Report

A Stable and Economic Paradigm for EBA and FBA Localization

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Abstract

Despite growing interest in the selective areas in the visual cortex for the processing of the human bodies, there are still many aspects we do not yet understand about the extrastriate body area (EBA) and the fusiform body area (FBA). In this study, a short experiment for the localization of the EBA and FBA in a single subject and group analysis using functional magnetic resonance imaging (fMRI) is presented. The subjects (n=15) were scanned watching images of body parts relative to motorbike parts as control stimuli. Our goal of the examined paradigm was to provide a method for a stable and economic localization of the EBA and FBA. The results showed significant activation for the presentation of body parts in the occipitotemporal lobe and fusiform gyrus, corresponding with spatial coordinates for EBA and FBA in previous studies. Furthermore, two clusters in the superior parietal lobule and the intraparietal sulcus showed significant activations. This suggests that the paradigm is suitable for the localization of EBA and FBA in single subjects and group analyses.

1. Introduction

To understand the visual perception of human bodies and faces is an essential part of understanding social interaction and behavior as well as an individual's perception of his or her body. While there has been a lot of insightful research about the visual cortex on human face-selectivity of the fusiform face area (FFA) (e.g. Halgren et al. 1999; Kanwisher, McDermott & Chun, 1997), the research on the neural mechanisms of the visual processing of human body parts has only been conducted since the early 2000. Downing, Jiang, Shuman and Kanwisher (2001) reported evidence from a series of functional magnetic resonance imaging (fMRI) experiments for a body-selective cortical region in the lateral occipitotempoal cortex, which they named "extrastriate body area" or EBA.

Further research conducted promising insights, but the processing of body parts and the function and anatomical structure of the EBA is still not understood in detail. So far there have been interesting empirical findings, such as the topographical organization of the occipitotemporal cortex and the EBA (Orlov, Makin & Zohary, 2010). Furthermore, several fMRI studies revealed another body-selective region in the posterior fusiform gyrus, the fusiform body area (FBA) (Peelen & Dowing, 2005), which partially overlaps with the FFA (Schwarzlose, Baker & Kanwisher, 2005; Taylor, Wiggett, & Downing, 2007).

Still, there is much more we need to understand about this complex cortical area. This is why there is a need for a stable and yet economic paradigm for the localization of the EBA. In this study, a short localizer fMRI experiment is presented, in which the subjects were scanned while watching multiple configurations of body parts relative to motorbike parts for less than 11 min. The reason for choosing motorcycle parts was the resemblance in structure compared to human body, as it consists of different conjoined elements and its handlebar and wheels appear similar to human limbs. As shown in various studies before, the distinct attributes of objects and body parts form a suitable contrast to localize the body-selective areas in the fusiform gyrus, as well as in the lateral occipitotemporal cortex (e.g. Schwarzlose et al., 2005; Orlov et al., 2010).

The hypotheses are that the examined paradigm can be used to localize EBA and at least one of the two FBAs in single subjects as well as in a group analysis in a short period of time. Beside our main hypotheses, we want to look for other cortical areas with significant activations during the paradigm and discuss their potential purpose and relation to EBA and FBA.

2. Methods

2.1 Participants

The sample consisted of 15 psychology students (4 male) from Freie Universität Berlin who were members of the seminar “Perception of Bodies: Functional Magnetic Resonance Imaging Study”. The average age was 21.67 (SD=0.87) with an age range of 21- 24. All participants had normal or corrected-to-normal vision and no history of neurological or psychiatric disorders.

2.2 MRI Acquisition

The scanning for the whole brain functional and anatomical images was conducted on a 3.0 T Magnetom TrioTim MRI scanner (Siemens, Erlangen, Germany) using a 12-channel head coil. A high-resolution 3D T1-weighted dataset was recorded for each participant (176 sagittal sections, 1 x 1 x 1 mm^3; 256 x 256 data acquisition matrix). Functional images were acquired using a T2*-weighted, gradient echo-planar imaging (EPI) pulse sequence recording 37 sections in interleaved order oriented roughly parallel to the anterior commissure- posterior commissure line at an in-plane resolution of 3 x 3 x 3 mm^3 (interslice gap=0; TE=30 ms; TR=2 s; FA=70°; FoV=192 x 192 mm^2; 64 x 64 data acquisition matrix). A total of 166 whole-brain volumes were recorded for each experimental run.

