

THE NEURAL REPRESENTATIONS OF SOCIAL STATUS: AN MVPA  
STUDY

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## ABSTRACT

Status is a salient social cue, to the extent that it shapes our attention, judgment, and memory for other people, and it guides our social interactions. While prior work has addressed the traits associated with status, as well as its effects on cognition and behavior, research on the neural mechanisms of status perception is still relatively sparse and predominantly focused on neural activity during explicit status judgments. Further, there is no research looking at the involvement of person-processing networks in status perception, or how we embed status information in our representations of others. In the present study I asked whether person-specific representations in ventral face-processing regions (occipital face area (OFA), fusiform face area (FFA)) as well as more anterior regions (anterior temporal lobe (ATL) and orbitofrontal cortex (OFC)) contain information about a person's status, and whether regions involved in affective processing and reward (amygdala, ventral striatum) decode status information as well. Participants learned to associate names, career titles, and reputational status information (high versus low ratings) with objects and faces over a two-day training regimen. Object status served as a nonsocial comparison. Trained stimuli were presented in an fMRI experiment, where participants performed a target detection task unrelated to status. MVPA revealed that face and object sensitive regions in the ATLs and lateral OFC decoded face and object status, respectively. These data suggest that regions sensitive to abstract person knowledge and valuation interact during the perception of social status, potentially contributing to the effects of status on social perception.

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## CHAPTER 1

### INTRODUCTION

Both humans and non-human primates rapidly assign status information to others based on a host of variables, such as physical size, lineage, financial status, and reputation. This ranking of group members, or the formation of social hierarchies, is highly pervasive across human cultures (Sidanius & Pratto, 1999), and appears spontaneously in both human and primate social groups (Anderson, John, Keltner, & Kring, 2001; Berger, Rosenholtz, & Zelditch, 1980; Chase, Tovey, Spangler-Martin, & Manfredonia, 2002; Gould, 2002; Magee & Galinsky, 2008).

Given the natural variation in skills, knowledge, and traits, differences in status are inherent to social relationships, and social animals are adept at perceiving such inequalities. Both humans and primates rapidly assign status information to unfamiliar others (Deaner, Khera, & Platt, 2005; Moors & Houwer, 2005; Paxton, Basile, & Hampton, 2011), even when observing third-party interactions (Mascaro & Csibra, 2012; Paxton, Basile, & Hampton, 2011). Humans also demonstrate high levels of consistency with status judgments regarding themselves and others (Anderson, Beer, Spataro, & Chatman, 2006), suggesting status is both a salient and reliable social cue.

The automatic tendency to assign status to group members may serve an important function: understanding where we rank relative to others provides essential information regarding our social roles and how to behave in social interactions, and facilitates intergroup cooperation and function (Halevy, Chou, & Galinsky, 2011; Savin-Williams, 1979). Thus, the ability to rapidly identify and respond to status information in others may be essential to the existence and maintenance of social groups. Those

individuals with higher status tend to possess more power and influence, and display more dominance, than lower status individuals (Fragale, Overbeck, & Neale, 2011; Mazur, 1985; Zitek & Tiedens, 2012). The ability to rapidly recognize higher status in others may be especially important given the potential threat associated with these individuals (Galinsky, Magee, Inesi, & Gruenfeld, 2006).

Several behavioral studies illustrate the salience of status information by demonstrating its impact on social attention and cognition. For instance, monkeys will forgo a juice reward to view high ranking members of the group, but require juice overpayment to view lower ranking members (Deaner et al., 2005), suggesting that viewing high-status group members has a high value to the degree that doing so can trump intrinsic caloric rewards. Humans demonstrate a similar bias as shown by our tendency to fixate high status, as compared to low-status speakers more often and for longer periods of time (Foulsham, Cheng, Tracy, Henrich, & Kingstone, 2010). Attentional biasing effects of status are revealed in dynamic aspects of attention as well. Gaze patterns serve as an indicator of dominance relationships in both monkeys and humans with low-status members rapidly attending to and following the gaze of their superiors (Deaner et al., 2005; Jones et al., 2010; Shepherd, Deaner, & Platt, 2006) and this effect appear to be involuntary (Jones et al., 2010). Interestingly, the averted gaze of high-status individuals influences subtle and immediate shifts in attention even when faces are unfamiliar and status is implied via fictional career information (Dalmaso, Pavan, Castelli, & Galfano, 2012). Thus, reputation alone can elicit status-based attentional biases.

Evidence of the impact status has on social cognition, as well as the function and prevalence of social hierarchies, suggest that we not only rapidly assign status

information to others, but we rely heavily on this information in our social interactions. Recent studies have attempted to understand the neural basis of these effects, and have identified regions involved in rank and magnitude, affective and value/reward processing, and executive processing, involved in making status judgments (Chiao et al., 2009; Ly, Haynes, Barter, Weinberger, & Zink, 2011; Mason, Magee, & Fiske, 2014; Zink, Tong, Chen, Bassett, & Stein, 2008). However, it is presently unclear where in the brain abstract information about an individual's status is represented, and how neural signals contribute to influences of status information on social cognition.

In the next sections, I briefly summarize the current literature regarding status processing in the brain, and then introduce regions involved in face processing and conceptual knowledge that have yet to be explored in the context of status perception.

### The Neural Basis of Social Status Processing

The complexity of status processing likely requires a large network of neural regions, including those involved in general rank-ordering and social cognition, as well as those involved in social valuation and person perception. Here I summarize the current literature regarding status processing in the brain.

#### *Perceptions and Judgments of Status*

Prior neuroimaging studies have demonstrated activation in the inferior intraparietal sulcus (IPS) when making social and nonsocial status judgments (Chiao, Bordeaux, & Ambady, 2004; Chiao et al., 2009; Mason, Magee, & Fiske, 2014). Additionally, frontal regions involved in executive processes are sensitive to status cues, but in a vague, underspecified way. Several studies link activity in the ventrolateral prefrontal cortex (VLPFC), dorsolateral prefrontal cortex (DLPFC), and medial

prefrontal cortex (MPFC) with social status perceptions or judgments (Cloutier & Gyurovski, 2014; Farrow et al., 2011; Marsh, Blair, Jones, Soliman, & Blair, 2009; Mason, Magee, & Fiske, 2014; Zink, Tong, Chen, Bassett, & Stein, 2008).

These findings do little to explain the salience of status information and how status is integrated with person knowledge. For instance, the IPS appears to serve as an amodal center for computing numeric rank order, and not specifically social status, while the anatomical interpretations of findings implicating frontal regions are not grounded in a well-established lesion literature. To elaborate on the latter point, patients with large frontal lobe lesions often have gross personality and social deficits, and at least one study reported that patients with lesions to the DLPFC show impairment in making general social judgments, but not status judgments (Mah, Arnold, & Grafman, 2004), suggesting that we should look elsewhere in the brain for status-related functions.

#### *Social Status and Social Valuation*

As noted earlier, behavioral studies in monkeys suggest that viewing high-status group members may be rewarding (Deaner et al., 2005). Regions involved in value computations and reward processing, including the orbitofrontal cortex (OFC) and ventral striatum, as well as the amygdala, involved in the emotive coding of stimuli, may comprise a network important for assigning social value and guiding visual orienting (Klein, Shepherd, & Platt, 2009). Neurons in the OFC may be particularly sensitive to motivationally salient social information, including status (Azzi, Sirigu, & Duhamel, 2012). Additionally, surgical lesions to limbic (the amygdala) and paralimbic regions (the temporal pole, OFC, and ventral anterior cingulate) in non-human primates can cause a

dramatic loss of social status as well as the ability to react appropriately to the social status of others (reviewed in Olson, Plotzker and Ezzyat, 2007).

While a direct comparison has not been made in humans, there is suggestive evidence from neuroimaging implicating some of the same limbic and paralimbic regions in social status processing. One study reported that the rate at which we learn about other's social status correlates with volumetric differences in the amygdala, anterior hippocampus, and temporal pole (Kumaran, Melo, & Duzel, 2012). Also areas known to be involved in reward processing, such as the ventral striatum, are active when viewing or making status judgments about others (Ly et al., 2011; Zink et al., 2008). However, these prior studies involve either active status judgments (e.g. Kumaran et al., 2012; Ly et al., 2011) or engaging in virtual social interaction (Zink et al., 2008) during fMRI data collection. It is unclear how much task demands influenced attention and neural activation, and not status perception per se.

