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The influence of familiarity on brain activation during haptic exploration of 3-D facemasks

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Abstract

Little is known about the neural substrates that underlie difficult haptic discrimination of 3-D within-class object stimuli. Recent work [A.R. Kilgour, R. Kitada, P. Servos, T.W. James, S.J. Lederman, Haptic face identification activates ventral occipital and temporal areas: an fMRI study, Brain Cogn. (in press)] suggests that the left fusiform gyrus may contribute to the identification of facemasks that are haptically explored in the absence of vision. Here, we extend this line of research to investigate the influence of familiarity. Subjects were trained extensively to individuate a set of facemasks in the absence of vision using only haptic exploration. Brain activation was then measured using fMRI while subjects performed a haptic face recognition task on familiar and unfamiliar facemasks. A group analysis contrasting familiar and unfamiliar facemasks found that the left fusiform gyrus produced greater activation with familiar facemasks.

Keywords: Object recognition; Perceptual learning; Face recognition; fMRI; Haptics

Object recognition is one of the most important cognitive operations that people perform. Objects surround us constantly and to direct the appropriate actions toward these objects first requires successful identification. From an evolutionary perspective, the ability to reliably recognize objects is extremely adaptive because of the need to identify predators, edible foods and conspecifics. Furthermore, for social organisms such as humans, specialized forms of object recognition such as face recognition are extremely important for maintaining normal social interactions. The fact that face recognition seems relatively effortless is a clue to its special nature. Despite the similarity in geometric structure between different human faces, which should make face recognition extremely difficult, we tend to recognize faces with the same facility as other objects that are less similar [30,31]. Most of the evidence points to the existence of specialized brain systems in humans for processing visual stimuli of special significance, such as faces [9,13,28].

The majority of studies investigating object recognition in humans use visual stimuli, because humans are predominantly visual animals. Nevertheless, to attain a more thorough understanding of object recognition processes, they should be studied using input through multiple sensory systems. Theories of object recognition, which have been developed largely based on visual data, can be elaborated or constrained by the inclusion of data from other sensory systems. Of the other possible sensory inputs, recognition through haptic exploration (active touch) may be the most informative, because vision and touch share the ability to extract information about the complex geometric structure of objects [2,3,20,22,23,26]. Furthermore, there is ample evidence that object recognition tasks carried out using visual or haptic information rely on overlapping brain regions. In particular, parts of the lateral occipital complex (LOC [21]) appear to be involved in both visual and haptic exploration of objects [11,25] and these same brain regions are more responsive to objects than to textures [1] or nonsense objects [27]. Responses in LOC are also modulated by previous experience. Previous haptic or visual experience with objects increased activation in these regions when the same objects were subsequently viewed [11]. Finally, visual and haptic object activations in ventral occipital and tem-

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poral cortex show patterns that are distinctly category-specific [25]. Together, these studies suggest that there are significant similarities between visual and haptic object recognition for both behavioral and neural measures, not just for object recognition in general, but also for specific categories of objects.

The general aim of the present study was to investigate the neural substrates involved in haptic face processing. Previous work [17] shows that haptic exploration of a face can convey sufficient information to successfully perform a face identification task. Furthermore, a study of an individual with prosopagnosia (inability to recognize visual faces) revealed that the individual also had difficulty recognizing faces haptically, even though control objects were recognized normally [15]. Prosopagnosia is thought to involve injury to the ventral temporal cortex and in particular the fusiform gyrus, predominantly in the right hemisphere [4,32]. The lesion data is consistent with fMRI studies that find stronger activation in the fusiform gyrus for faces than for other objects, with a stronger selectivity in the right hemisphere [13,28]. A recent fMRI study, however, found unilateral activation of only the left fusiform gyrus during haptic face identification [16]. Therefore, haptic face identification, like visual face identification, involves the fusiform gyrus, although the subregions of the fusiform gyrus that are recruited by visual and haptic face identification may be different.

