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Neural correlates of self-reflection in fMRI: Brain activation differences between males and females

Tyler Eugene Owens
Brigham Young University - Provo

NEURAL CORRELATES OF SELF-REFLECTION IN FMRI:

BRAIN ACTIVATION DIFFERENCES BETWEEN MALES AND

FEMALES

by

Tyler E. Owens

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Tyler E. Owens

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Mark D. Allen, Chair
Date	Dawson Hedges
Date	Ross Flom

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Tyler E. Owens in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date	Mark D. Allen Chair, Graduate Committee

Accepted for the Department

Date	Harold L. Miller Jr. Graduate Coordinator

Accepted for the College

Date	Susan Rugh Associate Dean, College of Family, Home and Social Sciences

ABSTRACT

NEURAL CORRELATES OF SELF-REFLECTION IN FMRI:
BRAIN ACTIVATION DIFFERENCES BETWEEN MALES AND FEMALES

Tyler E. Owens

Department of Psychology

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Many studies in affective neuroimaging have addressed the question of how the "self" is represented in brain activation. The medial prefrontal cortex (mPFC) is implicated in many of these studies and an essential component self-representation in the brain. In this study we looked at differences between men and women in the mPFC in terms of how they assessed comparisons of the body image. Participants viewed images of thin and overweight bodies and were asked to consider how they would feel if someone were to compare them to the image. Brain activations were measured using functional magnetic resonance imaging (fMRI). Results indicate that men did not react significantly differently to thin or overweight images while women showed increased mPFC activation when considering comparison to the overweight images. These findings provide some insight into the differences between men and women in terms of self-evaluation and body image.

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Neural correlates of self-reflection in fMRI: Brain activation differences between males and females

In neuroscience and neuroimaging there is a propensity to identify areas of the brain which are, more or less, responsible for a particular thought or behavior. Currently the understanding is that the patterns and sequences of activation among many areas acting in concert are what give rise to our thoughts and behaviors. Even when considered holistically, it is apparent that there is a division of labor in the brain such that it is divided into functionally and anatomically specialized areas. The architecture and function of these brain regions have proven to be amazingly consistent across people, and while individual differences exist and can be profoundly different in some instances, much can be learned by considering the general case.

Development of the brain begins with a genetic framework and is shaped by environmental factors. Inclusion in a particular population, defined here as a group characterized as having similar genetic or cultural traits along a selected set of dimensions, may help predict brain activation differences when compared to activation patterns of some different population. One of the most basic groupings of people is along the dimension of gender. The differences between men and women have been studied extensively in neuroscience. Often cited are differences in verbal processing, spatial conceptualization, and cross-lateralization (Hyde & Linn, 1998; Voyer, Voyer, & Bryden, 1995; Wager, Phan, Liberzon, & Taylor, 2003). Studies on gender differences have been a fertile area of inquiry and as such have resulted in a vast body of research. There still remain domains that have been less closely examined. One such domain that is central to this paper is “the self.” More precisely, of interest are the patterns of activation that are the neurological corollaries of self-referential cognition and how these patterns may differ between men and women. It is reasonable that if other complex forms of cognition, such as executive function, can be strongly associated with a specific region or network, then self-evaluation may have a similar area of association. With the existence of such an area or network of areas, the question left is whether gender differences in that area can be found.

Neurological corollaries

A fundamental assumption in neuroscience is that underlying patterns of cognition give rise to corresponding behaviors. If this is so, then these same cognitive patterns should also give rise to corresponding neurological activation patterns. Looking at functional patterns could be well measured through functional magnetic resonance imaging (fMRI). FMRI provides an effective method to examine in vivo the active components of cognitive processing in the brain. Cognitive processing occurs at every level of function from subliminal, as shown by implicit association tasks (Greenwald & Farnham, 2000; Silvera, Moe, & Iversen, 2000), to high-level conscious thought. Only recently have strategies been developed that can address social processing and self-examination in fMRI. Unique to social cognitive fMRI experiments is the importance of a person to be actively aware of “self” and the self’s relationship to “other”. FMRI studies addressing the self show a number of areas consistently activated across individuals. Among these are the left and right medial prefrontal cortex (mPFC) and anterior cingulate cortex (ACC) (Johnson et al., 2002; Ochsner et al., 2005), posterior cingulate cortex (PCC)(Ochsner et al., 2005; Zysset, Huber, Ferstl, & Von Cramon, 2002), and parietal cortex (Lou et al., 2004). Most prominent of these areas is the mPFC, which has been shown repeatedly to be differentially activated when participants think about self-relevant and self-evaluative concepts versus non self-dependent concepts. Understanding the meanings of activation in these areas is necessary to further understand how humans evaluate themselves in relation to the social world.

