A potential second feedback loop in fMRI neurofeedback with emotional feedback

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Objective

Functional magnetic resonance imaging neurofeedback (fMRI-NF) is a promising therapeutic tool for several neurological and psychiatric disorders, like schizophrenia, depression or Parkinson‘s disease [1]. In order to find the most suitable feedback design for future fMRI-NF studies on emotion regulation, different feedback schemes were compared in a former study [2]. Based on the previously shown benefits of utilizing social reward [3], feedback was given in form of an emotional stimulus (a smiley with changing facial expressions), where one group received only positive, the second group also negative feedback. Since the subgenual anterior cingulate cortex (sgACC) is involved in emotion regulation [4], it was chosen as target region with the intended regulation strategy of positive thoughts. In this work we assessed an additional feedback loop due to the emotional stimulation.

Methods

The data was taken from Klöbl et al.[2], where the sgACC activation of six healthy subjects per group were measured in two training sessions with each three runs. Assuming that the invoked activation of the sgACC is proportional to the magnitude of the shown feedback, the latter (corrected for the time course of the experimental design) was convolved with a canonical hemodynamic response function and used as model regressor for the target region. To account for the temporal delay of the reaction, the time derivative of the feedback was added as regressor [5] (Figure 1). For the group with positive and negative feedback, the valence-dependent influence of the presented emotion was estimated. A linear mixed effects model was used to estimate the influence on group level. To test the improvement of the model due to the inclusion of the feedback stimulus a cross-validation was carried out.

Results

Analyzing the single training runs of the subjects, around 25-35% (depending on the group) of the feedback parameters showed a significant influence ($p<0.05$) on the model (Figure 2). The time derivative more often had a significant influence with 40-55%. Considering the different influence of positive and negative feedback for the group that received both, positive feedback was more often significant in the feedback parameter than the negative feedback. In the time derivative parameter, the negative feedback had a higher percentage of significant values than the positive feedback. For both the feedback and the time derivative regressor, the negative feedback had a higher amplitude, as well as the group which received both positive and negative feedback. Thus, the positive feedback and the temporal change of the negative feedback are the main driving factors of the second feedback loop. Correction of the activation for the feedback influence reduces the amplitude of the regulation and mitigates the influence of the feedback (Figure 3).
On a group level, no significant influence could be estimated for both groups and regressors. Also the cross-validation showed no significant increase of the correlation between model prediction and measured data. This could be explained by the high individual variability of the measured activation between different subjects and even different runs, which does not allow for a group-wide statement.

Conclusion

The studied effect is highly variable for individual subjects and probably needs to be treated separately from case to case. In NF studies using emotional feedback, integrating the influence of the stimulus presentation into the online processing algorithm could promote learning by increasing the accuracy of the given feedback (Figure 3). Further investigations will be necessary to confirm improvements in the learning process and whether other feedback schemes would also benefit from this correction.

References

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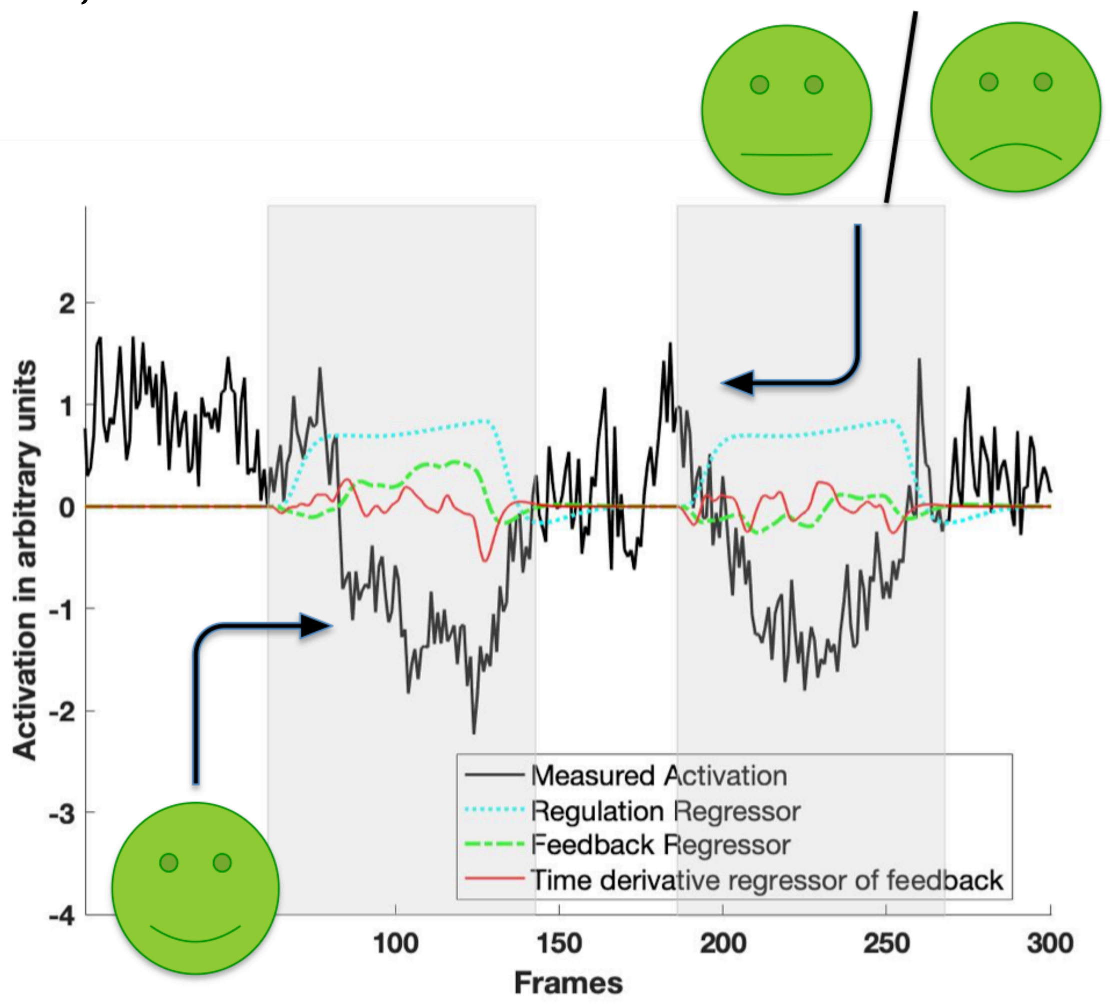

