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Representations of individuals in ventral temporal cortex defined by faces and biographies

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ABSTRACT

The fusiform gyrus responds more strongly to faces than to other categories of objects. This response could reflect either categorical detection of faces or recognition of particular facial identities. Recent fMRI studies have attempted to address the question of what information is encoded in these regions, but have reported mixed results. We tested whether the creation of richer identity representations via training on visual and social information, and the use of an adaptation design, would reveal more robust representations of these identities in ventral temporal cortex. Examining the patterns of activation across voxels in bilateral fusiform gyri, we identified unique patterns for particular identities. Attaching distinctive biographical information to identities did not increase the strength of these representations, but did produce a grouping effect: faces associated with the same amount of biographical information were represented more similarly to each other. These results are consistent with the possibility that identity exemplars are represented in posterior visual areas best known for their role in representing categorical information, and suggest that these areas may be sensitive to some forms of non-visual information, including from the social domain.

1. Introduction

Multiple regions in ventral temporal cortex, including the lateral fusiform gyrus (FG), respond more strongly to faces than to other categories of objects (Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997; Tsao, Moeller, & Freiwald, 2008). However, since individual faces convey both category-level and exemplar-level information, these regions could be involved in the categorical detection of faces or the differentiation between specific face exemplars. Neuroimaging techniques such as adaptation and multi-voxel pattern analysis (MVPA) have been used to address the question of what these regions represent.

Univariate analyses of the FG have revealed adaptation for repeated versus novel facial identities (Rotshtein, Henson, Treves, Driver, & Dolan, 2005; Verosky & Turk-Browne, 2012). In such studies, the FG response measured by functional magnetic resonance imaging (fMRI) is attenuated when two faces depicting the same identity are shown sequentially, despite changes in physical properties such as viewpoint. Although multivariate analyses have revealed that distributed patterns of activation in ventral temporal cortex convey information about object categories (Haxby et al., 2001), finding patterns associated with specific identities has proven more difficult. Two published studies have found evidence for identity-specific patterns in the right anterior temporal lobe (ATL; Kriegeskorte, Formisano, Sorger, & Goebel, 2007; Nestor, Plaut, & Behrmann, 2011), but only one of them additionally found evidence for such patterns in the FG (Nestor et al., 2011). In the present study, we replicate and extend this novel finding.

While previous studies have tended to define identity in terms of visual features, identity representations in everyday life are much more complex. For instance, mere acquaintances see each other multiple times, know each other's names, and often know detailed social information about each other (e.g., group membership). Becoming familiar with someone in one or more of these ways alters face processing in the brain: familiar faces engage a broad network of regions more strongly than unfamiliar faces (Gobbini & Haxby, 2006, 2007; Todorov, Gobbini, Evans, & Haxby, 2007; Cloutier, Kelley, & Heatherton, 2011). Many of these regions are involved in processing emotional and social information, and such higher-level knowledge may influence how identity is represented in perceptual brain regions.

Behaviorally, face recognition is superior for familiar versus unfamiliar faces across changes in visual properties (such as lighting, viewpoint, context, and emotional expression; Johnston & Edmonds, 2009), indicating that experience produces more invariant facial identity representations. Research in other domains further supports

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this notion. In the developmental literature, for example, teaching infants to individuate versus categorize monkey faces with verbal labels prevents a later decline in the ability to discriminate between those faces resulting from perceptual narrowing (Scott & Monesson, 2009). In the social psychological literature, warning subjects about the cross-race recognition deficit—that face recognition is worse for faces from other races—can reduce or eliminate the effect, suggesting that the deficit partly results from categorization of out-group members (Hugenberg, Miller, & Claypool, 2007). Together, these studies suggest that learning to individuate others through everyday interactions, verbal labels, or by increasing motivation, improves face processing.

Here we test whether richer experience with a set of identities produces neural representations that can be better identified in ventral temporal cortex. Prior to scanning, subjects completed a behavioral training task in which they saw multiple identities from different viewpoints and learned to associate each identity with a unique name. For half of the identities, subjects also learned fictional biographical information about that person. During a subsequent fMRI session, subjects were presented with sequential pairs of faces followed by pairs of names. For each pair of faces, the two faces depicted either the same identity or different identities. In univariate analyses, we measured whether there was an attenuated response to pairs of faces where the identity was the same versus different (fMRI adaptation or repetition suppression; Grill-Spector, Henson, & Martin, 2006; Turk-Browne, Scholl, & Chun, 2008) in bilateral FG regions of interest (ROIs). In multivariate analyses, we created an activation map for each identity and correlated these maps across runs within each ROI. We tested whether the activation maps for a given identity were more highly correlated with themselves than with those for other identities, which would provide evidence of distributed identity representations.