Role of fMRI

Functional MRI is a safe, non-invasive process by which activity in the brain may be studied on people in vivo. In preparation for a scan, a participant placed inside the magnetic resonance imaging scanner. A strong magnetic field, generally ranging from 1.5T (tesla) to 7T, polarizes targeted molecules in the brain and surrounding tissues. For fMRI these are typically hydrogen protons. These molecules respond to strong magnetic fields and so line up with the magnetic field produced by the scanner. By disturbing the alignment of these protons to various degrees, a signal can be collected which describes the nature of a particle’s disalignment or realignment with the primary magnetic field. Every substance responds to these fluctuations in a way that is uniquely characteristic to its chemical composition. An fMRI targets the amount of oxygen-rich hemoglobin present in the blood, which is the blood oxygen level dependant signal, or BOLD signal. Astroglial cells supporting neurons monitor the metabolism of the neurons. When a neuron begins firing, consuming resources more rapidly, astroglial cells expand nearby blood vessels to provide the neurons more oxygen and glucose. More oxygen than is used by the neuron is supplied. The relative increase of oxygenated hemoglobin in these areas is interpreted to mean increased firing of nearby neurons indicating activity in that area while performing a task, interpreted to show the brain processes occurring in real time. The relationship between the BOLD signal and neuronal activity is well understood and predictable. Experiments conducted using fMRI as a tool to gather data have yielded theoretically and pragmatically relevant results. This experiment presented aspires to follow in that trend.

Roles of cortical areas in self-evaluation

The most commonly implicated area in self-referential or self-evaluative mental tasks is the medial prefrontal cortex (mPFC). The mPFC tends to have a relatively high resting metabolic activity (Raichle et al., 2001) and is activated during many cognitive processes. Some of these processes are goal-oriented behavior (Gusnard, Akbudak, Shulman, & Raichle, 2001), fear responses in post-traumatic stress disorder (Shin, Wright, Cannistraro, Wedig, McMullin, Martis, et al., 2005; Shin, Rauch, & Pitman, 2006), and attentional discrimination in attention (Small et al., 2003). The variety of functions implied to the mPFC is not surprising considering the generalized role in the neocortex for processing high-level tasks. The consistency of activations across self-reflections studies forms compelling evidence for a key role of the mPFC (Gusnard et al., 2001; Johnson et al., 2002; Schmitz et al., 2004; Zysset, Huber, Ferstl, & Von Cramon, 2001). Many studies interested in self-reference, despite showing similar activations patterns, still show meaningful differences in specific regions of activated areas. The subtle variations in types of tasks employed in self-reflection studies reveal subtle variations of functioning that indicate avenues for further research.

An early study addressing differential processing of self-evaluation and simple declarative memory was conducted by Zysset et al. (2002). Cognitively-healthy participants' functional patterns were compared across three types of memory. They were required to produce responses to statements featuring only semantic memory ("December

31st is New Year's Eve"), episodic memory ("I spent New Year's 2000 at home"), or evaluative statements ("I enjoy going to New Year's parties"). During the semantic memory task the data showed no difference in the mPFC compared to baseline. The episodic and evaluative tasks both show significant levels of mPFC activation with greater activation expanding into the anterior regions during the evaluative task. The above data support ideas that the mPFC is activated during self-referential stimuli and not for semantic memory. Additionally, significant activation was found bilaterally in the precuneus, an area with strong, direct corticocortical ties to the mPFC. Johnson al. (2002) presented a similar study with the stimuli presented aurally. Cognitively-healthy participants evaluated semantic statements (e.g. "Ten seconds is more than a minute") and personal statements (e.g. "I'm good at my job") while undergoing an fMRI scan. The results showed mPFC activation for the self-evaluative condition. Activation is also shown in the posterior cingulate gyrus, which is approximately the same area in Zysset al. (2001) described as the precuneus.