#### Neural Basis of Person Knowledge

There have been no neuroimaging studies in which social status is examined in the context of person-specific conceptual knowledge. One fruitful way to think about social status is in the context of 'person identity' nodes (Bruce & Young, 1986), the theoretical place in the brain where knowledge about individuals – their face, voice, and gait, as well as conceptual knowledge – is brought together to form an abstract conceptual representation of an individual that can be accessed through numerous distinctive retrieval cues. Because there is a well-studied network of inferior temporal regions associated with face processing, with more anterior regions supporting high-level conceptual representations of specific individuals (Von der Heide, Skipper, & Olson,

2013; Collins & Olson, 2014), it is worth examining how social status modifies and interacts with person processing neural regions in order to understand representations of status in the brain. Here I describe literature regarding these regions and their potential role in status perception.

### *The Face Network*

The human brain has a network specialized for processing faces (Haxby, Hoffman, & Gobbini, 2000; Kanwisher & Yovel, 2006), consisting of regions involved in lower-level visual analysis, such as the occipital face area (OFA), fusiform face area (FFA), and superior temporal sulcus (STS), as well as regions involved in extracting meaning from visual input, such as the anterior temporal lobe (ATL), amygdala, and OFC (Haxby, Hoffman, & Gobbini, 2000; 2002).

The OFA, located in the inferior occipital gyrus, is involved in the early stages of face perception, and thus sensitive to low-level perceptual elements and physical components (Haxby, Hoffman, & Gobbini, 2002; Pitcher, Walsh, Yovel, & Duchaine, 2007) but not facial identity or familiarity (Rotshtein, Henson, Treves, Driver, & Dolan, 2005). It is likely that the lower level representations processed in this region are then integrated into a more complex representation at later processing stages, like in the FFA, located bilaterally on the fusiform gyrus, and the ATL (Nasr & Tootell, 2012; Pitcher et al., 2011; Rothstein et al. 2005).

The FFA and ATLS are sensitive to facial identity (Eger, Schyns, & Kleinschmidt, 2004; Gauthier et al., 1998; Grill-spector, Kourtzi, & Kanwisher, 2001; Rotshtein et al., 2005). The ATL, however, may also play role in processing semantic information associated with faces (Turk, Rosenblum, Gazzaniga, & Macrae, 2005). By some accounts

this region serves as an amodal semantic ‘hub’ that serves to link sensory and conceptual knowledge, with the left ATL more sensitive to verbal information and the right to nonverbal semantic associations (Patterson, Nestor, & Rogers, 2007). Notably, evidence from both monkeys and humans suggests the ATLs contain specialized face-sensitive regions (e.g., Freiwald & Tsao, 2010; Ku, Tolias, Logothetis, & Goense, 2011; Leopold, Bondar, & Giese, 2006), and our lab has found that the ATL face patch is sensitive to social knowledge that we use to differentiate individuals, such as occupation information (Collins, Koski, & Olson, submitted). It is unclear whether face selective regions of the ATLs are sensitive to status information more generally.

Finally, the orbitofrontal cortex (OFC), located in the ventral medial region of the prefrontal cortex, is involved in social perception and behavior (Hornak et al., 2003), as well as social and nonsocial valuation (Lin, Adolphs, & Rangel, 2012; Rushworth, Behrens, Rudebeck, & Walton, 2007). Several investigators have reported the presence of face-sensitive neurons in the macaque OFC (Rolls, 2000) as well as face-specific activations using fMRI in both humans and macaques (Ishai, Schmidt, & Boesiger, 2005; Tsao, Schweers, Moeller, & Freiwald, 2008). Recent findings from our laboratory indicate that face sensitive patches in the medial OFC are sensitive to faces over and above other rewards, whereas the lateral OFC has a more general reward sensitivity, responding both to food and social rewards. Moreover, individual differences in social motivation predict the sensitivity of the medial OFC to faces (Troiani and Olson, 2015). Although the function of the OFC face patches is poorly understood, it would be plausible if this region played a role in evaluating socially important information, like conspecific’s social status, that could be used to rapidly modulate behavior towards high-

status groups members (Klein et al, 2008).

### Overview of the Present Study

Although previous studies have shown that status information influences activity in brain regions responsible for magnitude processing and reward and emotional generation, it is presently unclear where knowledge about an individual's status is represented, and how neural networks involved in social knowledge and valuation potentially interact when viewing high or low status individuals. Additionally, it is unclear whether the neural processes underlying status perception are exclusively social, or whether they apply to nonsocial valuation as well.

The present study uses functional magnetic resonance imaging (fMRI) and multivoxel pattern analysis (MVPA) to examine neural representations of person status, and object status as nonsocial comparison. The study tests the following hypotheses: (1) Brain regions that store face and object concepts will have status information embedded in the abstract concept and will be able to discriminate high from low status faces and objects respectively; and 2) Brain regions that have a general role in valuation will be able to discriminate high from low status information, regardless of stimulus category. Additionally, the present study examines the robustness of social status discrimination in neural networks involved in person processing and valuation, in order to build on previous literature suggesting social status is a salient and powerful social cue.

## CHAPTER 2

### METHOD AND DESIGN

#### Participants

Twenty participants (12 males) ranging in age from 18 – 29 years ( $M = 24.4$ ;  $SD = 2.96$ ) were recruited from a database of individuals from Temple University and the surrounding community who had previously contacted the lab expressing interest in research participation. Only participants with, at minimum, some college education, were included in the study, to control for the possibility that personal status may influence status perception (e.g., Ly et al., 2011). All participants were without history of brain injury or psychiatric illnesses, had normal or corrected color vision, and were right-handed. Written informed consent was obtained from participants prior to the first training session, and they received monetary compensation for their participation.

#### Behavioral Training Paradigm

##### *Stimuli and Design*

Participants learned to associate 3 pieces of conceptual information with 8 unfamiliar faces and 8 objects: 1) name; 2) category (occupation or object type); and 3) performance ranking (2 or 5 stars; see Table 1a and 1b).

Face stimuli consisted of grey-scale images of 8 male faces, all lacking facial hair and glasses and facing forward. Images were provided by Michael J. Tarr (see <http://www.tarrlab.org/>). Object stimuli consisted of grey-scale images of 8 different restaurant or hospital tools from 4 different object categories. Object images were taken from the Internet. All stimuli were 360 by 360 pixels and displayed on a white

background. A null stimulus consisting of a grey background and central fixation cross was also used.

To make object and face information as conceptually similar as possible, two object categories and two occupation categories were selected from two familiar public locations: restaurants and hospitals. Objects with at least two different, distinct exemplars were selected, and these two exemplars represent the individual object names within each object category (see Table 1b). Similarly, different male names were chosen to represent individual faces within each occupation category (see Table 1a). Common, distinct male names were selected from the US Social Security list of the top 100 baby names for the 2000s ([www.socialsecurity.gov](http://www.socialsecurity.gov)).

This design allowed status to be manipulated in two ways: reputation-based status, and career-based status. Reputation-based status was indicated with a star ranking. Each object and occupation category had both a high ranking (5 stars) and low ranking (2 stars) identity. Star ranking was chosen because it has been used in prior fMRI work assessing status (e.g., Zink et al., 2008) and is intuitive for our sample population given that it is commonly applied to restaurants, hotels, and objects in online reviews. Career-based status was indicated via career titles.

Table 1. (a) Face identities and associated occupation category and rankings for training session, and (b) Object identities and associated object categories and rankings for training session.

<b><i>A. Occupation Category</i></b>	<b>★★</b>	<b>★★★★★★</b>
<b>Hospital</b>		
<i>Radiologist</i>	Logan	Owen
<i>Pediatrician</i>	Daniel	Matthew
<b>Restaurant</b>		
<i>Cook</i>	Ethan	Hunter
<i>Bartender</i>	Carter	Andrew

<b><i>B. Object Category</i></b>	<b>★★</b>	<b>★★★★★★</b>
<b>Hospital</b>		
<i>Thermometer</i>	Digital Thermometer	Infrared Thermometer
<i>Blood Pressure</i>	Automatic BP Gauge	Manual BP Gauge
<b>Restaurant</b>		
<i>Mixer</i>	Hand Mixer	Stand Mixer
<i>Wine opener</i>	Corkscrew Wine Opener	Electric Wine Opener