Figure 1: Overview of regressors and feedback scheme. To describe the measured activation, the following regressors are integrated into the general linear model: The regulation during the feedback period, the given feedback and the time derivative of the given feedback. All regressors are convolved with a canonical hemodynamic response function. For deactivation of the target area positive feedback (happy smiley) is given. Depending on the group either neutral or negative feedback in form of a neutral looking or sad smiley is provided if the target area activation increases.

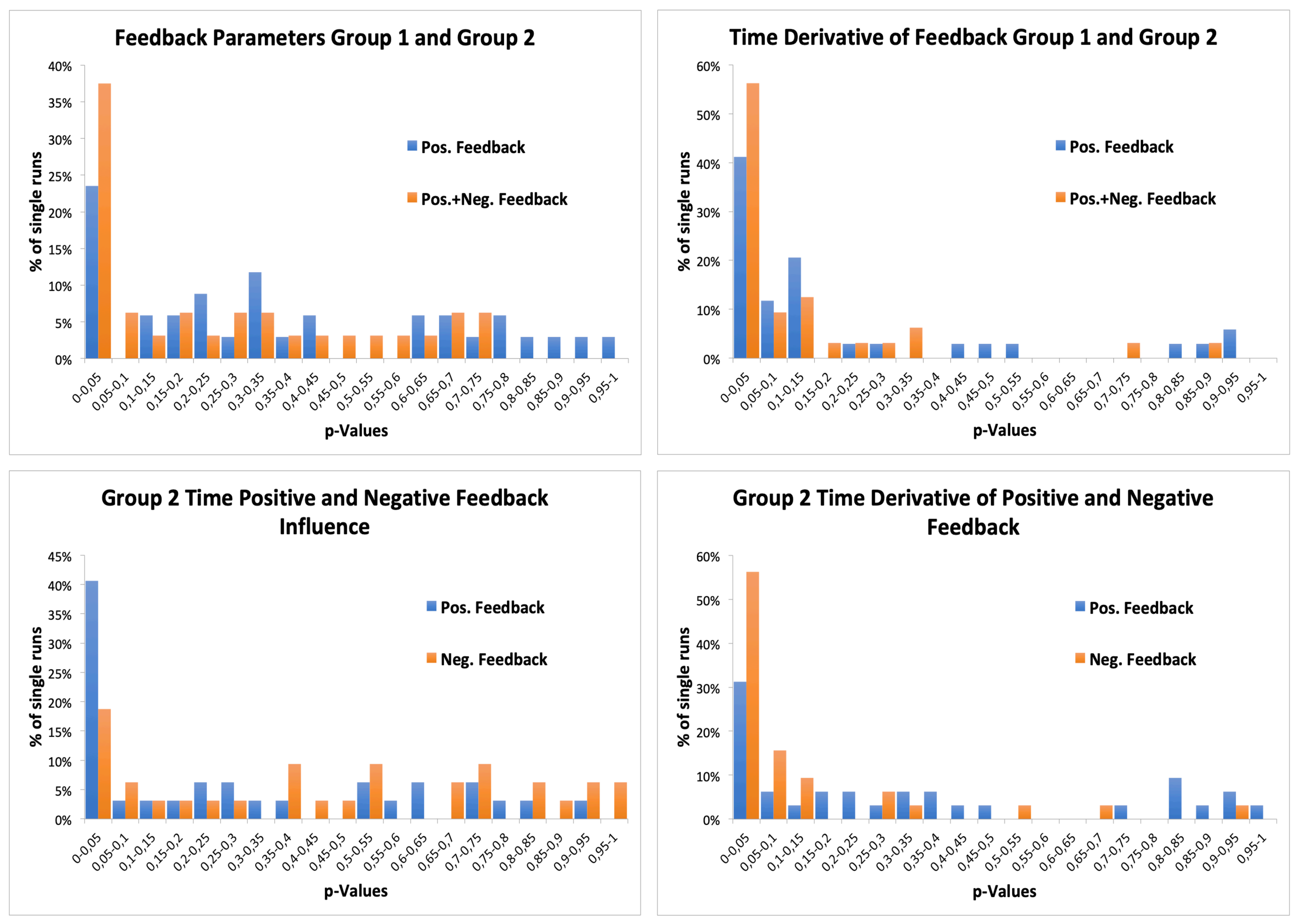

Figure 2 : Distribution of p-values for different regressors. For both feedback schemes, there is a considerable amount of single-run parameters with $p<0.05$. In Group 2 (positive and negative feedback) a higher percentage of single run parameters showed such a significant value, especially for the time