In a related study, Gusnard al. (2001) conducted an experiment using pictures as the stimuli. Participants were shown images of varying emotional content, which were designed to elicit either high emotional response (e.g. playing babies, burn victims) or low emotional response (e.g. household objects, neutral faces). For the first condition, the internally cued condition, participants were asked to judge whether the pictures made them feel pleasant or unpleasant. In the participants' second task was the externally cued condition, where they considered the same picture set from the internally cued condition based on purely visual features, which in this study was whether the image was indoors or outdoors. Regardless of a picture's emotional valence, anterior dorsal mPFC activation was shown during the internally cued condition compared with the externally cued condition. During the internally cued condition there was also marked deactivation in the ventral mPFC, which was attributed to attenuation of emotional processing during the attention-demanding tasks (Gusnard et al., 2001). This study examined self-reflection that beyond yes or no decisions and without using memory of specific past events to inform how they judged the stimuli. This difference in design further clarified the role of activated areas, which were consistent with results found by previous self-referential studies, as self-evaluative processes.

In the years following the aforementioned studies, research in social neuroscience has continued building a body of evidence about mPFC involvement in the brain's processing of self-relevant information (Johnson et al., 2005; Mitchell, Banaji, & Macrae, 2005; Ochsner et al., 2004; Schmitz & Johnson, 2006; Schmitz, Kawahara-Baccus, & Johnson, 2004). Through the progression of self-reference studies, differences among examination questions have shown some differences in functional processing. Mitchell et al. (2005) conducted a brief review of the tasks from several studies of self-reflection. This review showed that mPFC activation across studies is associated with self-evaluation of pictures (Gusnard et al., 2001), personal traits (Johnson et al., 2002; Kelley et al., 2002), self-knowledge (Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Zysset, Huber, Ferstl, & Von Cramon, 2002), emotional reactions to food (Schmitz et al., 2004), and first-person perspective (Vogeley et al., 2004).

What has emerged from the many studies in affective, cognitive, and social neuroimaging paradigms is a theory that two primary top-down systems are employed in the processing of self-relevant information (Schmitz et al., 2007). The first system orients the individual to potentially self-relevant features of environmental stimuli. This top-down process can anticipate and judge what relevant stimuli in the environment relate to the individual. An individual assessing the pain of a pin prick or evaluating a reward would be employing this system. Areas implicated in this system are the ventral mPFC, ACC, amygdala, striatum, and insula. The second system addresses self-evaluation and how one feels and thinks internally. These tasks make up the bulk of studies addressed in this paper so far. (e.g. how viewing images made oneself feel or how one felt about themselves and their preferences). This system is composed of the dorsal and ventral portions of the mPFC and the dorsorostral ACC and PCC. These two processing systems appear to be dissociable but often times the requirements of evaluative tasks will activate aspects of both systems. By understanding the types of stimuli that drive these processes it’s possible to make finer-grained inferences from the activation patterns resulting from evaluative tasks. For instance, the types of thoughts one has about oneself may also affect the activation of the mPFC and related areas in terms of general activation and in terms of specific regions within the mPFC.

Johnson et al. (2006) demonstrated there to be a double dissociation between the mPFC and the posterior cingulate gyrus when comparing thoughts about hopes and aspirations (activation in the mPFC) to thoughts about duties and obligations (activation in the posterior cingulate). While mPFC activity was found in both conditions, the differential activation is suggested to mean that relatively inward focused thoughts occur further anterior and ventral in the mPFC and that relatively outward focused thoughts are active more posterior and dorsal in the mPFC along with showing higher activation in the posterior cingulate. These activations are consistent with the second type of self-referential processing. This evidence, considered in concert with other findings presented, suggest that there is enough consistency to predict activation patterns elicited by socially relevant stimuli, similarly constructed to other experiments. In fact, many fine-grain distinctions can be made now about the systems and processes that underlie appraisal and self-evaluative thinking.

Social gender differences

The research presented thus far has generally relied on questions where participants consider a statement or an image and how it relates to them or another person. Gender differences have not been directly considered in the analysis or construction of these experiments, yet there is evidence in the literature which indicates males and females differ substantively in cognitive social processing. Females, particularly younger females, show more public self-consciousness than males (Gould, 1987). Females also appear to be more concerned than males with physical attractiveness, eating, body weight, and body-image related self-esteem (Feingold, 1998; Furnham, 2002; Mintz, 1986; Pilner, 1990). Satisfaction with one's body has a significantly correlation with self-esteem for females than it does for males (Furnham, 2002; Mintz, 1986; Pliner, 1990). Females relating body-image more closely to their sense of self-worth is suggestive of a difference in self-referential processing. Stimuli asking individuals to judge the personal relevance of external, body-image cues would likely show differential activation between males and females because of the behavioral differences observed in past studies. In terms of social cognitive differences, women are more sensitive to the availability of social support relationships (Kendler, 2005). In general and specifically in terms of body image, females appear to be more keyed into social context than men. Women seem to relate their self-esteem to external social cues while men are less sensitive to comparable cues. It seems then when given a task to relate socially relevant stimuli that address body-image, women and men will have differential activation as a result of qualitatively different cognition processes.