*Status survey*

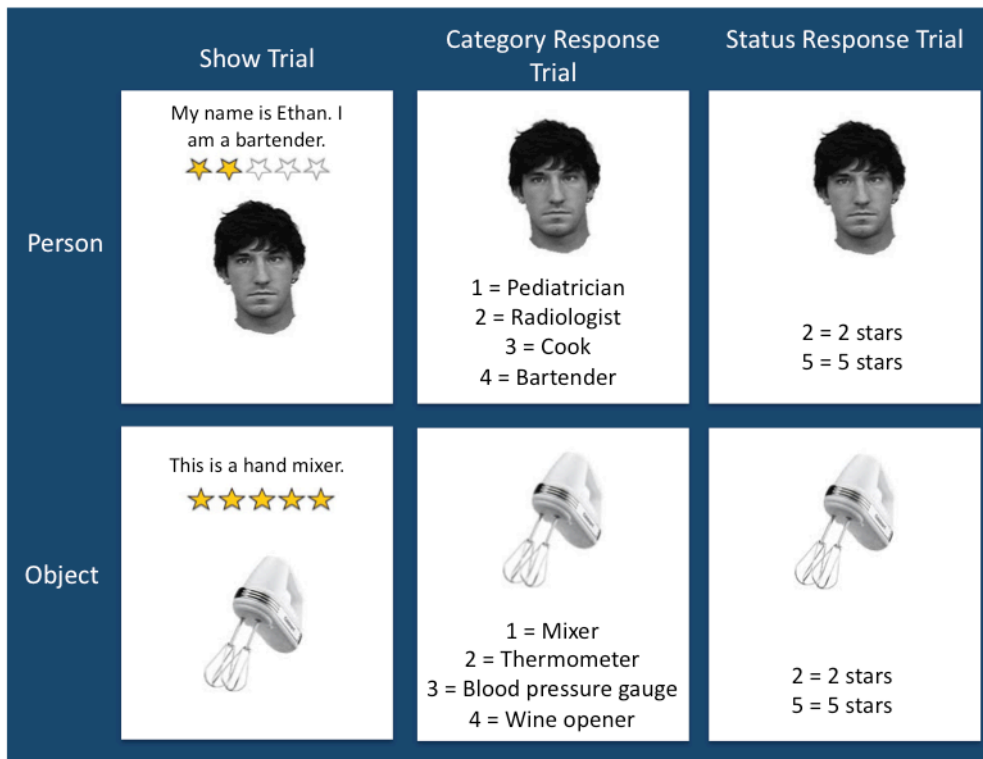
To identify whether objects and career titles presented in the stimulus set hold some inherent status or value among members of the population sampled, an additional survey was administered to a separate group of college undergraduates ( $N = 24$ ; 8 males), age 19-27 years ( $M = 21.67$ ,  $SD = 2.06$ ). These individuals completed a series of questions asking them to compare all possible pairs of objects within each category and report whether one was better than the other (e.g., “Do you think one of these is better: infrared thermometer, or digital thermometer?”). They were asked to make a similar

comparison between all possible pairs of objects categories (thermometer vs. blood pressure gauge, blood pressure gauge vs. mixer, etc) and career categories (pediatrician vs. radiologist, chef vs. bartender, etc.).

### *Procedure*

Training was conducted over 2 days in a laboratory setting, with the first session lasting approximately 45 minutes and the second lasting approximately 30 minutes. The first training session consisted of 3 trial types (see Figure 1). During the ‘show trial,’ participants viewed slides containing a face or object image, along with that face or object’s associated information, and were instructed to memorize the names, categories, and status ratings for each image. Each slide was presented 4 times (64 trials total) for 5 seconds in a random order. Next, participants completed ‘category-response trials’ in which they viewed the trained faces and objects one at a time and were instructed to select the category that matched with each from a list presented on screen. Following response, the correct answer was displayed for 2 seconds. Each image was presented twice (32 trials total) in a random order. Finally, during ‘status-response trials,’ participants viewed each trained image one at a time and were instructed to select the status rating assigned to each (either 2 or 5 stars). Following their response, the correct answer was displayed for 2 seconds. Each image was presented twice in a random order (32 trials total). Participants completed blocks of trials in the following order, two times: show trials (64 total), category-response trials (32 total), show trials (64 total), status-response trials (32 total).

Figure 1: Examples of trial types presented during training sessions.



The second training session used the same trial blocks in the same order as the first session. Afterwards, participants completed a free recall test, where a number was presented on the computer screen with one of the 16 trained images. Participants were instructed to write down on a separate sheet of paper all of the information they learned for each image, including name, category, and status information.

#### fMRI Session

The fMRI session occurred on the third day of study participation, following two days of training sessions. Participants completed an additional recall test immediately before their fMRI session, to ensure they had retained all information learned during training. The recall test consisted of a piece of paper with the 16 trained images, and

participants were instructed to write next to each face or object the associated name, category, and status information learned during training.

### *Functional Localizer*

A functional localizer scan occurred prior to the main experiment to localize areas sensitive to faces (specifically, in the OFA, FFA, ATL, OFC) and objects (the lateral occipital complex (LOC)). The LOC is a region of extrastriate cortex involved in object recognition, which extends bilaterally from the lateral occipital lobes into posterior regions of the temporal lobes (Grill-Spector, Kourtzi, & Kanwisher, 2001).

The localizer task was a block design, presenting category blocks of faces (famous and nonfamous), places (famous and nonfamous), objects, and scrambled images. Famous stimuli were included to improve localization of the ATL face patches, based on prior findings showing that the ATL face patches are particularly sensitive to well-known stimuli (e.g., Ross & Olson, 2012; Von der Heide et al., 2013). Objects and faces differed from those in the experimental task, and famous images were previously pilot tested (See Ross & Olson, 2012) to ensure that they are highly familiar within the cohort sampled in the present study.

Images were randomly selected from lists of 89 images per category, and presented one at a time for 400ms (350 ISI) in 8 category blocks consisting of 14 trials each. Participants completed two full localizer runs, each consisting of 5 cycles presenting all 8 category blocks in a fixed randomized order. Each cycle ended with a 12000 ms presentation of a central fixation cross. Two times per block, a randomly selected image was repeated, and participants were instructed to indicate with a button-

press each time this occurred. This detection task served to ensure attention was maintained throughout the task.

### *Main Experiment*

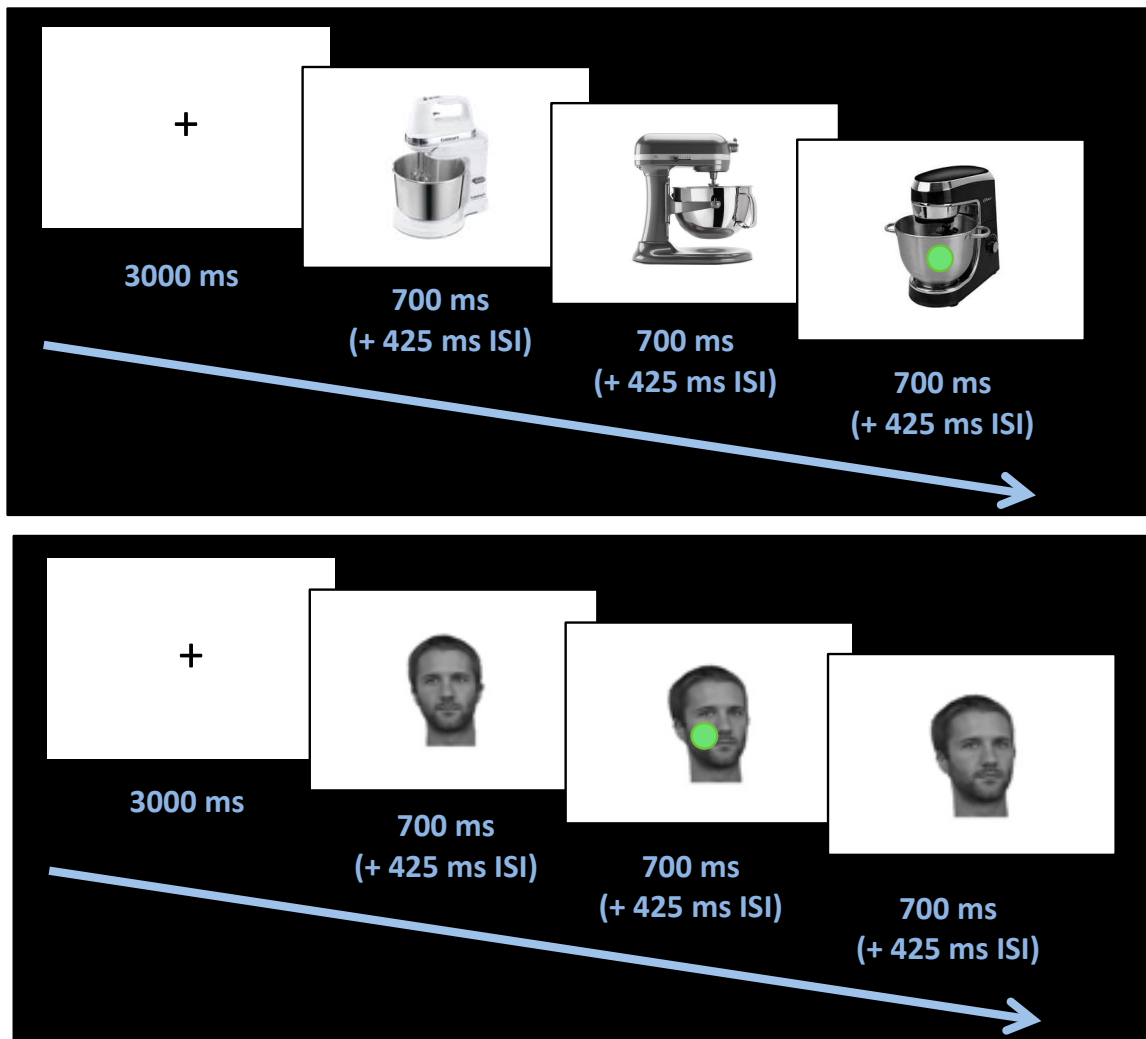
Four novel exemplars of each of the 8 objects used during training were used in the experimental run. This is similar to prior work looking at object representations in the ATLs (see Peelen & Caramazza, 2012) to avoid neural decoding of individual images, rather than object identity. Similarly, 4 exemplars of the same 8 male faces used during training were used in the experimental runs. Given that there were not novel “types” of these faces available, the trained faces were angled 30 and 45 degrees to the right and left to produce novel perceptual images for each identity, similar to previous work assessing neural decoding of face identity (e.g, Anzellotti, Fairhall, & Caramazza, 2013).

