Learning Faces as Concepts Improves Face Recognition by Engaging the Social Brain

Network

Adva Shoham\(^1\), Libi Kliger\(^1\) and Galit Yovel\(^{1,2}\)

1. The School of Psychological Sciences, Tel Aviv University
2. Sagol School of Neuroscience, Tel Aviv University

Adva Shoham [https://orcid.org/0000-0002-7923-2474](https://orcid.org/0000-0002-7923-2474)

Libi Kliger [https://orcid.org/0000-0001-8316-2854](https://orcid.org/0000-0001-8316-2854)

Galit Yovel [https://orcid.org/0000-0003-0971-2357](https://orcid.org/0000-0003-0971-2357)

**Corresponding Author:**

Adva Shoham

advashoham@mail.tau.ac.il

+972-509882221

Haim Levanon 30, Tel Aviv University, Tel Aviv, Israel.

Words is Abstract: 199

Words in the text: ~5200
Abstract

Face recognition benefits from associating social information to faces during learning. This has been demonstrated by better recognition for faces that underwent social than perceptual evaluations. Two hypotheses were proposed to account for this effect. According to the feature-elaboration hypothesis, social-evaluations encourage elaborated processing of perceptual information from faces (Winograd, 1981). According to a social-representation hypothesis, social-evaluations convert faces from a perceptual representation to a socially meaningful representation of a person. To decide between these two hypotheses, we ran a functional MRI study in which we functionally localized the posterior face-selective brain areas and social processing brain areas. Participants watched video-clips of young adults and were asked to study them for a recognition test, while making either perceptual evaluations or social evaluations about them. During the fMRI scan, participants performed an old/new recognition test. Behavioural findings replicated better recognition for faces that underwent social then perceptual evaluations. fMRI results showed higher response during the recognition phase for the faces that were learned socially than perceptually, in the social-brain network but not in posterior face-selective network. These results support the social-representation hypothesis and highlight the important role that social processing mechanisms, rather than purely perceptual processes, play in face recognition.
Introduction

Faces are visual stimuli that convey very rich perceptual and social information. The perceptual information refers to our ability to evaluate whether a given face has a large nose, thick lips, or large eyes (Abudarham & Yovel, 2016; Valentine, 1991). In addition, based on these perceptual features, humans also make automatic and consistent social inferences, such as how trustworthy or competent a face looks like (Todorov & Oosterhof, 2011; Willis & Todorov, 2006). Interestingly, even though both perceptual and social evaluations rely on judging the visual appearance of facial features, studies have shown that making social evaluations during face encoding significantly improves face recognition relative to perceptual evaluations (Bower & Karlin, 1974; Mueller, Carlomusto, & Goldstein, 1978; Schwartz & Yovel, 2019a, 2019b; Strnad & Mueller, 1977).

Two main hypotheses were suggested to account for this social evaluation benefit in face recognition. In line with the level of processing (LOP) framework (Craik, 2002; Craik & Lockhart, 1972), Bower and Karlin (1974) suggested that trait judgments lead to deeper encoding of faces by creating a rich, semantic network of associations. In contrast to the semantic account, Winograd (1981) proposed a perceptual account for the benefit of social evaluations in face recognition, known as the feature elaboration hypothesis, according to which trait inferences improve face recognition by encouraging elaborated processing of perceptual information and encoding more facial features.

In a recent study, Schwartz & Yovel (2019a) directly tested the feature elaboration hypothesis by measuring reaction times (RTs) for social and perceptual evaluations during the learning phase. In five different experiments that replicated the better recognition for socially than perceptually evaluated faces, they found that RTs were significantly shorter for social than perceptual evaluations. These findings imply that the social evaluation benefit in face
recognition cannot be attributed to more elaborated processing of facial features during learning. With the lack of support for the feature elaboration hypothesis, Schwartz and Yovel proposed that the difference between the representation that is generated following social and perceptual evaluations is not a quantitative perceptual difference but a qualitative conceptual one. In particular, making trait inferences about faces during encoding, generates a meaningful social representation of a person, thus converting faces from percepts to socially meaningful concepts, which consequently improves face recognition (Schwartz et al., 2019a). We will refer to this suggestion as the social representation hypothesis.

The importance of social processing during face learning was shown in several studies (Bernstein, Young, & Hugenberg, 2007; Hugenberg, Wilson, See, & Young, 2013; Rule, Ambady, Adams, & Macrae, 2007; Schwartz & Yovel, 2019b; van Bavel & Cunningham, 2012; Wilson, See, Bernstein, Hugenberg, & Chartier, 2014). In a series of studies, Hugenberg and colleagues have proposed that better recognition of own than other-race faces can be explained by social motivation and individuation of ingroup members rather than purely perceptual effects (Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 1996, 2000; Maclin & Malpass, 2001; Rodin, 1987; Sporer, 2001). Furthermore, Wilson and colleagues (2014) have shown that expectation for future interaction with people, improves face recognition for out-group members. In that study, students who expected future interaction with peers from a different institution performed better in a recognition test of these faces than students who did not have expectations for future interactions. These studies, therefore, emphasized the contribution of social context to face recognition.

Taken together, two possible mechanisms were proposed to account for the social evaluation benefit in face recognition: feature elaboration processes or social-conceptual processes. A feature elaboration account is expected to be mediated by perceptual
mechanisms, whereas a social account is expected to be mediated by social processing mechanisms. In the current study, we aim to decide between these two alternative accounts by assessing whether socially-evaluated faces engage perceptual or social processing mechanisms during recognition.