One study quite similar to the study proposed here examined where there would be processing differences between men and women who evaluated neutral words and unpleasant words associated with body image (Shirao et al., 2005). The gender differences found were that women showed higher left amygdalar activation and men showed increased left dorsal mPFC activation. Participants judged whether they found a word unpleasant, allowing researchers to examine the how self-generated evaluation differed between genders. The study we conducted used stimuli that were different from self-generated evaluation because the given task explicitly asked participants to evaluate themselves, rather than making value judgments of external objects, which is a process that is only indirectly self-evaluative. Because self-evaluation is central to our study, we may encounter similar activations as Shirao et al (2005), however the different types of stimuli (i.e. images versus words) and the different focus of the prompts (i.e. direct versus indirect) may lead to different activation patterns.

Predicted Activation

The task we used incorporated a number of features from the various studies presented above but is unique because it is looking exclusively at the differences between males and females in a given condition. We expect find activation patterns consistent with past self-evaluative studies along with nuances in those patterns consistent with the new aspects of cognition we are examining. The areas typically activated in cognitive-affective tasks such as ours are bilateral medial prefrontal cortex, anterior cingulate cortex, and medial parietal cortex. The areas where we strongly expect to see gender differences arise are in the mPFC, with possible differences in the PCC, parietal lobes, and visual areas. The more ventral activation is likely given the emotional processing associated with ventral mPFC and the increased self-image processing that females are likely to employ. Amygdalar activation similar to that found by Shirao et al. (2005) may also be observed. This activation may implicate the females processing the information more strongly with the ventral mPFC-ACC-subcortical system theorized by Schmitz and Johnson (2007). Visual processing may have a different pattern between females and males since we predict women will be more likely to scrutinize the images closely while considering their selves. Parietal areas may show increased activation in women as an indication of increased attention and resources that will be directed to the self-relevant processing.

Method

Participants

Female (n=9) and male (n=8) participants in this study were ages 18-30 years old. Participants were screened for neurological, psychological, and psychiatric disorders using a pre-testing questionnaire. Participants unable to safely be placed in the MRI machine, such as pregnant women or those with severe claustrophobia, were unable to participate. No participants in this study met the exclusion criteria and so are included in the data analysis. All participants were acquired on a volunteer basis and are not compensated monetarily.

The recruitment of participants was non-traditional and deserves comment. Because of the relative expensiveness of testing and sensitive nature of image acquisition, we require participants with high levels of comfort and compliance with the scanning procedure. Previous experience has shown that participants familiar with the lab or its members are more compliant and relaxed, maximizing the effectiveness of the scans and ensuring that scanning sessions are productive. Furthermore, participants of this sort have been found to be especially compliant and cooperative given that they are interested to see their own activation patterns at the end of the study. This means that rather than simple random sampling, selection was conducted as a convenience sample. This selection method is adequate for the aims of this study and similar methods have been successful in this lab in the past and in other studies with similar circumstances.

Location

All fMRI scans were conducted at the Riverwoods Imaging Lab in Provo, UT. The Riverwoods Imaging Lab is administered under the supervision of Dr. Wendell A. Gibby, MD. Participation instructions, map to the Riverwoods Imaging Lab, and contact information was provided at the Functional Neuroimaging Lab website, http://fnilab.com. Each session took approximately 60 minutes for a subject to complete, with 20-30 minutes of that time being spent in the scanner. The scan was conducted by a certified MRI technician and at least one trained member of the BYU Functional Neuroimaging Lab.

Stimuli

The stimuli presentation was managed by E-Prime software. Participants viewed stimuli on a back-projection screen via angled mirrors. Participants viewed full-body images of women or men of two types—thin or obese. Computer generated virtual models for both fat and thin conditions were used to create a variety of appearances (e.g. varying skin tone, hair color, hair style, and orientation—facing either forward, left, or right) while keeping consistent the physical builds of the men and women in the images. These variations were intended to keep the stimuli varied for the sake of participant interest to keep attention engaged in the task. The feature variations also were meant to control through randomization possible effects of any participants identifying systematically more strongly with a particular arrangement of appearance traits. The baseline condition stimuli were images from the evaluation conditions graphically distorted by a computer algorithm. This process maintained the color density and similar visual size of the evaluation stimuli while removing the visual features of a person or any other recognizable form.

