increases with progression of sentence. Remote condition shows increased confusion and frustration.

The **figure 2 and 3** represent the mean evidence levels of the emotions of confusion and frustration. The evidence value represents the odds in logarithmic (base 10) units of an emotion being present. E.g. An evidence value of 1 for confusion indicates that the observed expression is 10 times more likely to be categorized by an expert human coder as confused than not confused. These evidence values obtained were baseline corrected. The area under the curve (AUC) was obtained for each sentence. The positive AUC (integrated value: **Figure 6**) were computed for each participant for both conditions.

Speech scores(**Figure 4**): Main effect of SNR ($F(1,96) = 1742.43$, $p < 0.001$), Condition ($F(1,96) = 26.77$, $p < 0.001$) and interaction between SNR and Condition ($F(1,96) = 16.89$, $p < 0.001$) were significant. Speech scores for the remote condition were worse than the lab condition for both the quiet ($F(1,32) = 6.29$, $p = 0.017$) and the -1 dB SNR ($F(1,32) = 28.76$, $p < 0.001$) condition.

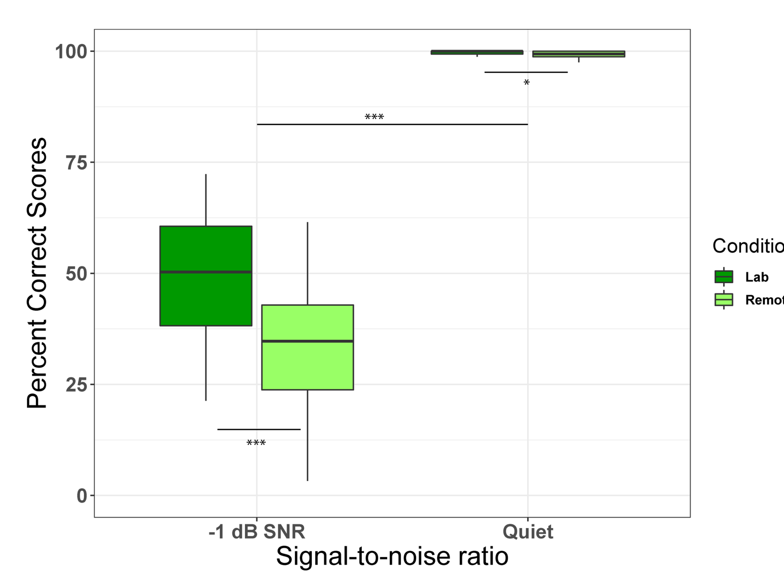

Figure 4. Speech recognition scores for -1 dB SNR and quiet for the lab and remote condition. Remote condition shows worse performance for quiet and -1 dB SNR.

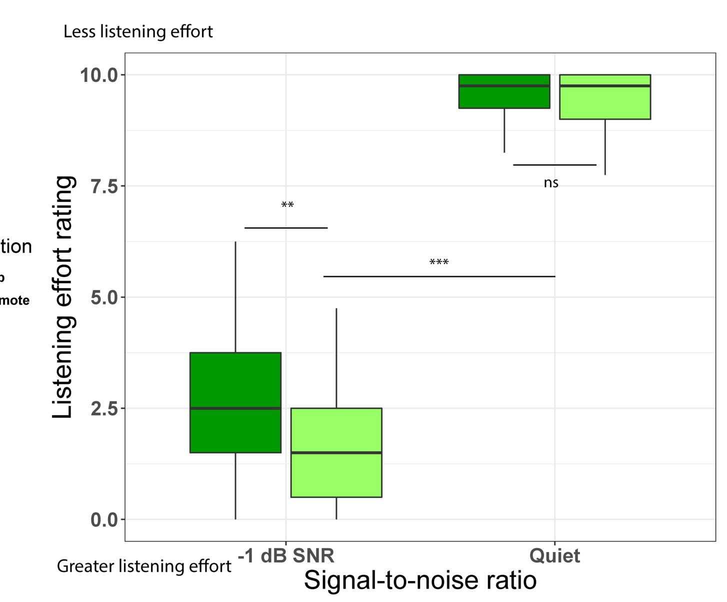

Figure 5. Listening effort rating for the lab and remote conditions. Increased listening effort is seen for the remote condition for -1 dB SNR.

Levels of significance, * < 0.05 **<0.01 *** <0.001.

- Speech scores in quiet condition were better the -1 dB SNR ($p < 0.001$).
- Multilevel correlation: weak positive correlation between lab and remote measures ($r = 0.29$, $p = 0.020$).
- **Listening effort rating** (**Figure 5**): Between remote and lab conditions- not significantly different for the quiet stimuli ($F(1,32) = 0.0089$, $p = 0.9254$), but the rating showed greater effort for the remote condition as compared to the lab condition ($F(1,32) = 11.171$, $p = 0.0021$) for -1 dB SNR stimuli.
- Multilevel correlation: Moderate positive correlation between lab and remote measures ($r = 0.40$, $p = 0.020$).