The main experiment was a block design with a target detection task (see Figure 2). Stimuli were presented in 16 identity blocks (8 face, 8 object), consisting of 16 trials each. Blocks were presented in a fixed random order, alternating between faces and objects. Within each block, each exemplar image was presented 4 times in a fixed random order for 700ms (425ms ISI), and each block ended with 3000ms presentation of a fixation cross. Participants completed 6 total runs consisting of 16 blocks each. This design was shown to be sufficient in prior MVP analyses in the temporal lobes (e.g., Peelen & Caramazza, 2012).

A target detection task served to ensure attention was maintained throughout the task. Importantly, the detection task was orthogonal to the interests of the study to ensure any observed activations were not due to top-down, task-related effects. Participants were instructed to respond with a button press each time a green dot is displayed on the image.

Target images appeared 3 times per block, with their exact locations following one of 4 predetermined patterns that varied across trial blocks in a fixed random order (to make the pattern unpredictable).

Figure 2. Experimental task. Example of object trials (top); and example of face trials (bottom). Note: the target image was presented in varying locations across trial blocks.



### *Data Acquisition*

Neuroimaging sessions were conducted at Temple University Hospital on a 3.0 T Siemens Verio scanner using a twelve-channel Siemens head coil. The functional runs were preceded by a high-resolution anatomical scan lasting approximately 10 minutes. The anatomical image was used to fit the volume of covered brain tissues acquired in the functional scan. The T1-weighted images were acquired using a three-dimensional magnetization-prepared rapid acquisition gradient echo pulse sequence. Imaging parameters: 144 contiguous slices of 0.9766 mm thickness; repetition time (TR) = 1900 ms; echo time (TE) = 2.94 ms; FOV = 188 x 250 mm; inversion time = 900 ms; voxel size = 1 x 0.9766 x 0.9766; matrix size = 188 x 256; flip angle = 90 degrees.

Functional T2\*-weighted images sensitive to blood oxygenation level-dependent contrasts were acquired using a gradient-echo echo-planar pulse sequence and automatic shimming. Imaging parameters: repetition time (TR) = 3000 ms; echo time (TE) = 20 ms; inversion time = 900 ms; FOV = 240 x 240; voxel size = 3 x 3 x 2.5mm; matrix size = 80 x 80; flip angle = 90 degrees. This pulse sequence was optimized for ATL coverage and sensitivity based on pilot scans performed for this purpose, details of which are reported in Ross and Olson (2010). Sixty-one interleaved axial slices of 2.5 mm thickness were acquired to cover the temporal lobes.

Visual stimuli were presented using a rear-mounted projection system, and stimulus delivery was controlled by E-prime software (Psychology Software Tool, Inc.; Pittsburgh, PA) on a Windows laptop located in the scanner control room. Responses were recorded using a five-button fiber optic response pad system.

### *Data Analysis*

Data preprocessing and univariate analysis of fMRI data were performed using FEAT (fMRI Expert Analysis Tool) version 6.0, part of the software library of the Oxford Centre for Functional MRI of the Brain (fMRIB; [www.fmrib.ox.ac.uk/fsl](http://www.fmrib.ox.ac.uk/fsl)). MVPA analysis was carried out using the Princeton MVPA Toolbox version 0.7.1 running on MATLAB R2012b, and with custom MATLAB software.

### *Preprocessing*

Preprocessing included removal of non-brain tissues using BET, MCFLIRT motion correction, high-pass temporal filtering with a 200 second cutoff, and fieldmap-based correction of EPI data to reduce spatial distortions. The EPI data was registered to each participant's T1-weighted anatomical scan using BBR and normalized to a standard Montreal Neurological institute (MNI-152) template. Functional localizer data was smoothed using a 5mm Gaussian kernel, however MVPA data was not smoothed.

### *Defining Regions of Interest (ROIs)*

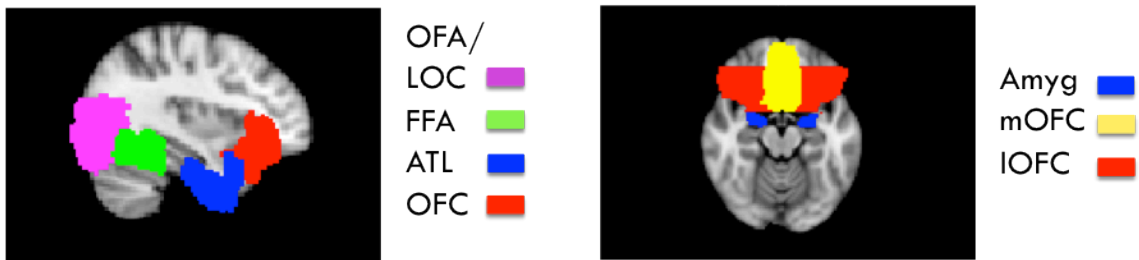
Preprocessed functional localizer data were submitted to a fixed effects general linear model including each condition of interest. Predictors' time courses were modeled for each experimental block type (faces, places, objects, scrambled images), excluding instructions and fixations, using a double-gamma model of hemodynamic response function. Functional data were z-transformed to normalize the time course.

Functional regions of interest (ROIs) were defined in both face and object sensitive cortex using the functional localizer data, using the uncorrected output from the general linear model with a threshold value of  $p = .05$ . The Harvard-Oxford Cortical and Subcortical Structural Atlases in FSL were used to identify anatomical regions (see Figure 3a). Contrasting the average activation to faces with objects + places identified

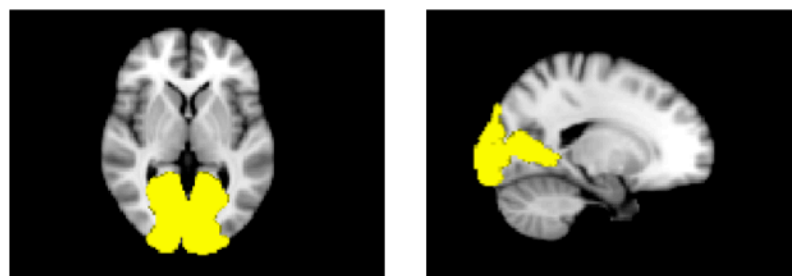
face selective regions corresponding to the OFA, located in the inferior occipital gyrus, the bilateral FFA located on the fusiform gyrus, and ATL face patches located on the ventral surface of the anterior temporal lobes. Face selective regions were also defined in the bilateral lateral OFC and in the medial OFC, separately. Regions were defined bilaterally based on prior evidence of face-specific lateralization of some of these regions, including the FFA and ATL (e.g., Kanwisher & Yovel, 2006; Patterson et al., 2007).

Figure 3: Regions for functional ROIs. (a) Masks used to locate functional ROIs for faces (using contrast face > place + objects) and objects (using contrast object > scramble), including occipital face area (OFA), lateral occipital complex (LOC), fusiform face area (FFA), anterior temporal lobes (ATL), amygdala (Amyg) medial orbitofrontal cortex (mOFC) and lateral orbitofrontal cortex (lOFC). Peak voxels were identified within each mask for each contrast, and 9mm spheres were drawn around peak voxel to create ROI. (b) Masks for early visual cortex V1 (using contrast all stimuli > fixations).

**A. Functional ROI Masks**



**B. V1 Masks**



Contrasting the average activation to objects with scrambled images identified object selective regions in bilateral lateral occipital cortex (LOC) and ATLs, as well as the lateral and medial OFC. Using the method employed by (Anzellotti, Fairhall, & Caramazza, 2013) final ROIs were defined by centering a 9mm sphere on the voxel of peak value in each face and object selective region. Each 9mm ROI mask contained approximately 919 voxels.