Huettel, Song, & McCarthy (2004) suggest a pattern of alternating stimulus and rest in blocks of approximately 12-18 seconds each. These block lengths are such so that there is optimal time for activations to show up in the statistical analysis. Cardiac and respiratory cycles directly affect acquisition of a robust blood oxygen level dependent (BOLD) signal. Because of the "boxcar-style" of statistical model was used for statistical analysis, this block design described above has been chosen.

Stimuli were presented one at a time at a rate of one per second. Stimuli were grouped in blocks of 12 sequential images for a particular stimulus type (evaluation or baseline). Within the evaluation blocks participants were presented images of obese or thin women. Each evaluation block was followed by a baseline block consisting of distorted images.

Figure 1: Examples of visual stimuli for males and females

This baseline "resting" period was a non-demanding task that was used to subtract out shared activation from the evaluation condition. Instructions that invite minimally demanding cognitive processing of the rest stimuli kept participants engaged in the task and prevented their minds from wandering and creating random, inconsistent results (Stark & Squire, 2001).

Instructions

Both men and women received the same verbal instructions. While being shown the series of images they were asked to consider the following: "Imagine that someone is comparing the way you look to the women/men you see in the pictures." When viewing the distorted pictures they were instructed simply to freely visually inspect the images. Protocol scripts for the instructions were created in order to ensure strict uniformity across experimenters.

Image Acquisition

Image acquisition was done using a 1.5T MRI scanner using an echo gradient, echo planar imaging (EPI) sequence with timing parameters of TR = 2000 and TE = 30 ms. A full image volume of 23 axial slices with a 5mm thickness was taken contiguously (no gaps) and completed every 2 seconds. The protocol used (EPIBOLD) is sensitive to the BOLD signal. A full brain volume was sampled with total of 64 x 64 x 23 (94,208) voxels (i.e. volumetric picture elements) at a resolution of 3.75 x 3.75 x 5 mm for each voxel.

Statistical Preprocessing

The analysis of collected data was analyzed using several computer tools. The data first was reconstructed using an epirecon on an Intel x86 computer running a SUSE Linux distribution. The data then was processed using SPM5 (i.e. statistical parametric mapping) software and statistical analysis software Matlab: Release 13 Version 6.5. Each dataset underwent a series of pre-statistical preparation. First, each participant's data underwent slice timing correction to adjust for the time differences between voxels scanned during a single volume acquisition. The next step was realignment and unwarping of the data. This procedure adjusted for distortions in the images caused by field strength differences across all voxels. In this step head movement is motion-corrected for translations in the x, y, and z axes and for changes in rotation, pitch, and yaw. Movement beyond 2 mm or 2 ° is considered excessive and will result in the participant's data being thrown out. The next step was normalization, which adjusted the brain images to fit the same space as the MNI (Montreal Neurological Institute) brain template. Normalizing each brain allowed comparisons to be made about specific areas of the brain because areas now share the same 3-dimensional space. The last pre-statistical step was to conduct spacial smoothing. This process removed the aliasing resulting from compiling the layers and created smooth continuation throughout the brain image. This process made the results easier to interpret and increase the effectiveness of the statistical analyses themselves.

Statistical Analysis

The primary statistical approach was from the General Linear Model using a time-series variant of ANCOVA (Analysis of Covariance). Each voxel was statistically tested against the null hypothesis in terms of rise and fall of BOLD signal as predicted by the statistical model. The model also weighed activation of voxels more highly if they are near other voxels with activation and less so when near less active voxels (Penny, Holmes, & Friston, 2003).

The design was a standard "boxcar" design and predicted a series of low activations (baseline task) and high activations (evaluation task) in BOLD signal. The activations, rather than being modeled like a simple on-off switch, followed a hemodynamic response function (HRF). The HRF modeled the natural progression of BOLD signal, including onset, peak activation, return to baseline, and baseline undershoot. The result of the ANCOVA analysis was a brain-volume map of t-values. The t-values have been represented as corresponding brightness visually mapped onto the 3-dimensional structural image.

Results

Simple t-test comparisons were made between the males and females to test for the effect of gender. We subtracted activation patterns for two conditions, thin and fat, for both males and females. This subtraction was done by subtracting thin-condition activation from fat-condition activation and in the reverse, subtracting fat-condition activation from thin-condition activation. The remaining activations represented the statistically significant areas that are unique to the main condition considered. These resulting regions have been mapped onto an average brain and compared between males and females and examined for differences in area. All reported statistics are significant at p > .05. The locations of peak activity of the reported clusters were in MNI coordinates.