To that effect, we conducted an fMRI study that enabled us to examine separately the response of posterior face-selective brain areas and social processing brain areas during retrieval of faces that were learned socially or perceptually. Participants performed a face learning task outside the scanner during which they evaluated faces socially or perceptually. The fMRI response to socially vs. perceptually-learned faces was measured during the recognition phase in posterior face-selective areas (Duchaine & Yovel, 2015; Kanwisher & Yovel, 2006; Yovel, 2016) and social processing brain areas (Alcalá-lópez et al., 2018; Brothers, 1990; Ciaramidaro et al., 2007; Frith, 2007; Frith & Frith, 2003; Mars et al., 2012; Overwalle, 2009; Rebecca Saxe, 2006; Schmälzle et al., 2017). According to the feature elaboration hypothesis, social learning encourages elaborated encoding of facial features (Winograd, 1981), predicting that the posterior face-selective network will show a higher response for socially than perceptually learned faces during the recognition stage. According to the social representation hypothesis, social evaluations convert a face image to a socially meaningful representation of a person (Schwartz et al., 2019a), predicting that the social processing brain areas will show a higher response for the socially than perceptually-learned faces during the recognition stage. Figure 1 displays the predicted results of the two hypotheses.
Methods:

Participants:

Twenty participants were recruited for this study (see the Supplementary Material for sample size justification). We collected data from 22 healthy (seven women, ages 19-42, 19 right-handed) participants, who received payment ($15/hour) for their participation. All participants were native Hebrew speakers, had a normal or corrected-to-normal vision, and provided written informed consent, which was approved by the Helsinki committee of the Sheba Medical Centre and Tel Aviv University. Two participants were excluded from analysis, one because his responses were not recorded due to a technical problem and one due to a large number of volumes removed during the motion correction procedure (see pre-processing for details), resulting in a sample of 20 participants.
Stimuli:

Main Experiment

Learning phase (prior to fMRI scan):

Stimuli were 12 silent video-clips that depicted a short scene (average duration of 3.75 seconds) in which three individuals were sitting in a cafeteria, conversing with each other (see Figure 2a). Thus, a total of 36 different individuals (20 females) were presented in the videos. The race of the individuals in the video-clips was Caucasian and matched the race of the participants. From the pool of 12 video-clips, eight clips (24 identities) were randomly assigned to the learning phase to each participant. Of the eight clips (24 identities) that were presented during the learning phase, four clips (12 identities) were randomly assigned to the perceptual evaluation condition and the other four clips (12 identities) were assigned to the social evaluation condition. The identities in the remaining four clips (12 identities) appeared only during the recognition phase of the experiment as novel identities. The choice to use video stimuli of people during social interaction, instead of the standard static faces that were used in previous studies (Bower & Karlin, 1974; Mueller et al., 1978; Schwartz & Yovel, 2019a) was to extend the social evaluation benefit to more naturalistic settings (for review of the importance of studying psychological phenomenon in naturalistic settings see: Shamay-Tsoory & Mendelsohn, 2019; Snow & Culham, 2021).
Recognition phase (during fMRI scan):

The recognition phase presented 36 silent colour video-clips of the 24 individuals that were presented during the learning phase and 12 novel identities. Each face was cut from a video-clip and was presented on the screen, one at a time, in sequential random order (see Figure 2b). The recognition test video-clips were cut from different clips of the same individuals that were taken on the same day as the learning phase video-clips.

Functional localizers

Face localizer:

Stimuli were silent colour video-clips of faces or inanimate objects with their background removed. The face stimuli depicted a single person face down to the shoulders, talking or
making facial expressions. The object stimuli were video-clips of moving objects, such as a fan or a ticking clock.

**Social-Perceptual evaluation (SPE) localizer:**

Stimuli were static colour images of faces of 12 young adults (see Figure 3), all were adopted from the Database of Moving Faces and People (O’Toole et al., 2005). All face images were frontal view, neutral expression with the same background.

**Familiar-Unfamiliar face localizer:**

This localizer was included to study the relationship between face familiarity and conceptual and perceptual processing and is beyond the scope of this paper.

**Apparatus and Procedure:**

**Procedure**

The experiment included a 15-min learning phase prior to the MRI scan, in which participants were asked to learn the identities presented in the video-clips for a later recognition test that would take place in the scanner. During the learning phase, participants were asked to make either social or perceptual evaluations about the 24 learned identities. The learning phase was followed by a single fMRI recording session with three runs of the recognition phase, two runs of the face-object functional localizer, two runs of the social-perceptual evaluation (SPE) localizer and two runs of familiar-unfamiliar face localizer. The three recognition phase runs were presented first, followed by the localizers runs that were presented in an interleaved manner. The fMRI acquisition parameters are presented in the Supplementary Material.

**Prior to fMRI scan: Learning phase**

During the learning phase, participants were asked to learn a total of 24 different identities, presented in 8 video-clips that included three identities each, and rate them based on either their perceptual appearance or their inferred personality traits. Each trial began with either a
perceptual or a social question from a set of three questions that were used in our previous studies (Schwartz & Yovel, 2019a, 2019b). Social and perceptual mini-blocks of three questions were presented in random order. Following the clip offset the participants were asked to rate each identity in the clip based on the question that appeared at the beginning of the trial on a scale of 1 to 7 (see Figure 2). The social questions were "How trustworthy/friendly/aggressive is the face of each of the individuals in the following clip?". The perceptual questions were "How smooth/round/bright is the face of each of the individuals in the following clip?".

**fMRI scan: Recognition phase**

Each of the three runs of the recognition phase included two presentations of 36 faces, of which 24 were faces of the learned individuals (half were evaluated based on personality traits and half based on perceptual features), and the remaining 12 faces were novel identities. The video-clip stimuli were presented sequentially in one of 6 different orders that were generated using Optseq2 (Dale, 1999). Participants were asked to press one key for old faces, regardless of whether the faces were learned with social or perceptual questions and a different key for new faces and (see Figure 2). Additional information regarding the recognition phase is presented in the Supplementary Material.

**Functional localizers:**

**Face localizer:**

Each run of the functional localizer included 21 blocks: five baseline fixation blocks and eight blocks for each of the experimental conditions: faces and objects. Each block presented 14 stimuli of 15 different video-clips of which two repeated twice for a one-back task. Each stimulus was presented for 0.85 seconds with 0.15 seconds Inter-stimulus-interval. Each block
lasted 16 seconds. Each run began with a six-second fixation (6 TRs) of dummy trials and lasted a total of 342 seconds (342 TRs).