Following methods used by (Bracci, Cavina-Pratesi, Ietswaart, Caramazza, & Peelen, 2014) a lower-level visual control ROI was functionally defined in early visual cortex, V1/Brodmann area 17 (located using the Juelich Histological Atlas in FSL), by contrasting the average response to all stimulus categories in the localizer task (faces, place, objects, scrambled images) with fixation periods (see Figure 3b). Since the number of voxels within an ROI may influence MVPA outcomes (e.g., Anzellotti et al., 2013; Eger, Ashburner, Haynes, Dolan, & Rees, 2008), the V1 control region was defined in a similar manner as the face and object ROIs, by centering a 9mm sphere in the voxel of peak value. Each 9mm ROI mask contained approximately 919 voxels.

Final ROIs were examined to ensure each was centered on a discrete cluster of voxels, and there was no overlap. In cases where regions overlapped, ROIs were manually repositioned to center on a discrete cluster of voxels. All participants had activation in bilateral V1, OFA, LOC, and FFA, while participants varied in ATL, amygdala and OFC activations (see Table 2). Medial OFC was not analyzed by hemisphere, as activation across participants was along the midline of the brain and discrete lateralized ROIs could not be identified with 9mm ROIs.

Table 2: Face sensitive neural regions across participants, by regions and hemisphere. Bilateral (B), left hemisphere (L), right hemisphere (R), or no activation (NA).

Subject	ATL			Amygdala				Lateral OFC			Medial OFC		
	B	L	R	B	L	R	NA	B	L	R	B	L	R
1	x						x			x			x
2	x			x				x				x	
3	x					x		x					x
4	x			x				x			x		
5		x			x			x				x	
6	x						x		x		x		
7	x			x					x		x		
8	x			x				x			x		
9			x	x						x		x	
10		x		x				x			x		
11	x					x		x			x		
12	x			x				x			x		
13	x			x				x			x		
14	x			x				x					x
15	x					x		x			x		
16			x				x	x			x		
17	x			x						x	x		
18	x			x				x			x		

*Note: All participants displayed bilateral OFA and FFA activation.*

Additionally, a structural ROI was created for bilateral ventral striatum using the Oxford-Imanova Striatal Connectivity Atlas in FSL, so that patterns of activation in these regions could be assessed. Each ventral striatum ROI mask contained approximately 617 voxels.

#### *Temporal Signal to Noise Ratio*

Given that the ATL and inferior portions of the frontal lobe are prone to susceptibility artifacts, TNSR maps were examined to ensure adequate signal in these regions. Probability maps were generated across participants using a threshold of 40, which prior work has deemed sufficient to detect BOLD differences between conditions (Murphy, Bodurka, & Bandettini, 2007). A group TSNR map indicated adequate coverage across participants.

### *Multivoxel Pattern Analysis (MVPA)*

Multivoxel pattern analysis (MVPA) was used to analyze the imaging data in the present study. Traditional fMRI analyses examine signal change in response to experimental conditions by averaging across voxels in a way that can conceal smaller changes in voxel activation and meaningful differences in voxel patterns. MVPA does not smooth across voxels, and therefore takes into account the *pattern* of voxel activation within a defined region. Thus, MVPA can add power to small effects and identify difference in patterns of activation that univariate analyses miss, and it examines whether these voxel patterns can reliably discriminate, or accurately classify, experimental conditions.

MVPA was used to examine the sensitivity of the functionally defined regions of interest to status information. Specifically, analyses assessed whether unique multivoxel patterns could accurately classify high from low status faces and objects, respectively. Separate regressors were created for each condition of interest. Data were z-scored within each run to control for baseline shifts in the magnetic resonant signal, and all regressors were convolved with a standard hemodynamic response function.

Analysis was performed using a Gaussian Naïve Bayes (GNB) classifier. This classifier has been shown to perform well in pattern analyses (Mitchell et al, 2004) and is commonly used in MVPA (see Coutanche & Thompson-Schill, 2012). For the main analyses, a 6-fold leave-one-run-out cross validation scheme was employed, where the classifier was trained on five runs of data and tested on the remaining un-trained run. This procedure was repeated 6 times, each time using a different test run, and the average

classification accuracy was calculated for each ROI and compared to chance using a group-level one-sample  $t$ -test.

## CHAPTER 3

### RESULTS

Two male participants were excluded from subsequent analyses. Both participants displayed problematic motion (> 5mm displacement) across experimental runs. One participant additionally had low recall performance (< 65% accuracy) for trained information. Thus final sample size was 18.

#### Behavioral Results

Accuracy measures for recollection of trained information collected immediately following training ( $M = .98$ ,  $SD = .05$ ) and immediately prior to the fMRI scan ( $M = .97$ ,  $SD = .04$ ) were high across participants, indicating training material was sufficiently retained for the main experiment.

Accuracy for target detection across both functional localizer runs ( $M = .97$ ,  $SD = .03$ ) and all six experimental runs ( $M = .98$ ,  $SD = .04$ ) was high across participants, indicating attention to stimuli was maintained across the experiment.

#### *Survey Data*

Survey responses identified medical professions as higher status than restaurant professions, with 100% of respondents identifying radiologists and pediatricians as higher status than bartenders, and 83.3% identifying radiologists and pediatricians as higher status than chefs. Pediatricians were identified as higher status than radiologists (41.7%) more frequently than the reverse (16.7%), and chefs were identified as higher status than bartenders by 79.2% of respondents. Thus, pediatricians and bartenders served as the high status and low status career in the career-based analysis.

There was also a slight preference for hospital object categories compared to restaurant categories, with the majority of respondents identifying blood pressure gauges and thermometers as higher status than wine openers (75% and 66.7%, respectively) and mixers (70.8% and 66.7%, respectively). Within object categories, the majority of participants identified stand mixers (54.2%), digital thermometers (58.3%), electric wine openers (66.7%) and automatic blood pressure gauges (66.7%) as higher status. These items were evenly divided across trained status categories (5 star: digital thermometer and automatic blood pressure gauge; 2 star: electric wine opener and stand mixers), and therefore these ratings were not considered problematic for object reputation analyses.

#### MVPA Results

Results will be presented as two separate analyses, relating to the hypotheses that face and object selective cortex involved in conceptual knowledge and valuation discriminate high from low status. The first analysis assessed whether face and object ROIs are sensitive to face and object reputational status, respectively. The second analysis assessed whether face selective ROIs are sensitive to status cues defined by career title, and whether reputational classification is still present within high status careers only. Finally, I will present analyses testing the extent to which reputational status classification generalizes across different stimuli.

#### *Reputational Status*

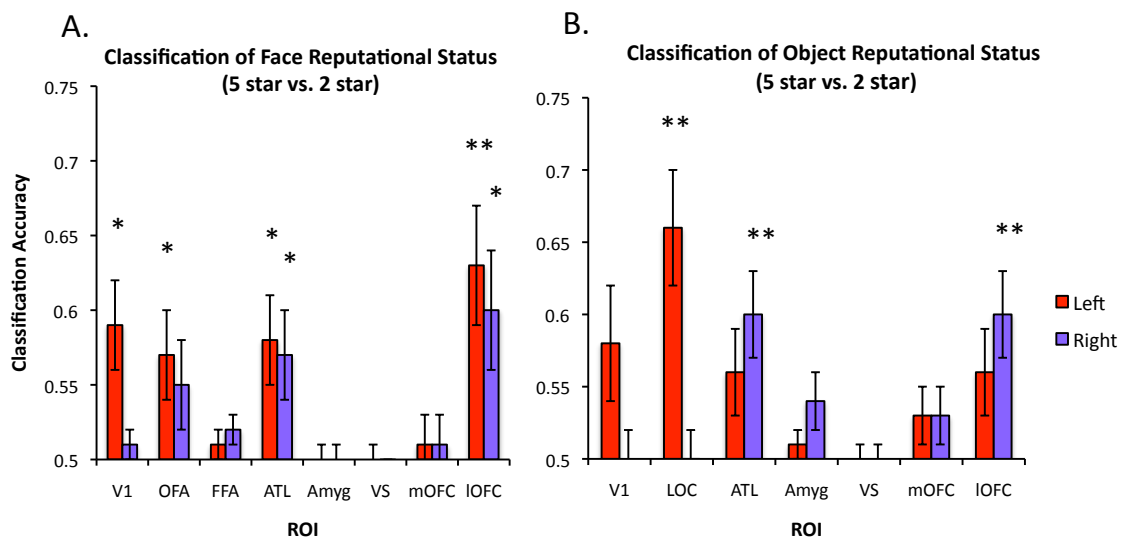
I first assessed whether unique multivoxel patterns could accurately classify high from low rated faces, based on the trained star ranking associated with each individual. Regressors were defined for 5-star faces and 2-star faces, collapsing across career title. MVPA was conducted in the functionally defined extended face network, including the

bilateral OFA, FFA, ATL, lateral OFC, medial OFC, amygdala, as well as a control region, V1. Classification accuracy for high versus low status was calculated and averaged across 6 iterations of cross-validation and compared to chance (.50) in a group level one-sample *t*-test (see figure 4a).

