Real-time Feedback of Affect and Working Memory Load based on Neurophysiological Activity

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Introduction

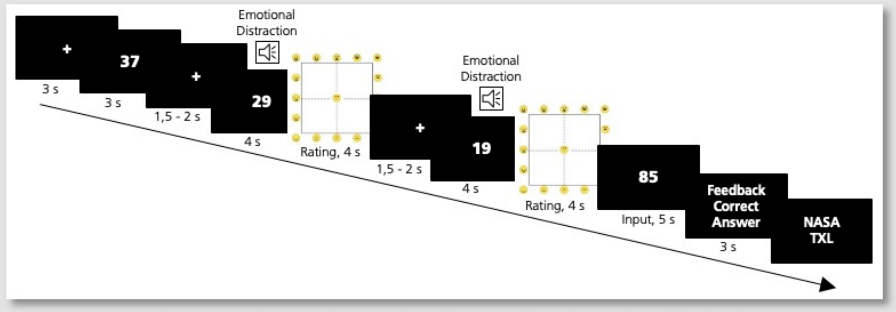
For **neuro-adaptive systems**, feedback on the recognized **affective and cognitive states** is essential. Users' acceptance and trust regarding and their attitude towards a closed-loop human-machine system are influenced by perceived **accuracy, feedback appropriateness** and **error tolerance** [1-2]. To investigate how precise neuro-adaptive systems should be, we explored users' feedback error tolerance. We continuously monitored their affective and cognitive states based on **electroencephalographic (EEG) recordings**. In a secondary study, we explored users' reactions to a sham feedback that was either legit (consistent with the task condition) or inappropriate (inconsistent with the task condition) [3-4].

Study Design

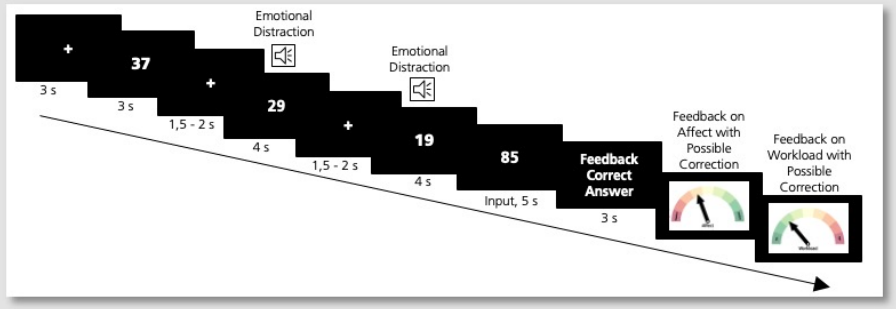
In both studies, participants performed **arithmetic tasks** (low working memory load vs. high working memory load) with concurrent **auditory emotional distractions** (low valence, neutral valence, and high valence). Brain activity was recorded using a wireless dry-electrodes EEG headset.

Study Procedure

In the preliminary study, participants (n = 8) rated their subjectively perceived affect and effort after each task.

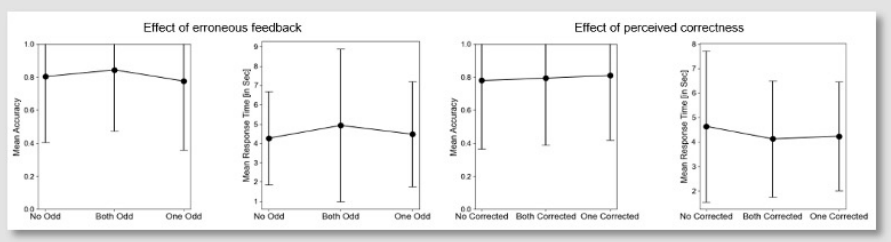


In the second study, we showed participants (n = 7) a sham feedback allegedly based on their brain activity and asked them to optionally correct it according to their own perception. In 80% of the trials, the feedback corresponded to the experimental condition (legit); in 20% the feedback was inappropriate.

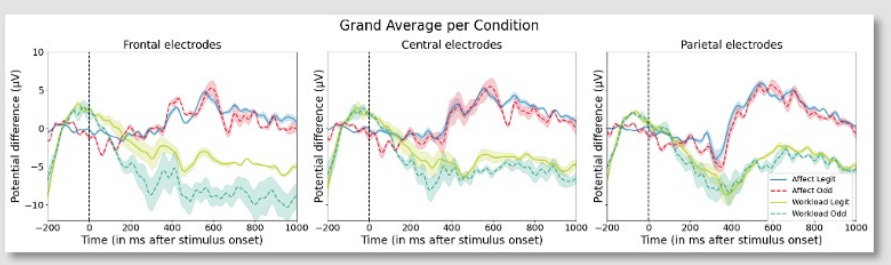


Results of the Feedback Study

Regarding behavioral effects of the feedback, participants were significantly more likely to correct inappropriate feedback regarding cognitive effort, $F(1,6) = 30.82$, $p < .001$, $\eta_p^2 = .84$. For the affective state, we observed only a trend, $F(1,6) = 5.14$, $p = .064$. No effects of the feedbacks were found on participants' performances, that are accuracy and response time, in the subsequent trial.



To identify differences in the ERPs between the feedback conditions, we used a cluster-based, non-parametric randomization approach [5]. No significant spatio-temporal cluster indicating a difference between the legit and inappropriate feedback was found.



Discussion

Our study revealed **two challenges for adaptive feedback systems**:

1) We observed **no significant positive effect of the legit feedback on participants' performance**. This may be because participants had low trust in the system and did not perceive it as reliable and consistent [6]. An alternative explanation might be that participants did not perceive it as relevant for solving the arithmetic task.
2) We observed **no difference in feedback-related potentials** (FR Negativity, P300) between the conditions in the EEG. This might be explained by low number of trials per condition.

Concluding, our real-time EEG-based feedback approach contributes to the **development of closed-loop human-machine systems** allowing to **recognize users' states**, **provide feedback**, and **adapt the system parameters** to individual capabilities and demands.

References

1. Chen, M., Nikolaidis, S., Soh, H., Hsu, D., Srinivasa, S.: Planning with Trust for Human-Robot Collaboration. In: Proceedings of the Anual ACM/IEEE International Conference on Human-Robot Interaction, Chicago, IL, USA 2018, pp. 307-315.

2. Alder, G.S., Ambrose, M.L.: Towards Understanding Fairness Judgments Associated with Computer Performance Monitoring: An Integration of the Feedback, Justice, and Monitoring Research. Human Resource Management Review 15(1), 43-67 (2005).

3. Enriquez-Geppert, S., Huster, R.J., Herrmann, C.S.: EEG-Neurofeedback as a Tool to Modulate Cognition and Behavior: A Review Tutorial. Frontiers in Human Neuroscience 11(51), 1-19 (2017).

4. Logemann, H.N.A., Lansbergen, M.M., Van Os, T.W.D.P., Böcker, K.B.E., Kenemans, J.L.: The Effectiveness of EEG-Feedback on Attention, Impulsivity and EEG: A Sham Feedback Controlled Study. Neuroscience Letters 479(1), 49-53 (2010).

5. Maris, E., Oostenveld, R.: Nonparametric Statistical Testing of EEG- and MEG-Data. Journal of Neuroscience Methods 164(1), 177-190 (2007).

6. Kluger, A.N., DeNisi, A.: The Effects of Feedback Interventions on Performance: A Historical Review, a Meta-Analysis, and a Preliminary Feedback Intervention Theory. Psychological Bulletin 119(2), 254-284 (1996).

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