Social-Perceptual Evaluation (SPE) localizer:

Each run of the SPE localizer included 21 blocks: five baseline fixation blocks and eight blocks for each of the experimental conditions: social evaluations and perceptual evaluations. Each block started with a social or a perceptual evaluation question from a set of four questions (that we used in our previous studies; Schwartz & Yovel, 2019a, 2019b), followed by a sequence of six different face images (see Figure 3). The participants were asked to decide for each face if it matches the trait that was presented at the beginning of the block, by pressing one key if it does and a different key if it does not. Each block lasted 16 seconds. The four social questions were: is the face trustworthy/friendly/aggressive/intelligent? The four perceptual questions were: is the face smooth/round/symmetric/wide?. Each run began with six seconds (6 TRs) of fixation and lasted a total of 342 seconds (342 TRs). Additional

Figure 3: The SPE localizer includes a Social evaluation block (A) and a Perceptual evaluation block (B). The participants were asked to judge for each face if it matches the trait that was presented at the beginning of the block, by pressing one key if it does and a different key if it does not match. (For illustration we present AI-generated faces by Generated Photos https://generated.photos/)
information regarding the SPE localizer procedure is presented in the Supplementary Material.

**Data Analyses:**

*fMRI pre-processing*

The fMRI pre-processing is described in the Supplementary Material.

**Regions of interest (ROI) Analysis:**

All extracted ROIs are presented in Table S1 and are detailed in the section below. All ROIs were defined individually for each participant using contrast t-maps as clusters of voxels selective to a given category based on the relevant localizer data and contrast (see Table S1).

**Face Localizer:**

**Posterior face-selective areas:**

The posterior face-selective areas were defined based on the face-object localizer for voxels that showed a significantly higher response for faces than objects (p < .001), in high-level visual cortex: Left and right fusiform face area (FFA) within the fusiform gyrus; Left and right Occipital face area (OFA) in the lateral occipital cortex; Left and right Superior temporal sulcus (STS).

**Anterior face-selective area (ATL):**

The Anterior face-selective area (ATL) face area was defined based on the face-object localizer as voxels that showed a significantly higher response for faces than objects (p < .001) in the anterior temporal lobe.

**Social-Perceptual evaluation (SPE) Localizer:**

**Social processing brain areas**

Social processing regions of interest were defined based on the SPE localizer for the contrast social-evaluations > perceptual-evaluations (p < .001). This contrast revealed the following
activations in the majority of the participants (see Table S1): Dorsal medial prefrontal cortex (dmPFC); Ventral medial prefrontal cortex (vmPFC); Precuneus; Left and right temporal-parietal junction (TPJ). These areas correspond to the social brain network that was reported in many previous studies (Brothers, 1990; Ciaramidaro et al., 2007; Ciaramidaro et al., 2007; Dodell-feder, Koster-hale, Bedny, & Saxe, 2011; Frith, 2007; Frith & Frith, 2003; Mars et al., 2012; Mitchell, Macrae, & Banaji, 2004; Saxe, 2006).  

**Perceptual processing brain areas:**

Perceptual processing regions of interest were defined based on the SPE localizer data for the contrast Perceptual evaluations > Social evaluations (p < .001) revealed the following activations in the majority of the participants (see Table S1): Left and right lateral occipital cortex (LOC); Left and right superior parietal lobule (SPL); Left and right inferior frontal gyrus (IFG); Left and right supramarginal gyrus.

**Brain areas defined based on a meta-analysis of an external data set (Neurosynth):**

**Social network brain areas**

We extracted the social brain network with an independent functional localizer. We used a mask of social areas using Neurosynth (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011) association test of the term ‘social’. This mask reveals a large set of regions including the Amygdala, ATL, dmPFC, vmPFC, precuneus, TPJ and the fusiform gyrus. For the purpose of this analysis, we focused on the dmPFC, vmPFC, precuneus, and TPJ for the following reasons: First, these regions were also revealed by our SPE localizer (Social > Perceptual). Second, these regions overlap with the “extended face network” (Gobbini & Haxby, 2007) that was shown to be involved in social and semantic processing of faces. Third, these regions were shown to work together as a social network (Schmälzle et al., 2017). These regions therefore provide us with an independent method to test the social representation hypothesis. We do also report
results in the Amygdala and ATL in the next section and show similar findings in these regions. We divided the mask into different areas using SPM, by the intersection of the mask with suitable boundaries, which are described in the Supplementary Material. We then converted all regions of interest to the native space of each subject individually. One participant was omitted from this analysis due to artefacts in frontal brain areas.

The Amygdala

The Amygdala ROI extraction is described in the Supplementary Material.

**Main experimental task:**

The main experimental task was the recognition task of the perceptually and socially-evaluated faces that were learned prior to the scan (Figure 2). The time courses of the BOLD signal were extracted from each voxel for each experimental condition in the pre-defined region of interest (ROI, see Table S1) using the MarsBaR ROI toolbox of SPM (Brett, Anton, Valabregue, & Poline, 2002). The mean percent signal change (PSC) of the three-peak time-points (6-8 seconds) was calculated for each participant, for the Type of Evaluation (Socially-learned faces, Perceptually-learned faces) in each ROI (see Table S1 and Table S2). An ANOVA with Hemisphere and ROI as factors includes only a small subset of participants who showed activations in all the pre-defined regions. Therefore, the analyses were conducted on the responses of the merged ROIs of each contrast (for more information see the Supplementary Material). A t-test was used to assess whether the effect of the Type of Evaluation was statistically significant for the merged ROIs of each of the pre-defined contrasts (see Table S1).

**ROI selection for testing the hypotheses:**

To test the feature elaboration and social representation hypotheses, we first examined the response of the posterior face-selective areas (OFA, FFA, STS) and the social processing areas
(Social > Perceptual evaluations based on the SPE localizer) to socially and perceptually learned faces during the recognition phase. Because of the similarity between the learning task and the SPE localizer task, we had to rule out an encoding-retrieval similarity account for the findings. This was done by measuring the response of areas that were defined by the opposite contrast of the SPE localizer (Perceptual > Social evaluations) to the socially and perceptually-learned faces in the recognition test. In addition, we defined social brain areas with an independent localizer based on meta-analysis (Neurosynth) in an attempt to replicate results with our SPE localizer.