Classification accuracy for face reputational status was greater than chance in both the right and left ATL ( $t(17) = 2.42, p = .03; M = .58, SD = .13; t(17) = 2.21, p = .04, M = .57, SD = .14$ ), as well as in the right and left lateral OFC ( $t(17) = 2.42, p = .03; M = .60, SD = .16; t(17) = 3.49, p = .003; M = .63, SD = .16$ ). Effects were not significant for the medial OFC, amygdala, or ventral striatum (all  $p$ 's > .05). Classification was also greater than chance in left V1 ( $t(17) = 2.76, p = .01; M = .59, SD = .14$ ) and left OFA ( $t(17) = 2.19, p = .04; M = .57, SD = .14$ ), but effects were non-significant in other lower-level visual regions, including right V1 and right OFA, as well as bilateral FFA (all  $p$ 's > .05). Paired *t*-tests comparing classification across hemispheres revealed that left V1 classification was greater than right V1 ( $t(17) = 2.33, p = .03$ ), but no other hemispheric differences were present (all  $p$ 's > .05).

Next, analyses examined whether multivoxel patterns could accurately classify high from low rated objects, based on the trained star ranking associated with each item. Regressors were defined for 5-star objects and 2-star objects, collapsing across object category. MVPA was conducted in functionally defined object selective cortex, including the bilateral LOC, ATL, lateral OFC, medial OFC and V1. As with faces, classification accuracy for high versus low status was calculated and averaged across 6 iterations of cross-validation and compared to chance (.50) in a group level one-sample *t*-test (see figure 4b).

Figure 4: Classification accuracy for reputational status. (a) Classification accuracy for face reputational status in face-selective ROIs, including visual cortex (V1), occipital face area (OFA), fusiform face area (FFA), anterior temporal lobes (ATL), amygdala (Amyg), ventral striatum (VS), medial OFC (mOFC) and lateral OFC. (b) Classification accuracy for object reputational status in object-selective ROIs, including lateral occipital cortex (LOC). ROI classification displayed by hemisphere (left and right) compared to chance (.50). Significance levels (compared to chance) indicated by \*  $p < .05$ , \*\*  $p < .01$ . Error bars represent standard error of the mean.



Classification accuracy for object reputational status was greater than chance in right ATL ( $t(17) = 2.97, p = .009, M = .59, SD = .13$ ) and right lateral OFC ( $t(17) = 2.90, p = .01, M = .60, SD = .15$ ), as well the left LOC ( $t(17) = 4.21, p = .001, M = .66, SD = .16$ ). Effects were marginally significant in the left ATL ( $t(17) = 1.94, p = .07, M = .56, SD = .13$ ) and left lateral OFC ( $t(17) = 2.06, p = .06, M = .56, SD = .11$ ). Classification accuracy was not significantly above chance in *right* LOC and V1, or the ventral striatum (all  $p$ 's  $> .05$ ).

Comparing hemispheres, classification in the left LOC was greater than in the right LOC ( $t(17) = 3.31, p = .004$ ), and classification in left V1 was marginally greater

than in right V1 ( $t(17) = 2.16, p = .05$ ). No other differences occurred between right and left hemisphere ROIs (all  $p$ 's  $> .05$ ).

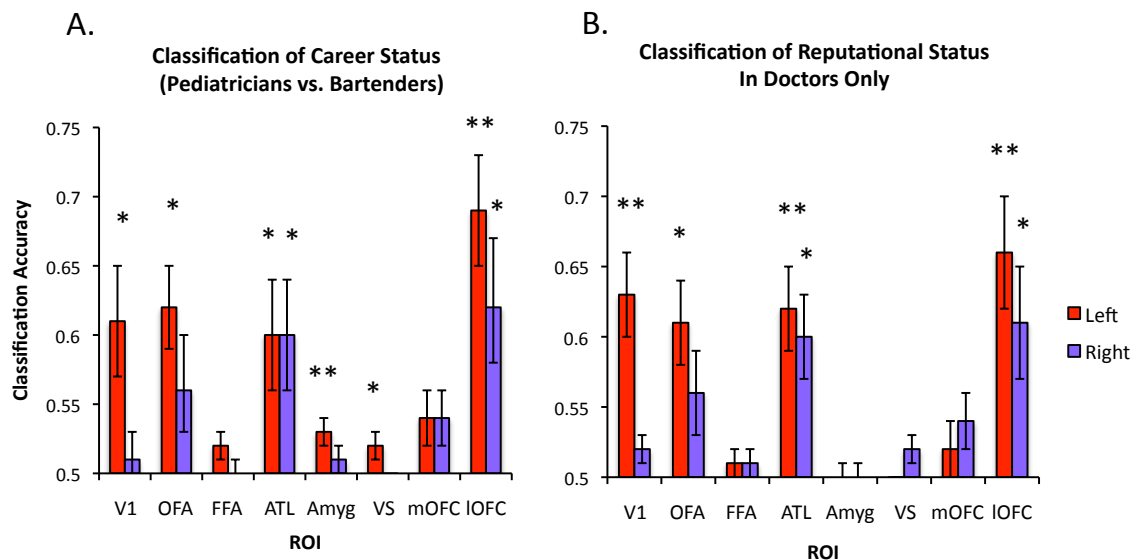
### *Career Status*

Career status was defined based on status ratings obtained in the Status Survey, which identified pediatricians as the highest status career and bartenders as the lowest status career. Analyses assessed whether multivoxel patterns could accurately classify high from low status faces, based on the status of the trained career title associated with each individual. Regressors were defined for pediatricians and bartenders, collapsing across reputational star ranking. As in previous analyses, MVPA was conducted in functionally defined face selective cortex, and classification accuracy for high versus low status was calculated and averaged across 6 iterations of cross-validation and compared to chance (.50) in a group level one-sample  $t$ -test (see figure 5a).

Similar to the results for reputational status, classification accuracy was greater than chance in both the right and left ATL ( $t(17) = 2.53, p = .02; M = .60, SD = .17; t(17) = 2.47, p = .02, M = .60, SD = .17$ ), as well as in the right and left lateral OFC ( $t(17) = 2.65, p = .02; M = .61, SD = .19; t(17) = 4.32, p < .001; M = .69, SD = .18$ ). Unlike the findings from the star-rating system, in this analysis there was a significant effect in the left amygdala ( $t(17) = 3.10, p = .01; M = .54, SD = .05$ ). Classification was also greater than chance in the right ventral striatum ( $t(17) = 2.19, p = .04; M = .53, SD = .05$ ), and effects were marginal for the left ventral striatum ( $t(17) = 2.07, p = .05; M = .52, SD = .04$ ). Effects were significant in left V1 ( $t(17) = 2.52, p = .02; M = .61, SD = .18$ ) and left OFA ( $t(17) = 2.88, p = .01; M = .62, SD = .17$ ), but were not significant in other lower-level visual regions, including right V1 and right OFA, as well as bilateral FFA (all  $p$ 's  $>$

.05). Comparing hemispheres, classification accuracy was greater in left V1 than right V1 ( $t(17) = 2.35, p = .03$ ), and in the left amygdala compared to right amygdala ( $t(17) = 2.37, p = .03$ ), but there were no other differences between right and left hemisphere ROIs (all  $p$ 's > .05).

Figure 5: Classification accuracy for (a) career status, and (b) doctor reputational status. Face-selective ROIs include visual cortex (V1), occipital face area (OFA), fusiform face area (FFA), anterior temporal lobes (ATL), amygdala (Amyg), ventral striatum (VS), medial OFC (mOFC) and lateral OFC. ROI classification displayed by hemisphere (left and right) compared to chance (.50). Significance levels indicated (compared to chance) by \*  $p < .05$ , \*\*  $p < .01$ . Error bars represent standard error of the mean.



Finally, I examined classification of reputational (star ranking) status for doctors only, given that these career titles were rated as higher status overall than restaurant careers by survey respondents. These analyses aimed to reduce any confounding effects of pre-existing status rankings associated with restaurant workers compared to doctors, which might interfere with the trained reputational status rankings. Regressors were defined for 5-star doctors (pediatricians and radiologists) and 2-star doctors.

Classification accuracy was greater than chance in both the right and left ATL ( $t(17) = 2.50, p = .02, M = .60, SD = .18; t(17) = 2.95, p = .009, M = .61, SD = .17$ ), as well as the right and left lateral OFC ( $t(17) = 2.27, p = .04, M = .61, SD = .19; t(17) = 3.27, p = .005, M = .66, SD = .21$ ). Classification accuracy was also greater than chance in the left OFA ( $t(17) = 2.67, p = .02, M = .61, SD = .12$ ) and left V1 ( $t(17) = 2.97, p = .009, M = .63, SD = .17$ ) and effects were marginal in the right OFA ( $t(17) = 1.89, p = .08, M = .56, SD = .14$ ). As in previous analyses, classification was greater in left V1 than right V1 ( $t(17) = 2.48, p = .02$ ). No other effects were significant (all  $p$ 's  $> .05$ ; see figure 5b).

