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Research Report

Task difficulty in a simultaneous face matching task modulates activity in face fusiform area

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Abstract

The level of difficulty of a task can alter the neural network that activates for performance of the task. Previous studies have shown increased activation with task difficulty in the frontal lobes while the effects in the extrastriate visual areas have been unclear. We hypothesized that the face fusiform area (FFA), an area specialized for face processing, would increase activation as task difficulty increased in a face matching task. The difficulty level was increased by degrading the quality of the images. The degradation levels were 10%, 20%, 40% and 60%. Based on the correct response rate, the data were divided into a baseline level (composed of non-degraded and 10% degraded images) and a difficult level (composed of the 20%, 40% and 60% degraded images). Brain activation was measured using functional magnetic resonance imaging. The baseline face matching task activated a wide network of regions that included bilaterally the occipital, temporal and parietal lobes and the right frontal lobe. A novel behavioral finding was that task difficulty did not linearly increase with image degradation. The novel brain imaging finding was that the FFA is modulated by task difficulty and performance in the task was linearly correlated to activation in FFA. In addition, we found that activation in the dorsolateral prefrontal cortex (DLPFC) had increased activation as task difficulty increased. When adding the response time as a covariate, the differences in the DLPFC did not remain statistically significant. Increased task difficulty also led to a decrease in activation of visual areas in the extrastriate cortex. Task difficulty increased activation in the FFA to enhance the face processing and suppressed activation in visual extrastriate areas that processed low level properties of the stimuli. Task difficulty led to enhanced response in the FFA and suppressed response in other visual areas.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Functional magnetic resonance imaging; Face processing; Object matching

1. Introduction

The human brain adapts to the demands placed upon it. Increasing the amount of effort to perform a perceptual task can affect how information in the visual system is processed. Task difficulty can be increased through stimulus degradation, which decreases the perceptual discriminability and enhances decision. One specialized perceptual area is the "face fusiform area" (FFA) defined as a region selectively activated in response to face stimuli (among them [15,43,45,77,80]). Previous studies have shown that the FFA was modulated by selective attention [60,80], and by working memory load [19]. Single unit recording in primates have documented the existence of face-selective and object selective neurons in the inferior temporal lobe and superior temporal sulcus [4,5,67,71,82]. In humans, the homologue to primate face

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selective region is the face selective region in the fusiform gyrus.

Given that the FFA can be modulated by attention and working memory load, one would expect that task difficulty would also modulate the FFA, with greater activation as task difficulty increased. Previous studies have found that activation in the early sensory areas decreased [30] or increased [39] as task difficulty was increased. A possible factor that may explain the differences was the decrease in the number of trials as task difficulty increased [30] or the loudness of the noise in the auditory stimuli increased as task difficulty increased [39]. Thus there was a confounding variable in investigating the effects of task difficulty in the sensory processing areas. We wished to investigate this issue further, in particular, the behavior of the FFA. We hypothesized that the FFA would increase activation as task difficulty increased. In addition, we thought it unlikely that activation in other visual areas would be suppressed. The effects of difficulty level on the FFA was investigated in a simultaneous perception-matching task utilizing the blood oxygen dependent level (BOLD) signal measured using functional magnetic resonance imaging (FMRI) as a measure of brain activation. In addition to our prediction of the FFA, we expected that the right DLPFC and ACC would be modulated by task difficulty as was shown by previous studies [30,40]. We examined the activation magnitude using a region of interest (ROI) analysis that included four ROIs in the right hemisphere: the DLPFC, the ACC, the FFA and the anterior fusiform gyrus. The ROI in the anterior fusiform gyrus was to demonstrate that the effects of task difficulty in the FFA, DLPFC and ACC were not due to differences in arousal. Task difficulty was modulated by varying the image quality of the faces presented from no degradation to 60% of the pixels in the face image replaced by random valued pixels. Based on the accuracy of the responses for each run, we divided the different runs into a baseline level and a difficult level. The number of trials and luminance of the images were kept constant across the different runs. In addition, we replicated previous findings using a voxel-based analysis approach.

2. Methods

2.1. Subjects

There were 14 healthy right-handed subjects (6 men/8 women) with an average age (standard deviation) of 26.8 (4.9) years. All subjects gave written informed consent to participate in the study after the study was explained to them. The subjects did not have a history of neurological or psychiatric illness. The study was performed in accordance with the Declaration of Helsinki and the Ethics Committee of the Faculty of Medicine of Ludwig Maximilian University approved the study. All subjects had normal or corrected to normal vision.

2.2. Stimuli and tasks

Two faces were presented simultaneously and participants were asked to decide in each trial if a pair of faces was identical or not. If identical, the subject responded by pressing a button held in the right hand using the thumb. No response was required if the faces were dissimilar. Each trial in the task, as illustrated in Fig. 1, had 2 squares in which two identical or dissimilar faces were placed. The faces were grey scale stimuli where only the face was visible. Each trial was 2.8 s long with an interval between pairs of faces of 0.318 s. There were 8 trials per block and there were 3 blocks of the task in each run. There were 4 blocks of the control task in each run. At the beginning of each block, there was a 7.2-s task instruction. There were 5 face matching tasks which were: no degradation of the images, 10%, 20%, 40% and 60% degradation. There was one run for each of the face degradation levels. The different conditions were counter-balanced across subjects. Eighty percent of the trials had identical pair of faces. The 10% degradation was measured on 11 from 14 subjects (with 3 subjects the acquisition of the response was not recorded due to equipment malfunction) and the 60% condition was measured on 10 from 14 subjects (data from 4 subjects not measured by chance). The faces were obtained from the

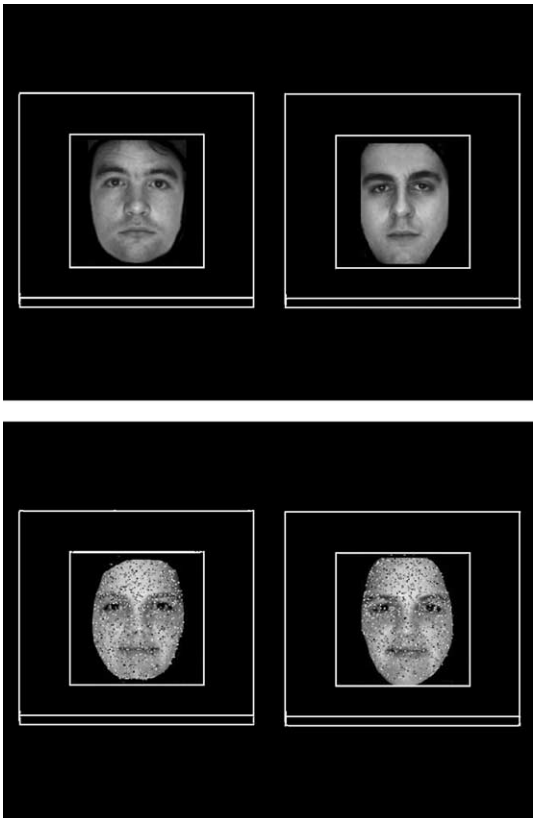

Fig. 1. Illustration of the cognitive task with a stimulus example with no degradation and one with 40% degradation. Random pixels were selected from each image, and converted to grey level such that the luminance did not change from the original image.