Results

Behavioural results:

Accuracy:

The participants performed the recognition test over three sequential runs. We calculated the averaged performance level for each run for the faces that were learned socially or perceptually (Hit rate) as well as for new faces (FA rate). A repeated-measures ANOVA with Type of Evaluation (Social, Perceptual) and Run (three runs) as within-subject factors, revealed a significant advantage for recognizing socially-learned than perceptually-learned faces.

Figure 4: Behavioural results. a. Recognition level (Hit Rate) of faces following social and perceptual evaluations. B. False Alarm Rate for new faces.
faces, $F(1, 19) = 8.34, p < 0.01, \eta^2_p = 0.30$. No interaction between Type of Evaluation and Run was found $F(2, 38) = 0.81, p = 0.48, \eta^2_p = 0.04$ (see Figure 4A) indicating that the magnitude of the social benefit was stable across all runs. Because new faces repeated three times across the three runs, we examined whether the participants did not judge the new faces as learned faces on the later runs by measuring the false alarm (FA) rate across runs: A repeated-measures ANOVA with Run as within-subject factor and Huynh-Feldt Sphericity correction, revealed no differences in FA rate across the 3 runs, $F(2, 38) = 0.7, p = 0.48, \eta^2_p = 0.04$ (see Figure 4B). Reaction time analysis revealed no differences between the conditions (See Supplementary material).

**Functional MRI results:**

To decide between the feature-elaboration and the social-representation hypotheses, we compared fMRI responses during the recognition task for the socially-learned faces and perceptually-learned faces in the posterior face-selective areas and the social processing areas.

**The response of posterior face-selective areas and social processing brain areas to socially and perceptually-learned faces.**

According to the feature elaboration hypothesis, social evaluations involve elaborated processing of the perceptual information of faces, predicting higher response of posterior face-selective areas to faces learned with social evaluations compared to perceptual evaluations. According to the social-representation hypothesis, social evaluations convert faces from a perceptual representation to a socially meaningful representation of a person, predicting higher response of social processing brain areas to faces learned with social evaluations compared to perceptual evaluations (see Figure 1). We found that the difference
in response to socially relative to perceptually learned faces was larger in social processing brain areas (M = 0.07, SD = 0.11) than the posterior face-selective areas (M = 0.019, SD = 0.05), t (19) = 2.85, p = 0.01, d = 0.63, 95% CI [0.015 0.10] (Figures 5 shows the social-perceptual difference score, Figure 6A shows the response to each condition). A repeated-measures ANOVA with Condition (Social, Perceptual) and Brain Areas (Social processing areas and Posterior face-selective areas) as within-subject factors. The ANOVA revealed a main effect of Condition, F (1, 19) = 8.71, p < 0.01, \( \eta^2_p = 0.31 \) and a significant interaction between Condition and Brain Areas, F (1, 19) = 8.15, p < 0.02, \( \eta^2_p = 0.30 \). Post-hoc tests revealed significantly higher fMRI response for socially-learned faces than perceptually-learned faces in the social processing areas (t (19) = 4.01, p < 0.001), and no difference in the posterior face-selective areas (t (1) = 0.99, p > 0.3). These results are consistent with the social representation hypothesis (see Figure 1). Additional analysis, which also includes the New
faces, revealed no difference between perceptually-learned faces and new faces, that were both lower than social-learned faces, consistent with a social account (see Supplementary).

The SPE localizer that was used to define the social processing areas is based on a task that is similar to the task that participants performed during the learning stage (social vs. perceptual evaluations). Thus, these results may merely reflect an encoding-retrieval similarity effect (for review, see Danker & Anderson, 2010). To rule out this possibility, we performed two additional analyses: We first examined whether the same effect, in the reversed direction, is found in perceptual processing areas that show higher response in the perceptual evaluation than the social evaluation conditions of the SPE localizer task. Second, we examined if the same effect is also found in social areas that were defined with an independent set of coordinates taken from independent data sets (based on Neurosynth, Yarkoni et al., 2011).

**Perceptual processing brain areas:**

If the social effect in social processing areas, defined by the SPE localizer, reflects encoding-retrieval similarity, we expect to find the same effect in the reverse direction (a perceptual effect) in areas that were extracted from the opposite contrast (perceptual evaluations > social evaluations): A paired t-test of Type of Evaluation (Social, Perceptual) revealed no difference between perceptually-learned faces ($M = 0.08$, $SD = 0.13$), and socially-learned faces ($M = 0.087$, $SD = 0.116$), $t(19) = 0.38$, $p = 0.70$, $d = 0.086$, 95% CI = [-0.025, 0.037] (Figure 6B, left). Therefore, the similarity between the localizer and the learning task does not account for the difference between socially and perceptually-learned faces in social processing brain areas.

**Social brain areas defined based on an independent localizer (Neurosynth):**
To examine if the social effect is also found in social brain areas that are defined by an external localizer, we compared between the response to socially and perceptually-learned faces in social brain areas extracted from a social localizer using Neurosynth (see methods): A paired

*The fMRI response to socially and perceptually evaluated faces during the recognition task*

A. **Posterior Face selective areas**

B. **Perceptual processing areas**

Figure 6: fMRI results. The differences between fMRI responses during the recognition task, for faces that were learned socially and perceptually. A: In posterior face selective areas (left) In social processing areas defined using the SPE localizer (right). B: In perceptual processing areas (left). In social brain areas defined by Neurosynth (right). n.s: non-significant; * $p < 0.05$; ** $p < 0.01$
t-test of Type of Evaluation (Social, Perceptual) revealed a significantly higher fMRI signal for socially-learned faces ($M = 0.002$, $SD = 0.087$) than perceptually-learned faces ($M = -0.03$, $SD = 0.088$), $t(18) = 2.36$, $p < 0.029$, $d = 0.54$, 95% CI [0.004, 0.069] (Figure 6B, right). Therefore, the social effect in social brain areas is not specific to the areas that were extracted using our SPE localizer.