#### *Generalization Test*

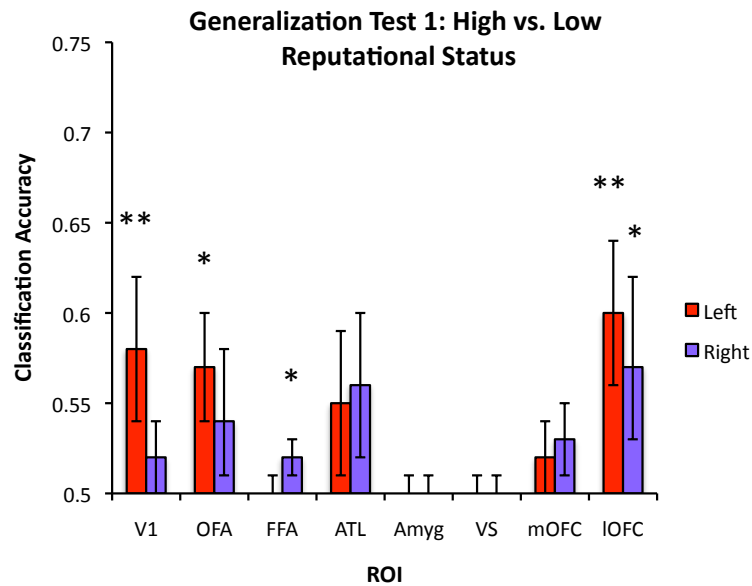
Finally, two analyses were performed to test the generalization of reputational status classification. In both analyses, specific stimuli varied between training and test, but were conceptually the same in terms of reputational status.

For the first generalization test, the classifier was trained on restaurant reputational status (star ranking for chefs and bartenders) and tested on hospital reputational status (star rankings for pediatricians and radiologists). Regressors used in the previous reputational face status analysis, for 5-star and 2-star faces, were used in the present analysis.

Classification accuracy in left ATL ( $t(17) = 1.98, p = .06, M = .55, SD = .11$ ) and right ATL ( $t(17) = 2.05, p = .06, M = .56, SD = .11$ ) was marginally significant. However, classification was greater than chance in both the left lateral OFC ( $t(17) = 3.18, p = .005, M = .60, SD = .13$ ) and right lateral OFC ( $t(17) = 2.49, p = .02, M = .57, SD = .12$ ). Classification accuracy was also greater than chance in the right FFA ( $t(17) = 2.24,$

$p = .04$ ,  $M = .52$ ,  $SD = .04$ ), left OFA ( $t(17) = 2.58$ ,  $p = .02$ ,  $M = .57$ ,  $SD = .11$ ) and left V1 ( $t(17) = 2.96$ ,  $p = .009$ ,  $M = .58$ ,  $SD = .12$ ). Again, left V1 classification was greater than right V1 ( $t(17) = 2.25$ ,  $p = .04$ ), but there were no other differences between left and right hemisphere ROIS (all  $p$ 's  $> .05$ ; see figure 6).

Figure 6: Classification accuracy for generalization test 1. Classifier trained for reputational status with doctor stimuli, tested on restaurant employee stimuli in face-selective ROIs, including visual cortex (V1), occipital face area (OFA), fusiform face area (FFA), anterior temporal lobes (ATL), amygdala (Amyg), ventral striatum (VS), medial OFC (mOFC) and lateral OFC. ROI classification displayed by hemisphere (left and right) compared to chance (.50). Significance levels (compared to chance) indicated by \*  $p < .05$ , \*\*  $p < .01$ . Error bars represent standard error of the mean.

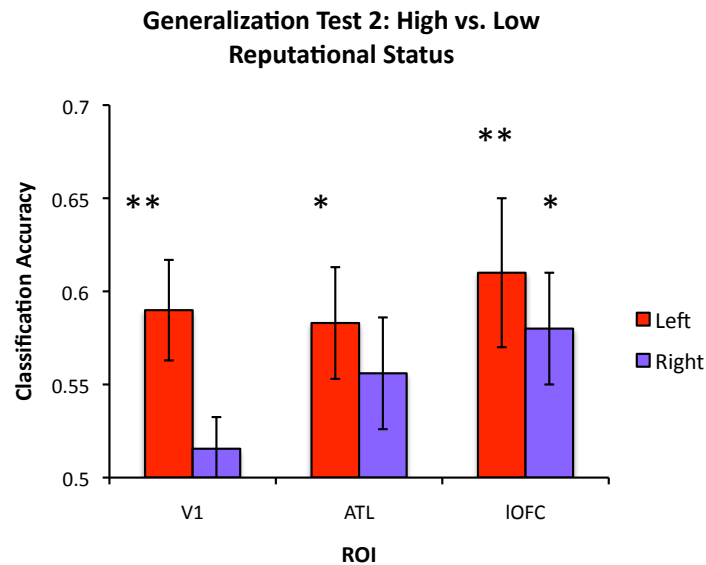


The second analysis aimed to address the generalized status decoding that occurred in the ATL and lateral OFC, given that both of these regions decoded social and nonsocial status. The classifier was trained on face reputational status and tested on object reputational status, to see whether these regions decode reputational status independently of the social or nonsocial nature of the stimulus. The regressor used in the

previous reputational face status analysis, for 5-star and 2-star faces, was again used here, and MVPA was conducted in face selective ROIs in bilateral ATL, lateral OFC, and V1.

Classification accuracy was above chance in left V1 ( $t(17) = 3.29, p = .004, M = .58, SD = .13$ ), left ATL ( $t(17) = 2.70, p = .02$ ) and in the right and left lateral OFC ( $t(17) = 2.99, p = .008, M = .61, SD = .16; t(17) = 2.51, p = .02, M = .58, SD = .14$ ; see figure 7).

Figure 7: Classification accuracy for generalization test 2. Classifier trained for reputational status with face stimuli, tested on object stimuli in face-selective ROIs, including visual cortex (V1), anterior temporal lobes (ATL) and lateral OFC. ROI classification displayed by hemisphere (left and right) compared to chance (.50). Significance levels (compared to chance) indicated by \*  $p < .05$ , \*\*  $p < .01$ . Error bars represent standard error of the mean.



## CHAPTER 4

### DISCUSSION

The present study builds upon previous literature examining the neural mechanisms of social status perception and explores whether social and nonsocial status perception use similar mechanisms. Participants learned to associate status information with faces and objects, and analyses examined whether unique multivoxel patterns discriminate high from low social and nonsocial status information. Results revealed that the anterior temporal lobe (ATL), a region thought to be involved in semantic processing as well as high-level social conceptualizations, and the lateral orbitofrontal cortex (OFC), a region sensitive to stimulus value, decode both social and nonsocial status information. Notably, these findings were replicated across multiple analyses regarding social status specifically, suggesting a mechanism by which we incorporate status information into our neural representations of people.

#### Status-General Processing

First, MVPA assessed which neural regions classified reputational status, trained via the association of high (5-star) or low (2-star) ratings with each face or object stimulus image. Results indicate face and object selective portions of the ATL and lateral OFC classify reputational face and object status.

The OFC plays a role in a number of processes, including emotional learning and value-based decision-making, and the lateral OFC specifically has been shown to be sensitive to both rewarding (social and nonsocial) stimuli (Troiani and Olson, 2015) and punishing feedback (Kringelbach, 2005; O’Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). On the other hand, the ventral ATL is thought to be the end point of the

ventral visual stream and is sensitive to visual stimuli, especially faces, as well as conceptual knowledge associated with faces (reviewed in Von der Heide et al. 2013). One interpretation of the present results is that social status is simply another type of social semantic knowledge that the ATLs are sensitive to, in the same way that this region is sensitive to personal names, occupation labels, and even abstract concepts about people (Skipper, Ross & Olson, 2011). However the consistent and strong decoding abilities of the lateral OFC indicate that social status goes beyond semantic knowledge: it is value-laden semantic knowledge and thus, the lateral OFC is excellent at decoding it. The lateral OFC may be signaling the potential reward or punishment that viewing high and low status people and objects evoke.

My results also revealed significant decoding of object status in the left lateral occipital cortex, a region sensitive to object identity. This region has been shown in previous work to classify object categories, even when exemplars within object categories vary (Eger et al., 2008). It is possible that, once object reputational status is learned, it becomes part of the object's identity, and the object is categorized accordingly when subsequently encountered.