Areas of activation in the thin-minus-fat comparison for females were found at the right inferior frontal sulcus [t(9) = 4.5, p < .05, at x = 45, y = 20, z = 33] and the left middle frontal gyrus [t(9) = 4.5, p < .05, at x =-50, y = 30, z = 33].

Areas of activation in the thin-minus-fat comparison for males were right precentral gyrus [t(8) = 5.8, p < .05, at x = 52, y = -2, z = 45], right inferior frontal gyrus [t(8) = 5.8, p < .05, at x = 52, y = 35, z = 10], left anterior calcarine sulcus [t(8) = 4.7, p < .05, at x = -5, y = -57, z = 5], and medial superior precuneus [t(8) = 6.9, p < .05, at x = 0, y = 68, z = 60].

For the fat-minus-thin comparison, activation for females was seen in the left superior frontal gyrus [t(9) = 4.9, p < .05, at x = -15, y = 56, z = 29], right anterior cingulum on the border of right superior frontal gyrus and right medial superior frontal gyrus [t(9) = 4.8, p < .05, at x = 13, y = 47, z = 24], right frontal operculum [t(9) = 4.5, p < .05, at x = 53, y = 13, z = 4], and right *pars opercularis* bordering on *pars triangularis*/inferior frontal gyrus [t(9) = 4.5, p < .05, at x = 53, y = 23, z = 9].

For the fat-minus-thin condition, males showed no significant activation at the p < .05 level. All information about significant activations is summarized in Table 1.

Table 1: Areas of activation significant at $p < .05$

Brain Region	*x*	*y*	*z*	t-score
Female (T-F)				
Right inferior frontal sulcus	*45*	*20*	*33*	4.5
Left middle frontal gyrus	*-50*	*30*	*33*	4.5
Male (T-F)				
Right precentral gyrus	*52*	*-2*	*45*	5.8
Inferior frontal gyrus	*52*	*35*	*10*	5.8
Left anterior calcarine sulcus	*-5*	*-57*	*5*	4.7
Medial superior precuneus	*0*	*68*	*60*	6.9
Female (F-T)				
Left superior frontal gyrus	*-15*	*56*	*29*	4.9
Right anterior cingulum	*13*	*47*	*24*	4.8
Right frontal operculum	*53*	*13*	*4*	4.5
Right *pars opercularis*	*53*	*23*	*9*	4.5
Male (F-T)				
No significant activations	-	-	-	-

Discussion

The aim of this study was to identify possible differences in the functional activation patterns between men and women in regards to how individuals process ideas about the self. The most interesting differences observed were in frontal areas, with some unexpected activations appearing in certain conditions.

Thin-Minus-Fat Condition

Though not the primary condition of interest in this study, the thin-minus-fat condition showed some interesting and unexpected results. Because a theoretical framework for these results has not yet been established, the discussion for these results is somewhat speculative, but nonetheless may help make tentative sense of the results and provide ideas for future research.

The differences between men and women are noticeable in the frontal lobes and in the very dorsal precuneus. The women display bilateral activation in the dorsolateral prefrontal cortex, which is an area associated strongly with working memory and attentional tasks. It is possible that the since the thin task is less emotional for women, there are fewer resources being devoted to mPFC areas and emotional processing, leaving more resources available for maintaining attention on their given task.

A rather unexpected activation appeared bilaterally at the dorsal precuneus in males. Activation in the precuneus has been implicated previously as part of a system that judges emotional state attribution of oneself versus that of another (Oschner, 2004) and thus may be being activated in this study by the instructions given (i.e. being asked to consider whether another would describe as being similar to the image). The activation in