2.3 Task and Stimuli

After giving written informed consent, the subjects were placed in the scanner and instructed to focus on the fixation cross and to concentrate on the presented images throughout the experiment. The experimental stimuli were presented on a 19-inch diagonal screen at the end of scanner bore through a 45° mirror. Optical distance between screen and subject eyes was 80 cm. The stimuli consisted of a variety of coloured photographs of female and male hands and feet, as well as partial photographs of motorbikes showing either handlebars or wheels (example see Figure 1).

Figure 1: Stimulus examples. Body parts (hands and feet) and motorbike parts

The stimuli were presented in blocks with duration 20 s each, separated by 20 s resting intervals during which a white screen with a fixation cross was presented. 4 blocks with body parts and 4 blocks with motorbike parts were presented in each of the two runs. In total, the paradigm was 640s long (each run 320s). The order of body parts and motorbike parts blocks was randomized across participants. Each run consisted of 8 conditions (Table 1) with the blocks of hands and feet and the blocks of motorbike handlebars and wheels forming the contrasts.

Table 1: Conditions in each run

1	2	3	4	5	6	7	8
hands left	hands right	feet left	feet right	motorbike handlebars left	motorbike handlebars right	motorbike wheels left	motorbike wheels right

2.4 Data Analysis

Preprocessing and statistical analysis were performed using Matlab R2008 and SPM8 software. Head motion correction and slice time correction were applied on the two runs in order to correct for movement and to improve the signal-to-noise ratio in the data. The functional images were then spatially realigned to correct for motion across and within sessions of an individual subject. To improve the following normalization, the functional images were co-registered to a high-resolution anatomical T1 image. The images were then normalized to the Montreal Neurological Institute (MNI) template and smoothed (three-dimensional 8 mm Gaussian kernel). To create an activation map of the volume data, we calculated P-values for the contrast (body parts vs. motorbike parts) for each voxel in the individual subjects and one sample t-tests for the group analysis.

3. Results

3.1 Single Subject Analysis

The analysis of a single subject, a 21-year-old female student, revealed 4 significant blood oxygenation level-dependent (BOLD) signals in the experimental condition compared with the control condition. The slices in Figure 2 show a significant cluster in the lateral occipitotemporal cortex of the right hemisphere [51, -70, -2] ($p<0.001$ (unc.)) and a corresponding significantly increased peak-level signal in the left hemisphere of the lateral occipitotemporal cortex [-48, -79, -8] ($p<0.001$(unc.), $T=4.98$). Furthermore, a significant peak-level activation in the right fusiform gyrus [48, -46, -26] ($p=0.011$(unc.), $T=2.31$) and a significant cluster in the right superior parietal lobule [48, -43, 64] (p=0.002(unc.)) were found (Figure 2). The signal change for the experimental condition relative to the control condition can be viewed in Figure 3.

