Predicting human Decisions in a social Interaction-Scenario using Real-Time Functional Magnetic Resonance Imaging (rt-fMRI)

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Introduction Making decisions in a social context is a fundamental part of our daily life. Is it possible to predict decisions in social interaction scenarios before a subject expresses the own will by investigating distributed activation patterns of the human brain? The presented manuscript addresses this question by using a standard paradigm from economic behavioral research: the Ultimatum Game (UG) [4]. In the UG, two players split a pre-defined sum of money. One player is deemed the proposer and the other, the responder. The proposer makes an offer as to how the money should be split between the two. The second player can either accept or reject this offer. If accepted, the money is split as proposed. If rejected, neither player receives anything. In standard approaches of mind-reading the analysis is done after the measurement [5, 6], prohibiting the usage of the prediction to influence user interaction or dynamic scene representation. In the presented study a real-time fMRI (rtfMRI) system [2] was used to derive the brain activation of the responder. Using pattern classification it was possible to predict the decision of the responder 'on the fly' by means of the activation of three distinct brain regions: Anterior Insula (AI), Lateral Praefrontal Cortex (LPFC) and Visual Cortex (VC). The classification result was presented to the operator 1-2 seconds *before* the subject pressed a button to convey the decision. The classification accuracy reached about 70% averaged over seven subjects.

Methods Nine healthy male subjects (23 to 28 years) were examined after giving written consent in participation in our experiments. The study was approved by the local ethics committee of the Medical faculty of the University of Magdeburg. The data of two subjects were used as initial training data for the system. At the start of each experiment the subjects were introduced to two male persons which were told to be the proposers in the UG. In the experiments the offers were presented in a pre-defined order to ensure a valid experimental setup [4]. During the experiment a subject completed 60 trials of 22 sec each. One trial consisted of two sec showing the money to be split (3 Euro), followed by the presentation of the offer of the proposer. After 12 seconds (this time was used to analyze the homodynamic response) the subjects had four seconds to decide whether the offer should be accepted or rejected, which is indicated by pressing a button (left or right hand). The button to be pressed for accepting or rejecting was switched randomly and the subjects saw the actual operation of the buttons on beginning of the decision phase. After the decision, the outcome of the actual trial was presented for four seconds. Please see figure 1 for the scheme of a single trial. The offers in each experiment were randomly distributed as follows (proposer : responder) : 6 x 50:50, 8 x 65:35, 12 x 70:30, 21 x 80:20, 13 x 90:10. After the experiments the subjects had to complete a questionnaire concerning their emotional states during the experiment. The experiments were performed on a 3 Tesla MRI-scanner (Siemens Medical Systems, Erlangen). The standard Siemens EPI-BOLD Sequence was modified to export EPI-datasets in real-time. The scan parameters were: TR 2000 msec, TE 29 msec, resolution 64x64x31, slice-thickness 4 mm. After the export every single dataset was processed by a custom-made matlab application [2]. The incoming data was at first normalized to MNI-space (3x3x3 mm) and smoothed using a Gaussian kernel of 9 mm. T-values for three distinct brain regions (AI, LPFC and VC) were computed in a constant window of 10 sec size after showing the offer of the proposer (figure 2). The regions of interest were determined using the data of the two training subjects. The same datasets were used to train a Relevance Vector Machine classifier [3] to discriminate accepted from rejected offers. This setup results in a three-dimensional feature space, which allows for fast classification. The initial training data is expanded in every trial by decisions and t-values of the former trials, resulting in an adaptive learning system to increase classification accuracy.

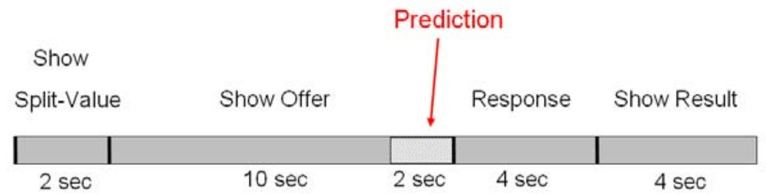

Fig. 1. The design of a single trial in the Ultimatum Game. The prediction of the decision is done 2 sec before the response phase, ensuring the result to be on hand before the actual response.

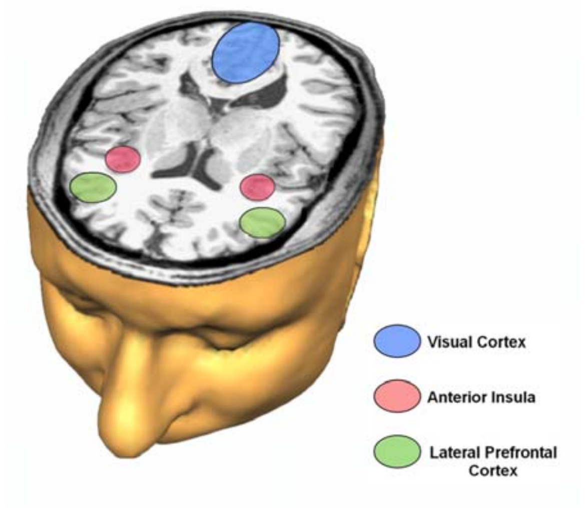

Fig. 2. Schematic view of the three template regions (3D clusters defined in the normalized MNI–space).

Results and Discussion The described system was able to differentiate between accepted and rejected offers with the accuracy of 70%. Compared to the guessing level of 49.3% this is a significant gain (p=0.0013). The described application performed normalization, smoothing, t-statistics, classification and re-training in about 1.3 seconds, which allowed for real-time application. The software-system proved to be applicable for real-time prediction of human decisions in socioeconomic interaction scenarios. The findings may facilitate the implementation of systems capable of "augmented" interaction of humans e.g. by presenting the arousal state of a communication partner. This allows for investigations of the neuronal correlates of human interaction and social decision-making, which is still poorly understood.

References [1] Weiskopf et al.. *J Physiol* - Paris, 98:357-373, 2004. [2] Hollmann et al.. *J Neurosc Meth. 175: 154–162, 2008*. [3] Tipping. J Machine Learning Research, 1:211–244, 2001. [4] Sanfey et al.. Human Brain Mapping, 9:156 –164, 2000. [5] J.D. Haynes, et al.. Nature, 7:523-34, 2006. [6] T. M. Mitchell et al.. Science, 320:1191-95, 2008.