The majority of studies investigating the role of the fusiform gyrus in face identification use unfamiliar faces; however, several studies [6,14,18,29] suggest that activation in the fusiform gyrus is influenced by familiarity of object stimuli. These findings, however, have come exclusively from visual experiments and, as mentioned earlier, to further our understanding of cognitive processes, it is important to include different sensory inputs. The role of the fusiform gyrus was previously investigated in its relation to haptic face identification [15,16]. In the following experiment, we extend these results by investigating the influence of familiarity on brain activation during haptic face exploration. Whether or not familiar faces produce greater or lesser activation than unfamiliar faces is somewhat ambiguous based on previous studies of visual face recognition; however, in most studies, experience with unfamiliar faces caused an increase in activation [10,12,14,18] (but see [29]). Thus, we predict an increase in activation in the left fusiform gyrus for familiar faces over unfamiliar faces when haptically explored.

Fourteen volunteers (seven male and seven female) between the ages of 22 and 30, all of whom gave written informed consent in accordance with the Declaration of Helsinki, participated in this study. The study was approved by the ethical review boards of both Queen's University and the University of Western Ontario. All subjects reported right-handedness, normal tactile sensation and no history of neurological disorders.

A set of 36 3-D clay facemasks were used as stimuli. As described in detail elsewhere [17], these facemasks were created using plaster molds of live faces. Examples are shown in Fig. 1. For each subject, 18 of the 36 facemasks were randomly chosen for use during the training phase leaving 18 facemasks that remained unfamiliar to the subject. During the scanning phase, subjects lay in a supine position within the scanner bore with a Plexiglas "table" placed over the lower half of the body, with the front edge at about the level of the abdomen (Fig. 2). On top of the table was a guide with a sliding a platform that supported one of the facemasks. Use of the table apparatus allowed the experimenter (who stood next to the scanner) to slide a new facemask into the bore within the reach of the subject's hand for each trial.

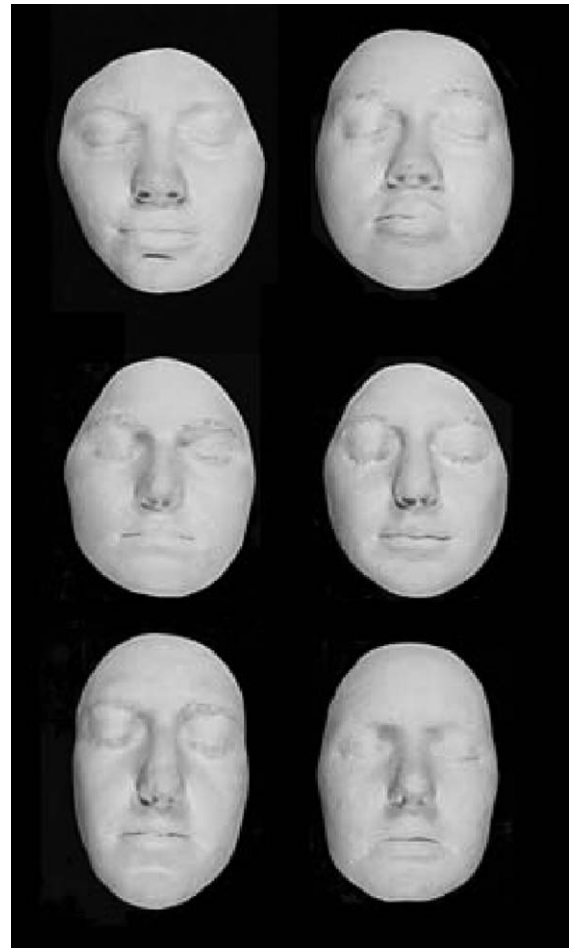

Fig. 1. Examples of clay facemasks.

Each subject was individually trained at the Touch Laboratory of Queen's University (Kingston, Canada) to identify a set of 18 facemasks by name. During training, subjects were kept under conditions similar to those under which they would be tested during the scanning phase. That is, each subject lay blindfolded on a bench in a supine position and the stimuli were presented at approximately abdomen level. Subjects explored the facemasks with their left hand. Training continued until subjects were able to identify facemasks with 100% accuracy and within ∼7–8 s. On average, it took 10–12 h of training to satisfy our highly demanding criteria for acceptable haptic identification.

During the scanning phase of the study, subjects performed a haptic face recognition task while brain activation was measured using fMRI. Facemasks were presented to the subject in a slow event-related design using the table apparatus described above. Subjects lay supine within the scanner bore, blindfolded, with their head secured firmly in the head coil with foam padding.