Interestingly, with the exception of object-sensitive LOC, these findings were replicated across variations in the social status manipulation, indicating that the ATL and lateral OFC may play an important role in social status processing, even when status is not a salient part of ongoing cognitive processing.

#### The Lateral OFC and ATL

The OFC has multiple anatomical subregions that differ in their connectivity with other neural regions and their sensitivity to sensory input (reviewed in Rolls, 2000). The

lateral OFC and ATL classified status across analyses in the present study, but the medial OFC did not. This is not surprising, given prior findings that the medial OFC is sensitive to social rewards, while lateral OFC is sensitive to rewards more generally (Troiani and Olson, 2015). Additionally, the lateral OFC is monosynaptically connected via a white matter tract called the uncinate fasciculus to the ATLs (Von der Heide, Skipper, Klobusicky, & Olson, 2013). This connectivity may provide a mechanism by which we assign value to abstract representations of people (or objects) based on their status, which serves as a sort of social currency.

#### Social Status as a “Valued” Person Attribute

Prior work has demonstrated the automaticity with which both humans and nonhuman primates organize social groups in a hierarchical manner and assign status to others, as well as the impact social status information has on social cognition. Notably, status appears to be an important social cue, and one that greatly biases social attention in favor of higher status individuals (Deaner et al., 2005; Foulsham et al., 2010; Jones et al., 2010; Shepherd et al., 2006). Recent neuroimaging evidence from both monkeys and humans begins to build a picture of the neural circuitry that underlies status perception, implicating regions involved in affective processing and reward – namely, the ventral striatum, orbitofrontal cortex, and amygdala (Klein et al., 2009; Ly et al., 2011; Zink et al., 2008). The present findings build on this model by suggesting the involvement of valuation and person-processing networks in status perception, perhaps providing a mechanism by which we embed status in our representations of others and signal these individuals as important, or worthy of privileged attention.

This “person-processing” network includes face-sensitive neural regions

extending bilaterally from early visual cortex to more anterior regions involved in forming complex representations of faces. This network includes the orbital face area (OFA) and fusiform face area (FFA), which are sensitive to perceptual features of faces and facial identity as well as more anterior regions, including the ventral portions of the ATLs and the OFC, which are sensitive to conceptual knowledge and valuation, respectively (Haxby et al., 2000; 2002). This network has not previously been explored in the context of social status perception, and evidence of the role of both the ATL and OFC in human face processing is relatively recent. These findings therefore build on the current knowledge regarding the function of these face-processing regions, and what types of person information they decode.

Further, the present findings demonstrate the involvement of face sensitive regions in the bilateral ATLs and lateral OFC in status perception across multiple analyses. These regions discriminated reputational status, based on star ratings, as well as career-based status. Additionally, face status analyses revealed status classification in the right ventral striatum and left amygdala as well, but only for the career-based status comparison. These regions have been implicated in prior imaging studies assessing status in humans (Kumaran et al, 2012) and monkeys (Noonan et al., 2008), so it is surprising they didn't play a larger role in the present study. It is obvious that most of us have long histories and rich semantic associations with various career titles while the star ranking system provides a more impoverished status representation. Thus it is possible that the career titles were simply more representationally rich and attentionally salient than the trained star ratings, and thus the amygdala and ventral striatum were more sensitive to these categories. An additional analyses examining reputational status within doctors

only – in an attempt to control for the effects of career status – revealed results similar to those found when collapsing across doctor and restaurant careers. The ATLs and lateral OFC decoded reputational status in this case, but effects were not significant in the amygdala or striatum.

It is important to note that number of voxels within the ventral striatum was smaller than in the 9mm ROIs used for functionally defined brain regions, and number of voxels can affect MVPA results (e.g., Eger et al., 2008). Similarly, the amygdala is small, and the 9mm sphere ROI likely included area surrounding the amygdala. Thus, MVPA may not be the best analysis for this region in the current design.

Interestingly, classification appears to be slightly left lateralized in the ATL and lateral OFC for social status specifically. This was unexpected, given that left hemispheric regions like the ATL tend to be most sensitive to verbal information (e.g., Patterson et al., 2007) and our stimuli were pictures. However, these findings are less surprising if the semantic nature of the status cues is considered. The meaning and status that we associate with pediatricians and bartenders is learned verbally; there are no visual status cues (e.g., greater height) that denote higher status of one profession compared to another. It is possible that if more primitive status cues were used, such as body size and dominance, results would display more right lateralized effects.

#### Generalizability of Reputational Status Representations

Two analyses were performed to examine whether the ATL and OFC classify reputational status across stimulus categories. Classification accuracy in the ATL in the first generalization test, where the classifier was trained on doctor reputational status and tested on restaurant employees, was no better than chance. These findings might indicate

that this region is sensitive to abstract representations of particular types of concrete knowledge associated with people, but not to signals of salience or value per se. However, in the second generalization test the classifier was trained on person reputational status and tested on objects, and results revealed above chance classification in the left ATL. It's possible that the second test benefitted from having more data to train the classifier with, which can improve its performance (Periera, Mitchell, & Botvinik, 2009).

Results from the second generalization test specifically suggest overlap in the regions that decode reputational status for objects and people. More data and further analyses may be needed to fully explain the sensitivity to value representations in the ATL.

#### Early Visual Classification

My findings unexpectedly showed significant classification accuracy in early visual areas – V1 and OFA – for social status only. This occurred across face status analyses in the left hemisphere. These early visual regions were included in the design as perceptual controls, since classifiers have a tendency to be sensitive to perceptual features of images and may over fit the data (Periera et al., 2009). One possibility is that facial features varied with status, and these results indicate classification according to systematic perceptual differences. Another possibility is that the effects for social status in early visual areas result from the increased salience of social compared to nonsocial status information. Prior research suggests that activity in early visual cortex can be modulated by value signals and salient stimuli (Serences, 2008; Vuilleumier, 2005).

A third explanation rests on the nature of the analysis, where training and testing

occurred with the same stimuli. Prior work found above-chance classification in the right OFA and V1 when training occurred on face identities in a subset of data and testing on the same faces in the remaining data (Anzellotti et al., 2013), but these effects were at chance when training and testing occurred on unique stimuli. This is similar to the first generalization test performed in the present study, which aimed to help control for systematic perceptual difference across social status categories. For this analysis, the classifier was trained on reputational status using doctor stimuli, and tested on restaurant employee stimuli. Similar to other social status analyses, left OFA and V1 decoded reputational status. If analyses are isolated to the right hemisphere, as in the study by Anzellotti and colleagues, V1 and OFA classification fall to chance.

#### Limitations

The present study has some inherent limitations. First, the stimulus categories – career title and object names – were undoubtedly familiar to the populations tested here, and is it therefore difficult to ensure that preexisting status or value associated with the stimuli did not interfere with the results presented here. Several actions were taken to minimize these confounds, including: 1) the collection of survey data from a separate group of untrained participants regarding the perceived relative status of stimuli; 2) a generalization tests, where the classifier was trained on one set of stimuli (doctors) and tested on another (restaurant workers); and 3) only including participants who sufficiently learned to associate trained information with the stimuli in the final analyses. However, future work should examine whether these effects hold for other measures of status. Additionally, the object exemplars in the stimulus set varied more than the face exemplars, which presents a challenge when drawing conclusions about comparisons

across social and nonsocial stimuli.

Second, while the Gaussian naïve bayes (GNB) classifier use in the present analyses is commonly used in MVPA (Coutanche & Thompson-Schill, 2012) and has been shown to perform well as a classifier (Mitchell et al, 2004), it may be a relatively poor classifier of BOLD data (Misaki, Kim, Bandettini & Kriegeskorte, 2010). Thus, the use of a more sensitive classifier may have yielded different results. Additionally, some effects in the current study are relatively small, and adding more data may produce different results as well.

Finally, the present analyses do not consider the potential effects of participant social standing, which has been shown to modulate activity in reward regions when viewing individuals of higher or lower status (Ly et al., 2011). Additionally, individual differences in the value attributed to social rewards can modulate functional connectivity between neural regions representing social information and value (Smith, Clithero, Boltuck, & Huettel, 2013), thus personal value attributed to status might modulate the effects found here. We are currently collecting data in the lab to examine the extent to which individual social standing, as well as self-reported dominance and value regarding social hierarchies, modulate neural activity.

### Conclusions

The present findings suggest neural networks involved in conceptual knowledge and valuation intersect during social and nonsocial status perception. These results indicate both shared and discrete mechanisms underlying social and non-social status perception, and potentially explain the value attributed to high status. The involvement of the regions involved in affective and reward processing in social status perception

supports prior findings, and the involvement of person-processing regions builds on prior findings by providing a mechanism by which status becomes embedded in our knowledge of people and signaled as important. Together, these findings can potentially elaborate on the impact status has on social cognition.

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