We next examined two additional brain areas that are involved in semantic-emotional processing of faces, the anterior temporal lobe face area (for review, see Wong & Gallate, 2012; Collins & Olson, 2014; Olson, McCoy, Klobusicky, & Ross, 2013) and the Amygdala (for review, see Adolphs, 2010). If socially-learned faces indeed engage a social-emotional-semantic processing areas the ATL and Amygdala are expected to show a similar preference to socially-learned faces (Figure 7). Both ATL and Amygdala showed significantly higher fMRI response for socially-learned faces than perceptually-learned faces. Theses analysis are fully described in the Supplementary Material.

Figure 7: fMRI results. The differences between fMRI responses during the recognition task, for faces that were learned socially and perceptually. In the anterior temporal lobe (ATL) face area (left) and the Amygdala (right). * $p < 0.05$
Finally, we performed an additional exploratory analysis to examine whether the magnitude of the social effect in social brain areas is correlated with the magnitude of the social effect on memory across participants. To that effect, we computed the Pearson correlation between the difference in recognition performance (hit rate) and fMRI response to socially vs. perceptually-evaluated faces in the social processing brain areas. This correlation was moderate and not significant \( r(18) = 0.26, p > .25 \). Thus, we found no evidence that individual differences in the magnitude of the social effect in social brain areas is associated with individual differences in the social benefit in recognition performance. Nevertheless, given that socially-evaluated faces activated the social brain areas more than perceptually-evaluated and new faces during a recognition phase, does suggest that the social brain is engaged during the retrieval of socially-learned faces.

**Discussion:**

Social processing of faces during learning improves face recognition relative to perceptual processing (Bower & Karlin, 1974; Mueller et al., 1978; Schwartz & Yovel, 2016, 2019a; Strnad & Mueller, 1977). However, this improved recognition performance does not inform us about the nature of the representation that is generated following these different types of learning strategies. The goal of the current study was to decide between two different mechanisms that were proposed to account for this social evaluation benefit in face recognition. The feature elaboration hypothesis proposes that the recognition benefit is a result of a perceptual enhancement to the face representation (Winograd, 1981), whereas the social representation hypothesis suggests that faces are converted from a perceptual to a socially meaningful representation (Bower & Karlin, 1974; Schwartz & Yovel, 2016, 2019a). To that effect, participants learned faces while making perceptual or social evaluations outside the
scanner and performed an old-new face recognition task in the scanner. Behavioral results on the face recognition task replicated the social evaluation benefit, showing better recognition for faces that were learned socially than perceptually. Examination of the response of social and perceptual brain areas to these faces during recognition revealed higher response to socially-learned than perceptually-learned faces in social processing brain areas but not in posterior face-selective areas. These findings are consistent with the social representation hypothesis suggesting that social evaluations convert faces to socially meaningful representations rather than enhance their perceptual representations.

The social processing brain areas in our study were defined as voxels that showed a higher response to socially-evaluated than perceptually-evaluated faces. This contrast revealed in each participant the known social brain network, including the dmPFC, vmPFC, precuneus, and TPJ (Brothers, 1990; Ciaramidaro et al., 2007; Frith, 2007; Frith & Frith, 2003; Mars et al., 2012; Saxe, 2006). Nevertheless, since the participants made social evaluations both in the study phase of the main task and in the SPE localizer task, it was essential to assure that the effect we found is not due to an encoding-retrieval similarity effect (for review, see Danker & Anderson, 2010). Additional analyses ruled out this interpretation. First, brain regions that showed higher response during perceptual than social evaluations in the SPE localizer, showed no difference between perceptually-learned and socially-learned faces (Figure 6B, left). Second, we found a higher response to socially than perceptually-learned faces in social brain areas that were extracted using an independent localizer, based on meta-analysis of previous studies that activated the social brain network (Neurosynth: Yarkoni et al., 2011) (Figure 6B, right). Furthermore, the same effect was also found in social/semantic-related areas, including the Amygdala and the face-selective ATL (Figure 7). Thus, we conclude
that social evaluations during learning activates social and semantic mechanisms, changing
the representation of faces from perceptual images to meaningful social concepts.

Several alternative explanations to the social benefit in face recognition, which were
addressed in our previous studies (Schwartz & Yovel, 2019a), are noteworthy. First, the
improved performance for socially-learned than perceptually-learned faces may reflect an
interference of perceptual evaluations rather than the benefit for social evaluations. This
possibility was ruled out by adding a no evaluation condition during learning. Results showed
no difference in recognition between faces learned with perceptual or no evaluations, which
were both lower than the socially-learned faces. This is also consistent with our findings that
the response of social brain areas to perceptually-learned and new faces was similar (see
supplementary) indicating no evidence for interference for perceptually-learned faces.
Another alternative account for a social benefit may be that social evaluations generate more
variable ratings than perceptual evaluations. Results of our previous as well as our current
study (see supplementary) revealed similar variability of social and perceptual ratings. Finally,
perceptual-evaluations in previous studies involved local shape-based features (e.g., eye
shape, lips), whereas social evaluations may involve global processing of facial information.
Our previous study show that the social evaluation benefit is as large relative to global
perceptual evaluations (e.g., face symmetry, skin tone), which were also used in the current
study.

The social brain areas that were found in the current study are also reported in studies
that have examined the neural response to familiar faces. In particular, Gobinni and
colleagues revealed that the TPJ, the precuneus and vmPFC, showed higher response to
familiar than unfamiliar faces (di Oleggio Castello, Halchenko, Guntupalli, Gors, & Gobbini,
2017; Gobbini & Haxby, 2007). These areas were considered part of the extended face processing system, which processes semantic and emotional information about familiar faces. We propose that social evaluation during encoding mimics the process by which we become familiar with socially-relevant faces, as familiar faces are typically encoded in a social context.