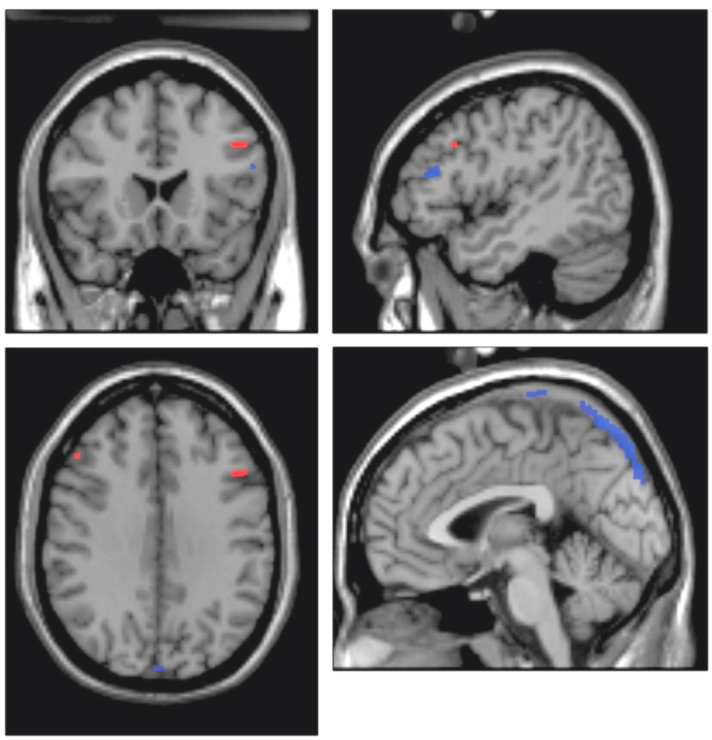

Figure 2 – Significant activations for T-F overlaid on an average brain; males = blue, females = red

this study is more dorsal and is bilateral, which may indicate that the activation may represent a different process altogether. Why this activation is seen only in the thin condition and only for males remains mysterious to us and warrants further attention in a later study.

Fat-Minus-Thin Condition

The fat-minus-thin condition in this study is the main contrast of interest. The results provide compelling evidence for the notion that social differences between men's body images and women's body images are reflected in differing thought patterns. In the fat-minus-thin condition, there is a stark difference between males and females in activation patterns; men show no significant activations while women show bilateral activation in medial prefrontal cortex and cingulate, consistent with the literature on this type of task and with the predictions of this study.

The initial possibility considered is that while the thin images were quickly identified with by the participants, the fat images required increased introspection. Since none of the female participants were obese, it is possible that they did not easily identify with the images of larger women. Rather, they were able to quickly identify with the thin images. This difference is reflected in the relative differences in activation between the fat and thin conditions. The women evaluated the verbal instructions for the thin images easily but had to exert more mental effort to evaluate the fat images, which were noticeably different from their actual appearance. In essence, the by not identifying with the larger women, there was no immediate agreement with the hypothetical person comparing them to the fat image and they would continue evaluating that image, searching again for elements that could be considered relatable. This possibility supports the idea that these women easily associated with images similar to them and less easily with those different from them, therefore requiring more intense use of self-reflective processes and further analysis when trying to relate to those which do not immediately seem comparable.

Men, however, showed no significant activation in the fat-minus-thin condition meaning there was nothing unique to the fat condition that was not described in the thin condition. This means that there was nothing particularly different or interesting to the men about the fat images insofar as there was no additional or different processing done by men compared to looking at thin images. Under the same interpretation being used for the women, the men must be easily identifying with both thin and fat images rather evenly or less strongly with either. Whatever the case, there is evidently a lack of preference for one or the other as there is with women.

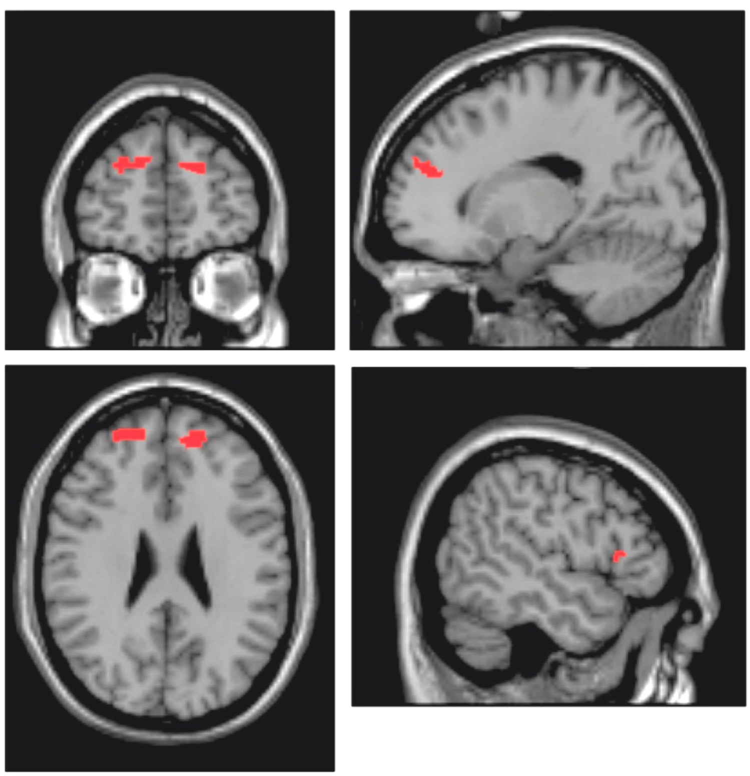

Figure 3 – Significant activations for F-T overlaid on an average brain; males = blue, females = red

Extending this interpretation, we consider that the bilateral activation of the mPFC in females relates specifically to the verbal prompt, where a third-person comparing the women to those in the fat image. The women may be deeply considering this possibility and even perhaps "taking it personally" as they consider that they may be overweight. The pressure associated with avoiding an overweight identity and the emotionality of the comparison leads to increased activity in the areas of the self. This second conclusion is more compelling when accounting for the male results in this same condition.

