Insight into Emotion and Body Part Representation in Relevant Brain Areas: An fMRI Study

Xiao-li YANG¹ and Jun-hai XU¹,*

¹School of Computer Science and Technology, Tianjin Key Laboratory of Cognitive Computing and Application, Tianjin University, Tianjin 300350, P.R. China
E-mail: *jhxu@tju.edu.cn
*Corresponding author

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Abstract. When talking about emotion perception, the different representations of emotion carriers (face, body, voice and so on) remain unknown in human brain. In this study, we make the participants watch videos of faces, bodies and whole persons with different emotions enclosed. Meanwhile, we used functional Magnetic Resonance Imaging to fulfill data acquisition. We analyses the 3D imaging data by applying univariate analysis and multi-voxel pattern analysis. Eventually, we find that the signal changes of whole persons were different with a simple average of the signal changes of faces and bodies. Additionally, the extrastriate body area (EBA) had the highest accuracies for emotion classification and body part classification.

Introduction

In our daily life, we can perceive others’ attitude by their facial expression, manner of speaking and body movement. So, there is no doubt that emotion understanding is a very important personal or social competence. In this study, we will deeply explore the emotion and body part representation in many relevant brain areas using the functional Magnetic Resonance Imaging technology with high spatial resolution. To make our study more comprehensive, seven main brain areas were localized, including face-sensitive areas (amygdala, inferior frontal gyrus and occipital face area), body-sensitive areas (extrastriate body area), both-sensitive areas (superior temporal sulcus and fusiform gyrus) and emotion specific sensitive area (Insula).

The core face-relevant network was proverbial and included the fusiform face area [1], the occipital face area [2], superior temporal sulcus and amygdala [3]. In addition, the expanding face network included inferior frontal gyrus and Insula. Correspondingly, the function of fusiform body area in body-relevant network was similar to that of fusiform face area, while the feature of extrastriate body area was similar to that of occipital face area. Some other studies find that the brain network activated by face and body were overlapped partly [4, 5]. Moreover, it stays unclear how to influence the activity situation in these areas by emotion. Some studies using static images had relative low activity intensities in brain [6], so we used dynamic videos. Some other studies had not localized regions of interest by using their own localization runs, leading to not precisely enough [7]. As a result, we designed a specific localization session. In short, our study was quite strict. According to the shortages of previous studies, we may put forward two questions. First, do the whole persons and the simple average of faces and bodies have the same signal change? Second, in which areas the emotions and body parts can be classified successfully, while in which areas they can’t be classified? Solving these question is the goal of our study and it can help us have an insight into the emotion and body part representation in our human brain.
Experimental procedure and methods

Univariate analysis and signal change

We used GLM to estimate the smoothed BOLD responses. Averaged time courses across voxels in each ROI were extracted for each stimulus categories using the MarsBaR software package (http://marsbar.sourceforge.net/). Univariate analysis was conducted mainly on the category response in the face- (AMG, IFG, OFA), body- (EBA) and both-selective (STS, FG, Insula) areas. The nine conditions (happy faces, angry faces, fearful faces, happy bodies, angry bodies, fearful bodies, happy whole persons, angry whole persons and fearful whole persons) were extracted separately. We defined the whole-part effect as the difference between the fMRI response to whole persons and the average response to faces and bodies [9]. Paired t-tests between the brain responses to the whole and part were conducted for three emotions to detect the magnitude of the whole-part effect in different ROIs.

Multi-Voxel Pattern Analysis and classification

We selected the normalized but no-smoothed data to conduct the multi-voxel pattern analysis (MVPA) and support vector machines (SVM) classification. The MVPA and SVM toolbox were all added in Matlab 2013b. We put the data of the first three runs together and mixed them. The total sample points were 540. Then we chose 360 sample points randomly to train the SVM model. The remaining 180 sample points were used to test the model.

Experimental procedure

Twenty-four healthy subjects participated in our experiment. We collected the functional and anatomical data by a 3.0 T Siemens scanner in Yantai Hospital Affiliated to Binzhou Medical University with an eight-channel head coil.

In our study, the stimuli was chosen from GEMEP Corpus [8]. After processing and editing with E-prime software, participants watched 9 kinds of videos: happy faces, happy bodies, happy whole persons, angry faces, angry bodies, angry whole persons, fearful faces, fearful bodies and fearful whole persons, corresponding to 9 conditions. In the experiment, we adopted block design. There were 4 runs in total. The first three runs were the main experiment runs, while the last run were the localization run. At the group level, we limited the regions of interest AMG, IFG, OFA, EBA, STS, FG and Insula to 'Amygdala', 'Frontal_Inf_Oper', 'Occipital_Inf', 'Temporal_Inf', 'Temporal_Mid', 'Temporal_Sup', 'Fusiform' and 'Insula' of AAL templates.