The question of whether perceptual or social mechanisms underlie face recognition abilities has been discussed in the context of other well-established face recognition phenomena. For example, whereas the Other Race effect, better recognition of own than other race faces, was primarily attributed to perceptual mechanisms (Crookes & Rhodes, 2017; Meissner & Brigham, 2001; Rhodes, Brake, Taylor, & Tan, 1989; Tanaka, Kiefer, & Bukach, 2004), later studies have proposed a social account that involves individuation and motivation (Hugenberg et al., 2010; Levin, 1996, 2000; Maclin & Malpass, 2001; Rodin, 1987; Sporer, 2001). In most of these studies, faces were provided with social context during study and show better recognition during test. Nevertheless, it was unclear in what way the representation of these faces changes during social encoding. Here we show that social encoding engages the social brain network during retrieval, highlighting the important contribution of social processing mechanisms for face recognition.

The roles of social or perceptual mechanisms in face recognition were also discussed in studies that reported impaired face processing in Autism spectrum disorder (ASD). ASD is associated with deficits in social interaction (for review see Rao, Beidel, & Murray, 2008) and with social cognition dysfunction (for review see Pelphrey, Adolphs, & Morris, 2004). One hypothesis that had been proposed to account for the face recognition deficit is that atypical eye contact of individuals with ASD (for review see: Jones, Carr, & Klin, 2008; Senju & Johnson, 2009) might lead to perceptual deficits in processing of the eye region of the face (Weigelt,
Koldewyn, & Kanwisher, 2012). Other studies have emphasized a social motivation account for face processing deficits in ASD (Dawson et al., 2002). According to this hypothesis, impairment in social motivation results in reduced attention to faces as well as to all other social stimuli such as the human voice, hand gestures, and so on (Dawson et al., 2002). This hypothesis is consistent with studies that found that people with ASD show reduced activity in components of the social brain network during social tasks (Fulvia, Chris, Francesca, & Uta, 2002) as well as generally reduced functional connectivity between these areas (Gotts et al., 2012; von dem Hagen, Stoyanova, Baron-Cohen, & Calder, 2013). Based on our findings, we predict that reduced activity of the social brain network during face learning and recognition may mediate ASD’s poor performance in face recognition, a hypothesis that should be tested in future investigations.

The current study presents a new functional localizer for defining the social brain network in an individual-based manner. There are several tasks that were used in previous studies to define brain areas that are involved in social cognition including the False-Belief task (Dodell-feder et al., 2011; Saxe & Kanwisher, 2003) and the Why\How task (Spunt et al., 2014). Both tasks were shown to activate brain regions that are commonly associated with theory of mind (TOM) and mentalizing tasks, which are also part of the social brain network. For the purpose of the current study, we created the new SPE localizer to individually localize areas that are involved in social and perceptual processing of facial information. The SPE localizer reveals the main areas of the social brain network in each subject individually, and can be therefore used in future studies to define the social brain areas in an individual-based manner, taking advantage of the improved statistical power of the functional ROI approach (Kanwisher, 2017; Saxe, Brett, & Kanwisher, 2006).
In summary, the current study aimed to decide between two hypotheses that were suggested to account for the social evaluation benefit in face recognition. We found that social encoding engages the social cognition system, rather than enhancing perceptual processing. Social processing is an integral aspect of face processing as we frequently encode faces for the purpose of social interactions. Thus, social processing should be considered and further explored to fully understand the mechanisms of face recognition. More generally, we show how different types of encoding strategies significantly modify the nature of the representation of the same stimuli, as evident by the different levels of engagement of task-relevant brain systems.

References


Membership, Collective Identification, and Social Role Shape Attention and Memory. 
https://doi.org/10.1177/0146167212455829

*Social Cognitive and Affective Neuroscience, 8*(6), 694–701. 
https://doi.org/10.1093/scan/nss053


Willis, J., & Todorov, A. (2006). First impressions: Making up your mind after a 100-ms exposure to a face. 
*Psychological Science, 17*(7), 592–598. https://doi.org/10.1111/j.1467-9280.2006.01750.x

*PLoS ONE, 9*(3). 
https://doi.org/10.1371/journal.pone.0090668


*Nature Methods, 8*(8), 665–670. 
https://doi.org/10.1038/nmeth.1635

Learning Faces as Concepts Improves Face Recognition by Engaging the Social Brain

Network – Supplementary Materials

Adva Shoham¹, Libi Kliger¹ and Galit Yovel¹,²

Methods

Sample size:

A sample size of 20 participants was chosen for this study, based on the sample size of previous fMRI studies that examined social cognition brain areas using an individual Region of Interest (ROI) analysis (Ames & Fiske, 2013; Etienne & Liuba, 2019; Isik, Koldewyn, Beeler, & Kanwisher, 2017; Saxe & Kanwisher, 2003; Saxe & Powell, 2009). Since the paradigm that we use here has not been used before, we could not use prior studies to estimate its effect size. We therefore performed a post hoc power analysis using GPower (Faul, Erdfelder, Lang, & Buchner, 2007) for paired samples t-test with a power of 80% $\alpha = .05$ and effect size of 0.63-0.7 indicating $N = 19-22$ participants, consistent with the sample size used in previous studies.

fMRI acquisition parameters:

fMRI data were acquired in a 3T Siemens MAGNETOM Prisma MRI scanner in the Strauss center for computational imaging at Tel Aviv University, using a 64-channel head coil. Echo-planar volumes were acquired with the following parameters: repetition time (TR) = 1.00 s, echo time = 34.40 ms, flip angle = 60°, 66 slices per TR, multi-band acceleration factor = 6, slice thickness = 2 mm, field of view = 200 mm and 100 × 100 matrix, resulting in a voxel size of $2 \times 2 \times 2$ mm. Stimuli were presented with MATLAB (The MathWorks Inc.) and Psychtoolbox (Brainard, 1997; Kleiner et al., 2007) and were displayed on a 32 high definition LCD screen (NordicNeuroLab) viewed by the participants at a distance of 155 cm through a mirror located...
in the scanner. Anatomical MPRAGE images were collected with 1×1×1 mm resolution, echo time = 2.45 ms, TR = 2.53 s.