We suggest that the difference of social pressure for men and women is reflected in this difference of processing. Since there is less social pressure for men to conform to a specific physical ideal, there was less reason to take personally the idea that they were being compared to any of the images. The thin and fat images may have both been considered too extreme to identify with closely or that there is simply a wider range of acceptable male body types and none of them carry the same emotional and social weight for men that women experience.

Areas where we predicted to see some activation and did not were in PCC, parietal areas, and visual areas. This indicates that the differences between the two tasks were primarily similar, especially at the lower levels of processing. This makes intuitive sense because the two conditions were nearly identical and the prompt was asking participants to consider aspects of the images and their selves in ways that would result in differential activation of frontal areas but not necessarily changes in the basic demands of the task. The two conditions did not require a significant difference in attention or visual scrutiny that would result in significant changes to PCC, parietal, or visual areas. By virtue of these areas not changing, we are, in fact, more confident that the changes seen in the frontal lobes are differences in executive function processing and not changes related to altered lower level processing.

Conclusion

The aim of this study was to investigate differences in functional activation patterns between men and women in regards to the role of body image in self-schema representations. The paradigm employed was designed to maximize mPFC activation by eliciting both self-reflective and self-reflexive processes (i.e. self-reflection in the context of social judgment), where known loci of activation within mPFC for these two processes appear to overlap (D’Argembeau et al., 2007; Ochsner et al., 2005). One might suggest that the lack of activation could be that some participants simply were not complying with the instructions during the task. This situation would require a selective failure to comply with instructions in all but the female-fat condition. Though we cannot say for certain that this possibility occurred, we find it highly unlikely that participants would be selectively compliant with instructions. Post-scan debriefings with participants also indicated that full effort was being given. Also, this explanation would require only females to be selectively comply with instructions.

The more likely explanation is that the brain activation patterns seen in this study appear to bear out the hypothesis that men and women evaluate their self-image in markedly different ways. Women, who regularly endure social pressures to conform to an ideal body type and are more tuned to social demands, seem to evaluate their self-image in a personal way when considering the possibility that they are overweight. Men, who have less social demands on their image, seem collectively indifferent when considering that they might be overweight. The experimental conditions did not elicit in men the same level of deep and meaningful analysis of the fat images that women did.

There are some limitations of this study that could be addressed in the future. The results we have so far are promising and allow us to put forth several compelling conclusions, but a greater sample size would result in several enhancements. Stronger statistical processes to be used when analyzing the data which could make apparent areas of activation that are missed using the smaller dataset. Increased sample size would also give us additional confidence in the conclusions we draw and make them more scientifically convincing.

It is important to acknowledge that every population is comprised by individuals who may vary greatly from one to another, especially in populations as large as men and women, and that the gross gender differences found in this study should not be blindly applied to any individual. These results are meant to contribute to a body of work regarding gender differences and to help form a starting point when working to understand the aspects of social cognition and self-evaluation for men and women.

This study leaves several questions left to be explored. Differences in gender and self-image and evaluation are a largely unexplored space. Self-identity subtypes within both genders may exist which could help be categorized by imaging techniques. Breaking down males and females into groups by weight or body mass index (BMI) is one grouping that may yield results. This grouping could explore whether individuals identify with images of a similar body type or whether there is a psychological identification relatively independent of body type that is related to social or personal ideals. Certain aspects of the results, particularly activations in the thin-minus-fat conditions, for the females in the dorsolateral prefrontal gyri, and for the males the strong dorsomedial precuneus, are not fully understood. Further replication and examination of these aspects could hopefully isolate and elucidate the functions of these areas and define better their contributions to this type of self-evaluative processes.

Despite some remaining mysteries, we have identified an important aspect of gender-related cognition that is revealed during self-evaluative processes. These findings are hopefully a useful contribution to the complex studies of gender identity and self-evaluation. Ideally this path of inquiry will have socially relevant use and lead to a healthier, fully-informed view of gender.

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