Results

% signal change

The neural difference between the whole persons and parts (the average of faces and bodies) were presented as a whole-part effect, as shown in Figure 1. For happy expressions, the significant whole-part effect was observed in face-selective area OFA and both-selective areas FG and STS. Paired t-tests revealed significantly higher responses to whole persons than parts in OFA ($t_{(19)} = 5.18$, $p < 0.001$), STS ($t_{(19)} = 2.14$, $p = 0.045$) and FG ($t_{(19)} = 2.16$, $p = 0.043$). Moreover, significantly more preferences for whole persons to parts in AMG ($t_{(19)} = 2.64$, $p = 0.016$), OFA ($t_{(19)} = 5.58$, $p < 0.001$), EBA ($t_{(19)} = 4.44$, $p < 0.001$), STS ($t_{(19)} = 3.19$, $p = 0.005$) and FG ($t_{(19)} = 4.35$, $p < 0.001$) were found. Unlike the responses for happy and angry expressions, only OFA showed significant responses to whole persons over parts ($t_{(19)} = 2.65$, $p = 0.016$) for fearful ones.
Figure 1. Results of univariate analysis. Mean time courses across voxels were extracted for each condition. The differences of percent signal changes between whole persons and the average of faces and bodies in each ROI were presented. OFA preferred to whole persons rather than parts for any emotion. EBA preferred to whole persons only for angry expressions. For happy or angry expressions, STS and FG preferred to whole persons. Error bars indicate SEM. *p < 0.05, **p < 0.01 and ***p < 0.001.

SVM classification

To examine the relative roles of brain areas involved in the perception of emotion and category, two classification analyses were performed. To eliminate the influence of voxel number on accuracy, we controlled the voxel numbers of each ROI to the same values. By using ANOVA feature selection to rank the features in an order from high to low, we selected same number of top voxels (20, 30, 40, 50, 60, 70, 80, 100, 200, 400, 800 voxels) for each ROI. Due to the small size of some ROI, the largest sizes they could reach were diverse (AMG: 60, IFG: 200, OFA: 200, EBA: 800, STS: 400, FG: 80, insula: 400). The classification performances were shown in Figure 2A and Figure 2B, which were then averaged among different voxel numbers.

For the classification analysis on emotion classification, one-sample t-tests showed that classification performances in emotions were significantly above the chance level (all p < 0.001) in 61 cases (7 ROIs with different sizes). And the emotion classification accuracies for the ROIs were ranked from high to low, with the order EBA, OFA, STS, FG, IFG, insula and AMG (shown in Figure 2C). The ANOVA analysis for precision ration with ROI and ROI size suggested a main effect for ROI ($F(10,190) = 17.17$, p < 0.001), ROI size ($F(10,190) = 96.67$, p < 0.001) which meant accuracy increased overall with it, and an interaction between them ($F(10,190) = 1.64$, p = 0.006). Paired t-tests revealed that body-selective area EBA made a greater contribution than any other regions, and the lowest was observed in face-selective area AMG (insula versus AMG: $t(19) = 4.77$, p < 0.001).

Second, classification performances in categories (face, body and whole person) were also found to be significantly above the chance level (all p < 0.001) in 61 cases. We ranked the ROIs from high to low according to the classification accuracies, resulting in a sequence of EBA, OFA, FG, STS, IFG, insula and AMG (shown in Figure 2D). The ANOVA analysis for accuracies with ROI and ROI size showed a main effect for ROI ($F(10,190) = 169.94$, p < 0.001), ROI size ($F(10,190) = 190.60$, p < 0.001) and a markedly interaction between them ($F(6,114) = 6.94$, p < 0.001). Paired t-tests indicated the performances of body-selective area EBA and face-selective area OFA exceeded those of the other five regions (EBA versus OFA: $t(19) = 1.21$, p = 0.241, OFA versus FG: $t(19) = 3.73$, p = 0.001), while AMG showed the lowest accuracy (Insula versus AMG: $t(19) = 4.73$, p < 0.001).
Figure 2. (A) Classification accuracies of emotion with the increase of the size of ROIs. (B) Classification accuracies of category with the increase of the size of ROIs (C) The averaged emotion classification results across various ROI sizes showed above chance discrimination among three emotions in all seven ROIs, and the most excellent classification performance was observed in EBA. (D) The averaged category classification results across kinds of ROI sizes demonstrated successfully discrimination in all ROIs of which EBA and OFA took over the highest accuracies than the other five regions. Error bars indicate SEM. *p < 0.05, * *p < 0.01 and * * *p < 0.001.

Discussion

We can conclude from our results that in most areas, the signal changes of whole persons were different with a simple average of the faces and bodies. Importantly, in all of the seven ROIs, emotion and body part classifications had the significant accuracies above chance level. EBA had the highest emotion and body part classification accuracies which were not influenced by voxel numbers. The relative classification accuracies in other brain areas were almost in line with a previous study [7, 10].

The present study represents an important step on understanding the emotion and body type representation in relevant brain regions. However, there were still some worth studying questions in the next work. First, the neutral emotion stimuli can be added into the experimental design and analysis. Thus, we can compare the differences between positive and neutral emotions, as well as negative and neutral emotions. That will make our study more rigorous. Second, the connections between brain regions in this study are still unknow. The next step can be achieved by applying causal modeling (DCM) or representational similarity analysis (RSA) to further explore the functional cross-linking between these brain areas.
Contribution
X.Y. and J.X. designed experiments. X.Y. performed experiments and analyzed data. X.Y. wrote the manuscript. J.X. contributed to manuscript revision.

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