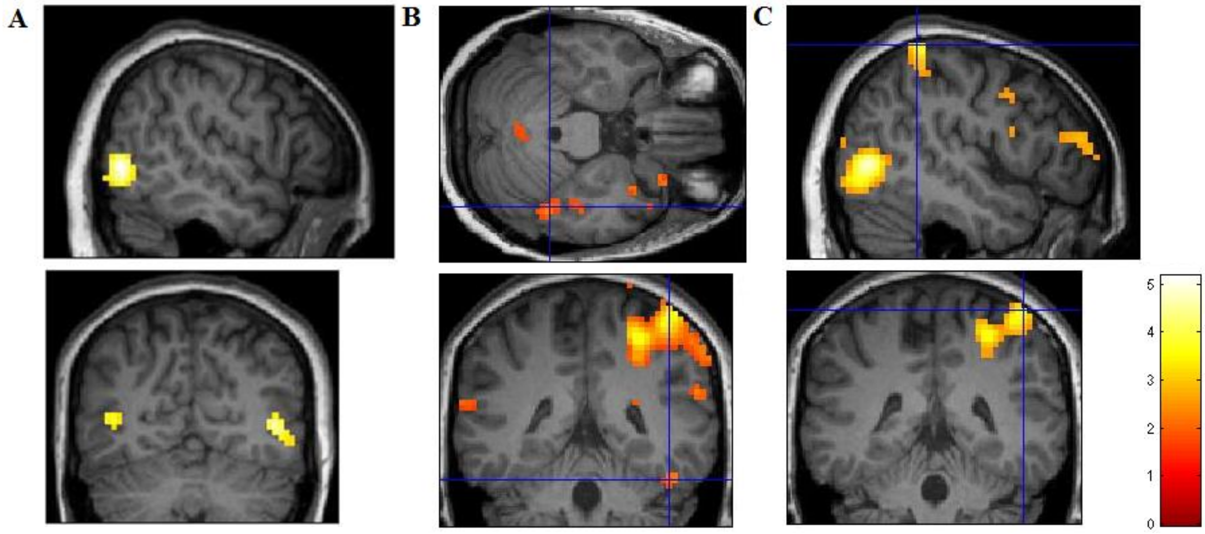

Figure 2: Slices from a single subject. Contrast: body vs. motorbike. **(A)** Sagittal and coronal slices showing the left and right occipitotemporal cortex, p< 0.001 (unc.), height threshold T = 3.12, extent threshold k= 10 voxels. **(B)** Axial and coronal slices of the right fusiform gyrus, height threshold T=1.65, p<0.05(unc.). **(C)** Sagittal and coronal slices showing the activation in the right superior parietal lobule.

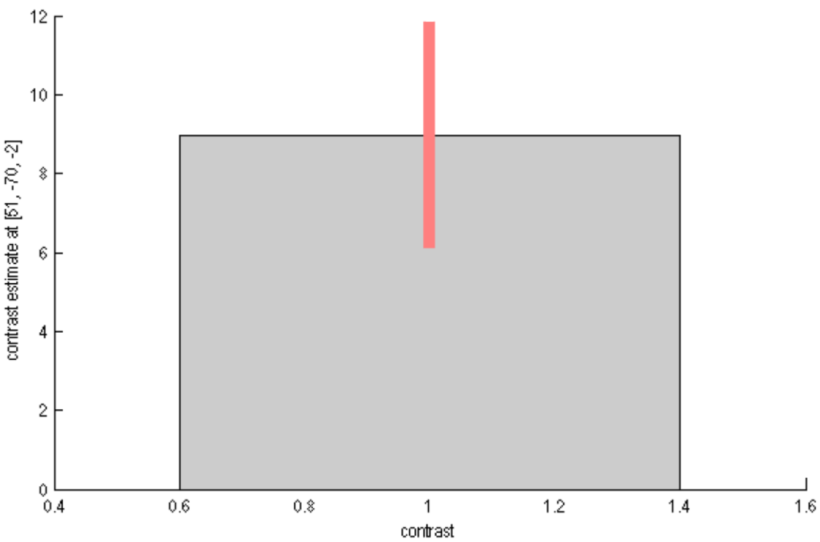

Figure 3: The signal change in the peak level of the EBA between the body vs. motorbike parts condition in the single subject analysis. Contrast (body > motorbike) estimates and 90% confidential interval (C.I.). Error bars indicate standard deviation. The signal change is summed over all contrasts and has to be divided by 8 to receive the average signal change.

3.2 Group Analysis

The group analysis of the contrast body parts vs. motorbike parts showed an activation pattern similar to the one in the individual subject. Figure 4A shows two significant cluster activations in the left and right occipitotemporal cortex (left: -54,-67, 1, p< 0.0001 (unc.); right: 54, -67,-2, p< 0.0001 (unc.)). Besides, significantly increased peak-level activation in the left fusiform gyrus [-42, -58, -17] (p<0.00001 (unc.), T=4.36), as shown in Figure 4B, and a significant cluster in the superior parietal lobule (Figure 4C) with the average spatial coordinates: [-30, -43, 49] (FWE corrected, p < 0.05, T=8.33) were revealed.