**Learning phase procedure:**

Each question appeared on the screen for 4 seconds, followed by a 1-second interstimulus interval after which a video clip was presented for about 4 seconds. Following the clip offset, three text boxes appeared accompanied by a title that indicated which of the people in the clip it refers to - the one on the right, the middle and the left (see Figure 2a). The participants were asked to rate each identity in the clip based on the question that appeared at the beginning of the trial on a scale of 1 to 7. A total of three perceptual or social questions were presented sequentially one after the other for each video clip. Thus, each identity was presented three times, following each one of the three different questions. The order of the three questions within each mini-block was random.

**fMRI scan - Recognition phase procedure**

Each stimulus was presented for 1.5 seconds with a minimum of 1-second Inter-stimulus-interval (see Figure 2b). The participant's response was recorded starting from the beginning of the clip until the next clip started. Each run first presented all 36 identities and then repeated the same clip for a second time but in a different order. Thus, a total of 72 clips were presented in each run. Each run began with six seconds (6 TRs) of fixation (dummy trials) and lasted a total of 246 seconds (246 TRs). Subjects were instructed to maintain fixation throughout the run and their eye movements were recorded with an eye tracker (EyeLink®).

**Social-Perceptual Evaluation (SPE) localizer procedure:**

The question was presented for 3 seconds and each stimulus was presented for one second with one-second Inter-stimulus-interval. The four questions of each condition were randomly assigned to each block, without repeating the same question twice in a row. The stimuli were
divided into two groups of six images (group-1 and group-2). Each participant was randomly assigned to a localizer version where the images of group-1 were presented during the social evaluation block and the images of group-2 were presented during the perceptual evaluation block, or vice versa. The images were presented in each block in random order.

**fMRI pre-processing**

MRI analysis was performed using SPM12 software, MATLAB (The MathWorks Inc.) and R (R core team, 2019). The first six volumes in each run were acquired during a blank screen display and were discarded from the analysis as "dummy scans". The data were then pre-processed using realignment to the mean of the functional volumes and co-registration to the anatomical image (rigid body transformation). Spatial smoothing was performed for the localizer data only (5 mm). A GLM was run with separate regressors for each run and each condition, including 24 nuisance motion regressors for each run (six rigid body motion transformation, six motion derivatives, six square of motion and six derivatives of the square of motion), and a baseline regressor for each run. Also, a "scrubbing" method (Power, Barnes, Snyder, Schlaggar, & Petersen, 2012) was applied for every volume with frame-displacement (FD) > 0.9 by adding a nuisance regressor with a value of 1 for that specific volume and zeros for all other volumes. We excluded from the analysis participants whose data contained at least one run in which at least 5% of the volumes were removed due to motion correction. Only one participant was excluded based on this criterion.

**ROIs defined by Neurosynth**

**Social Network ROIs**

The mask we extracted using Neurosynth (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011) was divided into different areas using SPM, by the intersection of the mask with the following boundaries: (1) dmPFC: x = [-13,13], y = [64,42], z = [-6, 200]; (2) vmPFC: x = [-13,
13], y = [64, 42], z = [-200, -6]; (3) Precuneus: x = [-10, 10], y = [-70, -40], z = [14, 52]; (4) Left and right TPJ: xL = [-64, -44], xR = [44, 64], y = [-68, -46], z = [10, 28].

Amygdala

We used mask of the Amygdala using Neurosynth (Yarkoni et al., 2011) association test of the term 'amygdala responses'. We separated the mask into anatomical areas (left and right Amygdala) using the intersection of the mask with anatomical definitions of right and left Amygdala according to the Anatomical Automatic Labelling2 (AAL2) SPM tool. We then inverse the amygdala regions of interest to the native space of each subject individually.

Data analysis:

An ANOVA with Hemisphere and ROI as factors includes only a small subset of participants who showed activations in all the pre-defined regions. We therefore first tested for each of the lateral ROIs if there was an interaction between the hemispheres and the experimental condition by performing a repeated measure ANOVA with Hemisphere (Left, Right) and Type of Evaluation (Social, Perceptual). No significant interactions between Hemisphere and Type of Evaluations were found for any of the nine lateral ROIs that were tested (p > .005, corrected for nine multiple comparisons). We therefore combined the response across hemispheres using a weighted mean of the response according to the size of the ROI in each hemisphere. We then tested for each contrast if there was an interaction between the different ROIs extracted using this contrast and Type of Evaluation. No significant interactions were found. We therefore merged the response of the ROIs of each contrast by calculating a weighted mean of the response, according to the size of the ROIs. The rest of the analyses were conducted on the responses of these merged ROIs. A t-test was used to assess whether the effect of the Type of Evaluation was statistically significant for the combined ROIs of each of the pre-defined contrasts (see Table S1).
Results:

**Behavioural data:**

**Reaction time analysis:**

We calculated the averaged RT for each participant during the recognition test, for the social and perceptual trials. Reaction times of 14 trials across all participants were not recorded due to technical issue (overall less than 1% of trials): A paired t-test of Type of Evaluation (Social, Perceptual) revealed no difference in reaction times during the recognition test between socially ($M = 1.13, SD = 0.23$) and perceptually learned faces ($M = 1.14, SD = 0.25$), $t(19) = -0.61$, $p = 0.54$, $d = 0.05$, 95% CI [-0.05, 0.028]. Indicating that a social evaluation benefit is reflected only in accuracy measures and that a difference in reaction time cannot account for the BOLD difference between conditions.