Additionally, we tested how learning biographical information influences identity representations in FG. For univariate analyses, we examined whether biographical information influences identity adaptation. For multivariate analyses, we considered two possibilities. First, biographical information might enhance the strength of representations for specific identities, such that the pattern correlation for the same identity across runs should be greater if it was versus was not associated with biographical information. Second, biographical information might affect identity representations more generally by adding a new dimension of information, in which case a given identity should show greater pattern correlations with other identities that were associated with the same amount of biographical information.

2. Materials and methods

2.1. Subjects

Twenty-two subjects participated in the study for monetary compensation (5 males; mean age = 22.2 years, range = 18–37 years). Informed consent was obtained for a protocol approved by the Princeton University Institutional Review Board. All subjects were right-handed, had normal or corrected-to-normal vision, and reported no history of neurological or psychological disorders. The data from two subjects were excluded from analysis due to excessive head motion (greater than 3 mm in one or more runs), resulting in a final sample of 20 subjects.

2.2. Stimuli

Color photographs of 16 female facial identities from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt, & Ohman, 1998) were used as stimuli. For each identity, there were three photographs: one facing forward and two with the head turned 30–40° to the left and right. The individuals displayed neutral facial expressions and eye gaze matched head direction.

2.3. Procedure

2.3.1. Training task

The day before the scan or earlier in the day of the scan, subjects completed a training task in which they learned a name for each face (Fig. 1). Faces were randomly assigned one of the twenty most popular female baby names for 1989 (www.ssa.gov/oact/babynames). This year was chosen to roughly match subjects' birth year, to ensure that they were familiar with the names. In addition, eight of the 16 faces were randomly paired with short biographical vignettes (mean words = 186, SD = 9). Four vignettes were primarily negative in tone and four were primarily positive (Appendix A in Supplementary material). We were not interested in valence effects due to limited power for examining such differences, but rather included valenced information to make the vignettes more memorable. Training was conducted by cycling between two phases, learning and test, until subjects reached criterion.

During the learning phase, subjects saw 16 identities, presented one at a time in a random order. For each identity, a name appeared in the center of the screen. When the subject pressed the space bar, the task forwarded to the next screen. For identities paired with biographical information, a paragraph of the associated vignette appeared in the center of the screen. Each vignette was broken into two paragraphs, shown on alternating blocks of the training task. Subjects were instructed to read the biographical information carefully and to try to form an impression of the person based on it (Hamilton, Katz, & Leirer, 1980). Subjects were not asked to recall the biographical information during the training or main tasks, but they were given a surprise memory

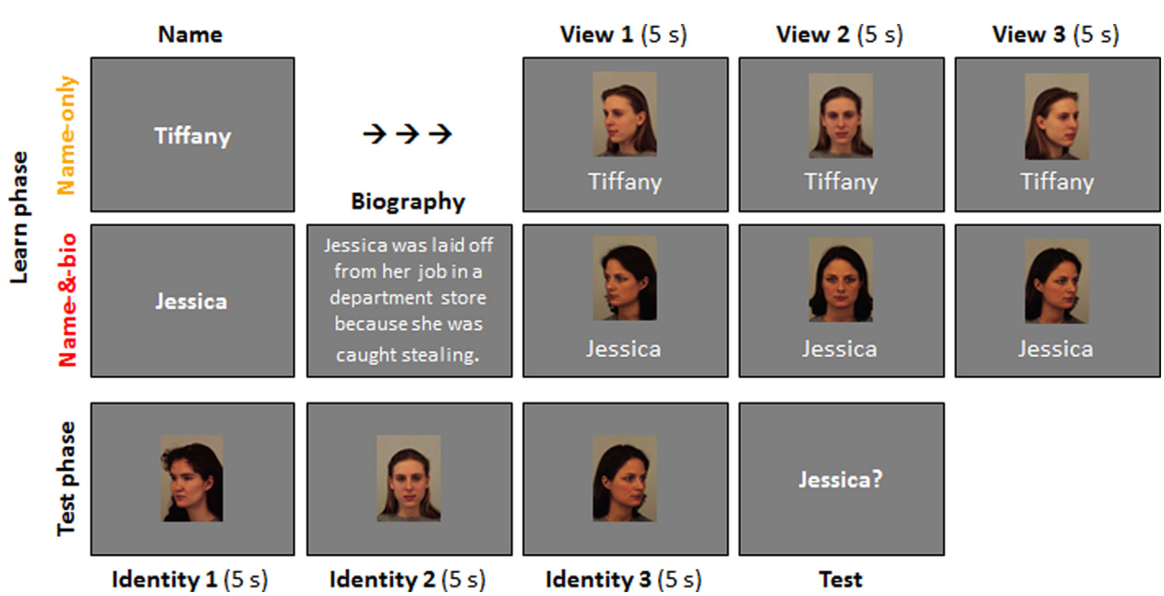

Fig. 1. Training task. On each trial of the learning phase, subjects were shown a name followed by three views of that facial identity. For faces associated with biographies, the biographical information appeared immediately after the name but before the faces. On each trial of the test phase, subjects were shown views of three different facial identities followed by a name and chose which face matched the name.