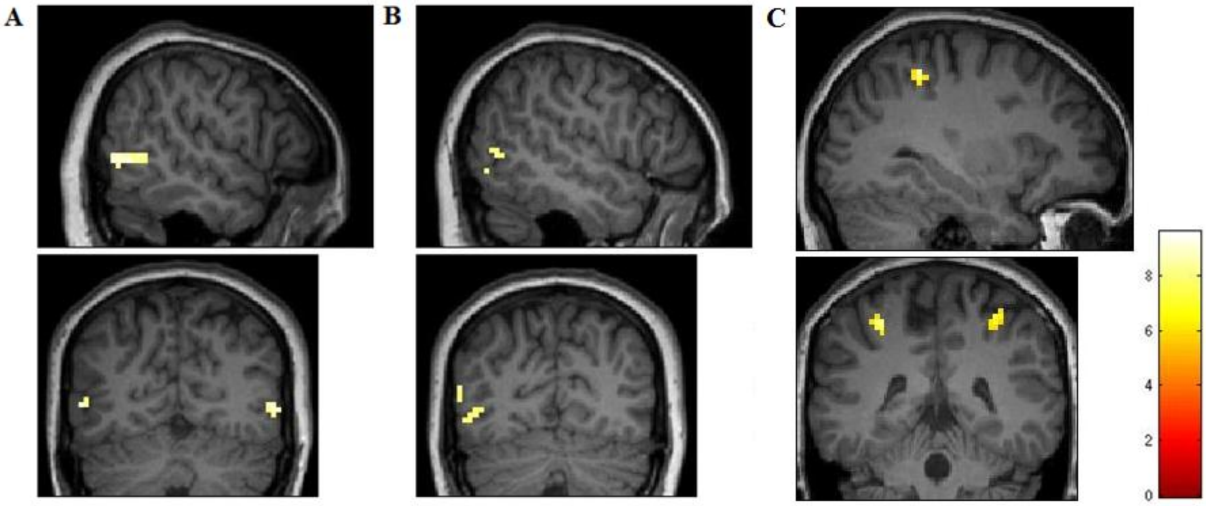

Figure 4: Sagittal and coronal slices from the group analysis. Contrast: body vs. motorbike. **(A)** Left and right occipitotemporal cortex, p< 0.0001 (unc.), at height threshold T =7.53, extent threshold k=5 voxels. **(B)** Left fusiform gyrus, p<0.00001 (unc.), height threshold T=7.53, extent threshold k=5 voxels. **(C)** Superior parietal lobule, p<0.001 (unc.), height threshold T=5.69, extent threshold k=10 voxels.

In Figure 5, the signal changes, averaged across the group, for the right occipitotemporal cortex and the fusiform gyrus during the experimental condition compared to the control condition are shown.