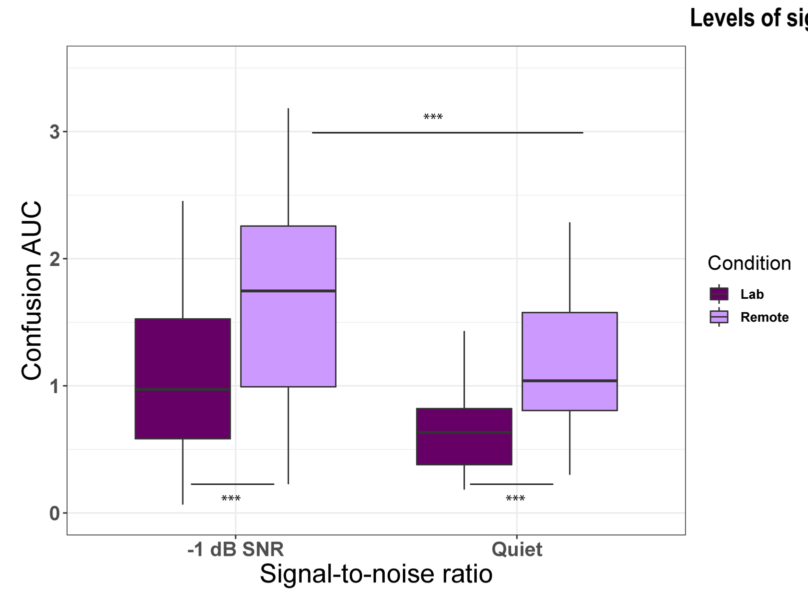

Figure 6. Area under the curve for the emotion of confusion. Significantly greater confusion is seen for the remote condition.

Levels of significance, * < 0.05 **<0.01 *** <0.001.

- **Confusion AUC** (**Figure 6**): Main effect of confusion was significant for SNR ($F(1,91.8) = 26.13$, $p < 0.001$) and condition ($F(1,94.45) = 24.25$, $p < 0.001$). The AUC for confusion was greater for the remote condition ($t = 4.920$, $p < 0.001$). The AUC for the -1 dB SNR was greater than the quiet condition ($t = 5.112$, $p < 0.001$).
- Multilevel correlation: weak positive correlation ($r = 0.27$, $p = 0.031$).
- **Confusion rating** (**Figure 7**): Main effect of SNR ($F(1,96) = 401.87$, $p < 0.001$) was significant. Participants rated more confusion in the -1 dB SNR condition than the quiet condition ($t = 20.05$, $p < 0.001$).
- Multilevel correlation: Strong positive correlation ($r = 0.71$, $p < 0.001$).

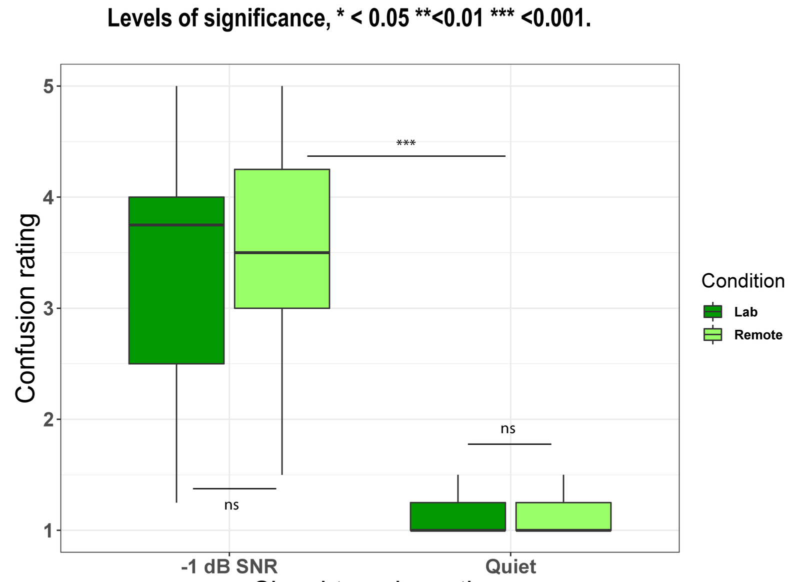

Figure 7. Confusion rating for the lab and remote conditions. Participants provided similar confusion ratings for both lab and remote conditions.

Levels of significance, * < 0.05 **<0.01 *** <0.001.

- Similar results were seen for the frustration AUC and frustration ratings.
- Overall, participants performed worse and showed greater evidence of confusion and frustration in the remote condition. Subjectively, though greater listening effort was seen for the -1 dB SNR in the remote condition, confusion and frustration ratings were not significantly different between the lab and remote conditions.

DISCUSSION

- Worse performance in the remote session could be due to transmission factors (Zoom, internet connection) and use of varying uncalibrated transducers (participant's own transducers) used for remote presentation of stimuli.
- The shorter test time for remote condition, relative to longer testing times for lab condition could have resulted in better engagement in the remote session leading to increased facial expressions of confusion and frustration. However, the signal fidelity issues may have affected their performance.
- Remote settings, being more real-world likely elicit more natural facial expressions, and display participants' annoyance at the difficult task, more than controlled lab settings where participant feels compelled to perform the task.

CONCLUSIONS AND IMPLICATIONS

- Increase in the emotional responses of confusion and frustration in the remote condition along with worse speech recognition performance was seen.
- Stimulus fidelity may be an important consideration in remote measurement of emotional responses (whether measured through facial expressions or other measures). Emotional responses may be affected by transmission and transducer effects.
- Further research is needed, and careful stimulus manipulations may be necessary when these stimuli are deployed and measured in the real-world.

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