derivative regressor of the feedback. Considering the different influence of positive and negative feedback, positive feedback has a higher amount of significant values for the feedback parameter, whereas the time derivative of the negative feedback is more often significant.

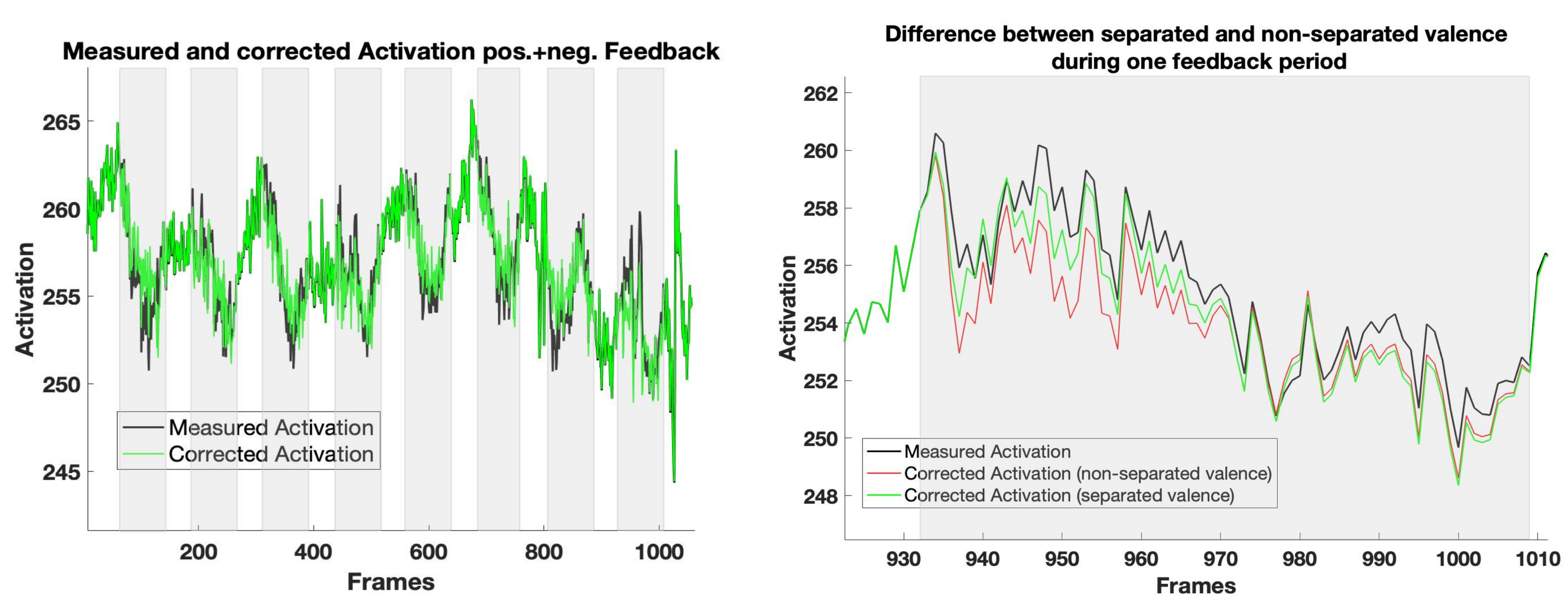

Figure 3a (left): Activation of the target area corrected for the feedback influence. The activation is corrected by subtracting the modeled influence of the feedback and its time derivative from the measured activation. The difference is only visible during the regulation blocks (grey area) as no feedback was given during the baseline periods. The correction reduces the amplitude of the regulation and mitigates the influence of the feedback on the target region.
3b (right): Difference between separated and non-separated valence during one feedback block.

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