How well do you know a face?

Fame as a predictor of Fusiform Face Area activation when seeing faces

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Abstract:

In this functional Magnetic Resonance Imaging study, Fusiform Face Area (FFA: Kanwisher et al., 1997) activity was investigated on a variety of face-like stimuli. Cartoon and human face-stimuli both delivered significant right FFA activity levels. To investigate fame as a predictor for FFA activity, both famous and non-famous cartoon and human stimuli were presented to the participant, and with a p-value uncorrected for multiple comparisons a significant positive increase in activity was found for the famous faces compared to the non-famous. Firstly, these results indicate that the FFA respond to a broad category of faces. Secondly, the heightened FFA activity to famous faces shows that the FFA activity can modulate due to fame, leaving room for further investigations into FFA's role in recognition.

Keywords: Functional Magnetic Resonance Imagining, 2x2 factorial design, Fusiform Face Area, Face Recognition, Perceptual expertise.

Introduction:

The ease at which you, me and every human can recognize faces have led researchers to question if the brain has some specially evolved neural machinery for face processing. (Farah, 1996; Friedenberg & Silverman, 2006) Assuming it to have evolved evolutionarily, as being able to draw out information about hostility and emotional-states within a fraction of a second greatly enhanced ones fitness at the time of our primate ancestors (Friedenberg & Silverman, 2006; Tong et al., 2000), recent studies have now had success in supporting the idea of a "brain-module", with some degree of processing autonomy, for face-recognition.

Early evidence of such a module came from cases of prosopagnosia, where patients show an incapacity to recognize faces, but no deficit to recognize other stimuli, after having their Fusiform Gyrus injured. (Bodamer, 1947; Meadows, 1974)
Using fMRI, a more specific part of the right fusiform gyrus was determined in studies on patients showing heightened brain-activity when presented with faces compared to common

objects such as flowers. (McCarthy et al., 1997) The area has since been called the Fusiform Face Area, coined by Nancy Kanwisher. (Kanwisher et al., 1997)

A first attempt to explain the FFA activity was a feature-detection model based on having specific low-level facial features rendering the activity. (Pelli et al., 2006) But studies comparing the FFA activity of participants watching pictures of human faces to that of animated characters and animals, that clearly deviate in both shape, aspect ratio, size, skin texture and colour, show that many types of faces can render the same activation. (Tong et al., 2000) A higher-order processing for general face-pattern processing has since been proposed for the FFA as the Face-specificity hypothesis. (Tong et al., 2000)

Face-specificity or Expertise

FFA activity remains controversial though, as alternative accounts to face specificity remains. (Lehmann, et al. 2004). The competing Expertise hypothesis proposes that the FFA is an area for general within-category expertise, as greater FFA activity has been found in professional birdwatchers, compared to novices, when looking at birds (Gauthier et al., 2000). Still, proponents of face specificity have shown contradicting evidence. Faces can render the same FFA activity though receiving notably different levels of training - e.g. differentiating between human faces has received much more training than differentiating between cat faces, but the faces show the same FFA activation, supporting the assumption that the FFA function might generalise to a broad stimulus category of faces including those of other species. (Tong et al., 2000)

Another study furthering the view of face specificity showed that it was possible to differentiate between famous face-identities, e.g. Leonardo Dicaprio and Brad Pitt, by decoding patterns of FFA activity. This illustrates how there might be more to FFA than detection and perception; that the FFA might also play an important role in recognition. (Axelrod and Yovel, 2015)

To give room for a discussion, another study in favour of the expertise hypothesis must also be introduced. Namely that of chess-experts showing a heightened activity in the FFA compared to novices when looking at meaningful chess positions. (Bilalic et al., 2011) Where studies on birds and bird watchers can have a hard time refuting face specificity, since the birds have faces, like the cats from the (Tong et al., 2000) study, chess positions are of an entirely different nature.

