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Comparative Study of Semantic Mapping of Images

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Abstract

Semantic mapping is typically used to find deep connections between different words or text documents. The purpose of this study is to extend the semantic mapping method to images. For this purpose, the publicly available affective image database was used. Five methods of semantic map construction were compared, including the methods based on (a) human ranking, (b) fMRI data, (c) metadata, (d) predominant colors found in images, and (e) analysis of verbal description of images. The compatibility of outcomes was evaluated using traditional and canonical correlation. Overall, results obtained using different methods appear to be compatible with each other, except that the correlation of the predominant color and semantic measures was found not significant. Comparative strengths and weaknesses of these approaches are discussed. The obtained semantic map provides an insight into the interpretation of brain activity recorded via fMRI, and will be useful for building and validating models of human emotional cognition.

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1 Introduction

The aim of this study is to develop an approach to evaluation of a biologically inspired, causal model of cognition that exposes the functional requirements for achieving emotional intelligence and makes testable predictions for neurophysiological measures. In general, a theory of how concepts are represented in the human brain should specify (i) the structure and semantics of concept representations in the brain, and (ii) types, formats and specific patterns of neuronal activity instantiating these representations. The key to a biologically-informed human brain model begins with the mapping of (i) to (ii): in our case, of the emotional Biologically Inspired Cognitive Architecture (eBICA) [1] to informative features and characteristics of brain activity. The eBICA model is based on three main extensions of the standard building blocks of a cognitive architecture: a moral schema, an emotional state, and an emotional appraisal that is attributed to every cognitive representation in this model and determines dynamics of learning and decision making. The general cognitive cycle of

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eBICA includes perception, cognition, decision making and learning. The values of emotional appraisals and emotional states are sampled from the weak cognitive map [2,3], which uses an abstract vector space to represent semantic relations among mental states [4], schemas and their instances [5]. This model is tentatively mapped onto the human brain [1,6], which allows us to test assumptions and predictions of the model; specifically, mechanisms of emotional thinking underlying behavior generation [1]. The eBICA model can be validated based on this approach via comparison of the computational model behavior, the human participant behavior, and the localized non-invasive brain imaging data. The latter include fMRI, EEG, eye-tracking, ECG, EMG, and other psychophysiological measures combined into one platform [7]. Methods involve the dynamic connectivity calculation and the use of regressors based on EEG and eye-tracking data [8]. In an fMRI study, effective connectivity can be measured using Structural Equation Modeling, Granger Causality Analysis, Transfer Entropy and Dynamic Causal Modeling [9,10]. The recording and analysis of eye movements provides access to the rapid unconcscious information processing. This approach has been applied to fMRI data collected in our study, representing human brain activity during cognitive tasks modulated by emotional state of the subject. Here we report preliminary results, including their comparison with other approaches.

2 Materials and Methods

2.1 Subjects and Procedures

In total, 25 participants (10 women and 15 men in the age of 21 to 35, mostly college students) were used in this study. The experiment was performed on 3T MRI scanner Magnetom Verio installed in NRC "Kurchatov institute". Details of the MRI recordings are described in related works [7-10]. Permission to conduct this experimental study was obtained from the Ethics Committee of the NRC "Kurchatov Institute".

Each participant placed in the scanner was asked about wakefulness during the study. Then, a sequence of images was presented to the participant on a computer monitor. During this presentation, the task for the participant was to rank 65 selected images on one of the three scales. The ranking was indicated using a joystick. At the same time, an fMRI scan was recorded. Each image was presented several times and judged on one scale at a time.

fMRI scanning was performed as follows. 3000 time points (with a repetition time of 1 s) were acquired resulting in 50 min. of scanning for game experiment and 1280 time points with the same repetition time were acquired resulting in approx. 20 min. of scanning for semantic experiment. MRI data were acquired using a SIEMENS Magnetom Verio 3 Tesla (Germany) using 32 channel head coil. The T1-weighted sagittal three-dimensional magnetization-prepared rapid gradient echo sequence was acquired with the following imaging parameters: 176 slices, TR = 1900 ms, TE = 2.19 ms, slice thickness = 1 mm, flip angle = 9°, inversion time = 900 ms, and FOV = 250 × 218 mm2. fMRI data were acquired using so called ultrafast sequence with the following parameters: 52 slices, TR = 1000 ms, TE = 25 ms, slice thickness = 2 mm, flip angle = 90°, and FOV = 192 × 192 mm2. Also the data which contain the options for reducing the spatial distortion of EPI images was received.

fMRI and anatomical data were preprocessed using SPM8 (available free at http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) based on Matlab. The center of anatomical and functional data were adducted to the anterior commissure and corrected for magnetic inhomogeneity using field mapping protocol. Slice-timing correction for fMRI data was performed (the correction of hemodynamic response in space and then in time to avoid pronounced motion artifacts) [11].To exclude motion artifacts, the images were pre-corrected, using a least squares approach and a 6 parameter (rigid body) spatial transformation. Then, spatial normalization were performed to bring them to the coordinates of the MNI (Montreal Neurological Institute) atlas in a coordinate system.