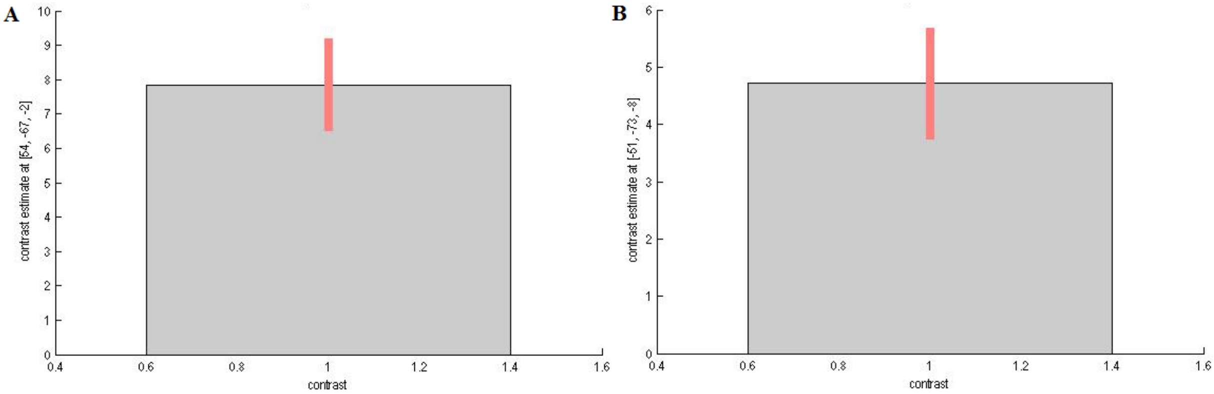

Figure 5: Signal change across the subjects. Contrast (body > motorbike) estimates and 90% C.I. Error bars indicate standard deviation. The signal change is summed over all contrasts and has to be divided by 8 to receive the average signal change. **(A)** Change in the peak of the right occipitotemporal lobule. **(B)** Change in the peak in the fusiform gyrus.

4. Discussion

In sum, the significantly increased activations in the occipitotemporal lobule in the single subject and the group analysis, correspond with the spatial coordinates for the EBA as identified in previous studies (e.g. Downing et al. 2001 [left: -51, -72, 8; right: 51, -71, 1];

Spiridon, Fischl & Kanwisher, 2006 [left: -58.2,-72.3, 4.7; right: 32.0, -67.6, -5.8]). In addition, the BOLD signals in the right fusiform gyrus in the single subjects and the cluster in the left fusiform gyrus in the group analysis are analogous to the FBA as reported by various studies before (e.g. Peelen & Downing, 2005b [right: 40, -43, -17]; Orlov et. al, 2010 [left: -40, -39, -21; right: 40, -44, -15]. Nevertheless, it should be noted, that the activation in the single subjects analysis for the FBA was only found with a p-Value of <0.05(unc.). This might be due to the characteristics of the stimuli, which presented body parts and not whole bodies. Taylor et al. (2007) showed a higher sensitivity of the FBA for torsos rather and limbs. In following studies, it should be examined, what kind of stimulus would be more appropriate to locate the FBA in individual subjects.

Beside the body-selective areas, the experiment revealed significantly increased areas in the parietal lobe. In the single subject analysis, the activation was found in the right superior parietal region. This area has been associated with feature conjunction (Baumgartner et al., 2013) and visuospatial attention (Corbetta, Miezin, Shulman & Petersen, 1993; Wardak, Olivier & Duhamel, 2004). In the group analysis, the parietal activity was found in the left superior parietal lobule/ intraparietal sulcus. Rushworth, Paus and Sipila (2001) showed in an event-related fMRI study, that the intraparietal sulcus is part of a network with the angular sulcus and critical for visual attention shifts.

Overall, one can say that the presented paradigm can be used for an economic and stable localization of the EBA in individuals as well as in group analysis corresponding with the spatial coordinates, previously found in fMRI studies. At least one of the FBAs (left or right) was also found in the analyses. These findings lead to the conclusion, that this paradigm can be used to gain more information on the variety of anatomical structures of the EBA and FBA between individuals, as well as its function in the processing of human bodies and body parts. Nevertheless, the experiment revealed potential needs for improvement on the single subject level. In addition, further research would be useful in order to investigate whether a single run would be sufficient to localize EBA and FBA. It would also be interesting to compare the perception of one’s own body parts vs. another person’s body parts and to investigate, whether the way of presenting the stimulus (e.g. 2- vs. 3-dimensional) influences the activity in EBA and FBA, as it may be of importance for the integration of the stimuli into one’s body scheme. Furthermore, it could be interesting to look into cultural differences in the activation of EBA and FBA (e.g. collectivist vs. individualistic cultures).

5. References

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Persönliche Erklärung

Ich, Sophia Rekers, versichere, diese Hausarbeit selbstständig und lediglich unter Benutzung der angegebenen Quellen und Hilfsmittel verfasst zu haben. Ich erkläre weiterhin, dass die vorliegende Arbeit noch nicht im Rahmen eines anderen Prüfungsverfahrens eingereicht wurde.

Berlin, den 15.08.2013

S. Rekers