**Social and Perceptual evaluation variability analysis during the learning phase:**

To rule a potential effect of increased variability during social than perceptual evaluations, we compared between the ratings variability of the two conditions. The rating variability was also addressed by Schwartz and Yovel (2019) who found no difference between the two conditions. We averaged the ratings of each participant to each question type. Levene’s test for equality of variances showed no difference between the variability of social and perceptual evaluations $F(1,38) = 2.43$ ($p = 0.126$).
Eye tracking data

![Social](image1.png) ![Perceptual](image2.png) ![New](image3.png)

Figure S1: Eye tracking data distribution. The density distribution of fixations of all subjects of all experimental conditions are plotted over a representative face. (a) Social-learned faces. (b) Perceptually-learned faces. (c) New faces

Functional MRI:

The response of socially and perceptually-learned faces relative to new faces, in social processing areas and posterior face selective areas:

A repeated-measures ANOVA with Condition (Social, Perceptual and New) and Areas (Social-Processing areas and Posterior-Face selective areas) as within-subject factors revealed a main effect in fMRI signal for condition, $F(2, 38) = 5.00, p < 0.02, \eta^2_p = 0.20$ and a significant interaction between condition and area selectivity, $F(2, 38) = 3.70, p < 0.05, \eta^2_p = 0.16$. Post hoc test for simple effects in the Social-processing areas revealed significantly higher fMRI signal for socially learned faces than perceptually learned faces ($t=3.67, p < 0.01$) and new faces ($t=3.49, p < 0.01$), while no difference was found between perceptually evaluated faces and new faces ($t=0.18, p > 0.9$; Figure S2, right). Post hoc test for simple effects in the Posterior
Face selective areas revealed no difference in fMRI signal for any of the experimental conditions (Figure S2 left).

![Graphs showing fMRI responses during the recognition task](image)

**Figure S2**: fMRI responses during the recognition task, for faces that were socially learned, perceptually leaned and new faces, in the posterior face-selective areas (left) and the social processing areas extracted using the SPE localizer (right). * *p < 0.05

**Interaction between Social processing areas (SPE) and Neurosynth social areas:**

A repeated-measures ANOVA with Condition (Social, Perceptual) and ROI selection method (Social-Evaluation Localizer, Neurosynth social areas) as within-subject factors revealed a significant interaction between type of evaluation and ROI selection method, $F(1, 18) = 6.02, p < 0.05, \eta_p^2 = 0.25$. Given that both methods for extracting social regions revealed a significantly greater response to socially evaluated than perceptually evaluated faces, this interaction indicates that the difference between Social and Perceptual conditions is greater in the Social-Evaluation areas than in the Neurosynth social areas and is therefore still consistent with our conclusions. Given that the social evaluation areas are extracted individually and the Neurosynth analysis is based on group level ROIs, it is expected that findings will be more robust with individual-based ROIs.
Emotional-Social-Semantic Areas Analyses:

Face-selective ATL:

The ATL is known to play a major role in the processing and retrieval of semantic knowledge, and in particular for social information (for review, see Wong & Gallate, 2012). Similarly, the face-selective ATL was shown to be involved in semantic processing of faces (for review see: Collins & Olson, 2014; Olson, McCoy, Klobusicky, & Ross, 2013). Thus, we examined whether the face-selective ATL will also show a neural correlate for the social evaluation benefit of face recognition: A paired t-test of Type of Evaluation (Social, Perceptual) revealed a significantly higher fMRI signal for socially evaluated faces ($M = 0.10, SD = 0.159666$) than perceptually evaluated faces ($M = 0.035, SD = 0.163363$), $t (14) = 2.68, p = 0.017, d = 0.69, 95\% CI [0.014, 0.125]$.

Amygdala:

The Amygdala has a leading role in the processing of socially relevant information and social behavior (for review, see Adolphs, 2010). Thus, we examined whether the amygdala also shows a neural correlate of the social evaluation benefit: A paired t-test of Type of Evaluation (Social, Perceptual) revealed significantly higher fMRI signal for socially evaluated faces ($M = 0.09, SD = 0.07$) than perceptually evaluated faces ($MD = 0.059, SD = 0.08$), $t (19) = 2.32, p = 0.03, d = -0.51, 95\% CI [0.003, 0.06]$. 
### Table S1:

**ROIs summary table:**

<table>
<thead>
<tr>
<th>Localizer</th>
<th>contrast</th>
<th>Region of interest</th>
<th>cluster size</th>
<th>Number of participants who showed activity in this region</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Face-Objects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Faces &gt; Objects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>left FFA</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right FFA</td>
<td>20</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left OFA</td>
<td>20</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right OFA</td>
<td>20</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left STS</td>
<td>20</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right STS</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left ATL</td>
<td>5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right ATL</td>
<td>5</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td><strong>Social-Perceptual Evaluation (SPE)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Social &gt; Perceptual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>dmPFC</td>
<td>20</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>vmPFC</td>
<td>20</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precuneus</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left TPJ</td>
<td>20</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right TPJ</td>
<td>20</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Perceptual &gt; Social</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>left LOC</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right LOC</td>
<td>20</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left Supramarginal</td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right Supramarginal</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left IFG</td>
<td>20</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>right IFG</td>
<td>20</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>left SPL</td>
<td>20</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Right SPL</td>
<td>20</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Neurosynth and AAI2 data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Social brain areas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>vmPFC</td>
<td></td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precuneus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>left TPJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>right TPJ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amygdala</strong></td>
<td></td>
<td>Amygdala</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>
Table S2

Average (and standard deviation) of PSC for socially and perceptually-evaluated faces in each ROI:

<table>
<thead>
<tr>
<th>Localizer - Contrast</th>
<th>ROI</th>
<th>Socially-evaluated faces</th>
<th>Perceptually-evaluated faces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face Localizer:</td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>FFA</td>
<td>0.63</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>OFA</td>
<td>0.77</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>STS</td>
<td>0.25</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>ATL</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>SPE localizer</td>
<td>dmPFC</td>
<td>-0.05</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>vmPFC</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>precuneus</td>
<td>-0.03</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>TPJ</td>
<td>-0.03</td>
<td>0.17</td>
</tr>
<tr>
<td>SPE localizer</td>
<td>LOG</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>supramarginal</td>
<td>0</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>IFG</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>SPL</td>
<td>0.14</td>
<td>0.12</td>
</tr>
<tr>
<td>Neurosynth social</td>
<td>dmPFC</td>
<td>-0.07</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>vmPFC</td>
<td>-0.02</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>precuneus</td>
<td>0</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>TPJ</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>Amygdala with</td>
<td>Amygdala</td>
<td>0.09</td>
<td>0.08</td>
</tr>
</tbody>
</table>