The experiment

Within the scope of this study, FFA activation was investigated with voxel-based fMRI scans, first and foremost to illuminate whether or not both animated cartoon faces and human faces render FFA activity, as was found in the (Tong et al., 2000) study. Secondly, whether famous faces would translate to a higher activity in the FFA, as to see if recognition/experience can modulate FFA activity. The hypotheses are as follows:

Hp1 - Animated cartoon characters contain human facial characteristics, therefore they will cause activation in the Fusiform Face Area.
Hp2 - Famous characters and famous humans will cause more activation in the Fusiform Face Area than non-famous.

Materials and methods:

Participant:

One participant amongst the Cognitive Science students at Aarhus University took part in the fMRI experiment after having given a written informed consent and having been pre-scanned to ensure neurological health. The participant was a 20-year old left-handed female with normal vision.

Material/Stimuli:

The experiment used pictures of either famous humans, non-famous humans, famous animated characters or non-famous animated characters cf. table 1 which shows an example from each of the four conditions. The pictures were acquired through the online search portal Google. The pictures were then edited in Keynote to have the exact same dimensions of 1024 × 768, in order to eliminate the possibility of activation solely based on differences in stimulation of the visual field.

	Human	**Character**
Famous		
Non-famous		

Table 1: Examples of stimuli from each condition presented to the participant

A questionnaire (See appendix) to be filled by the participant was made to ensure that the people and characters we listed as famous was indeed known to the participant as well as ensuring that the unknown characters were truly unknown to the participant. The questionnaire contained a scale from 1 - 10, where 10 is very familiar and 1 is unknown.

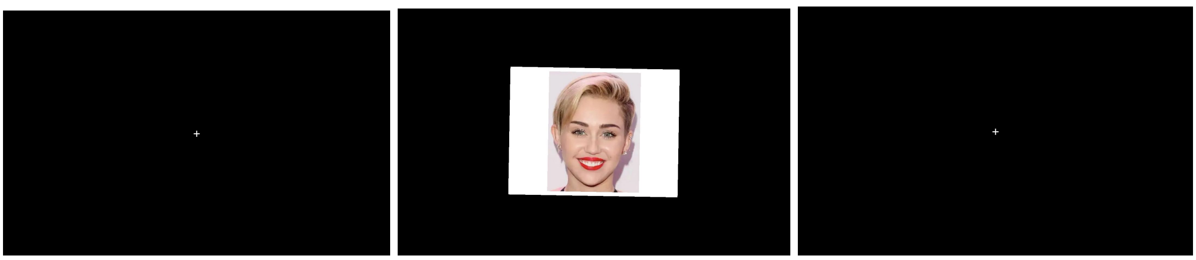
Procedure and design:

The experiment was a repeated measures design having one participant participate in all four conditions. The experiment was a 2x2 factorial design with 17 pictures in each condition cf. table 2. As the table shows the experiment held the independent variable *type of subject* with two levels, respectively human and character and the independent variable *degree of fame* with two levels, respectively famous and non-famous.

		Type of subject	
		Human	**Character**
Degree of fame	**Famous**	17	17
	Non-famous	17	17

Table 2: Design and structure of experiment

The experiment was programmed using PsychoPy2. The different stimuli pictures were shown in a randomized order for a duration of 0.7 seconds each. Between the photos a delay frame with a fixation cross ‘ + ‘ was shown to the participant. This frame was shown as a random mix of four different durations, as to maintain the participants focus and increase the study’s predictive power. The intervals durations were a mix of 2.1, 3.4, 4.8 and 6.1 seconds cf. figure 1.



2.1, 3.4, 4.8 or 6.1 s → 0.7 → 2.1, 3.4, 4.8 or 6.1 s →

Figure 1: Example of stimuli with delays intervals

Each session was programmed to show the 68 different stimuli twice and thus each session had 136 stimuli trials. The experiment was then showed to the participant in the Skyra scanner at CFIN in Aarhus Universitetshospital. Before the participant was placed in the scanner a consent form was signed and an oral introduction to the experiment was given. Inside the scanner the participant had to make a button press and judge whether the person or character in the picture was known or unknown. This was done to ensure the participant’s

attention to the pictures shown. These answers, reaction time, onsets of the different stimuli and other relevant information, such as name and date, were logged. The experiment was conducted three times.
After the three sessions, the participant was asked to fill a questionnaire about the familiarity of each person or character.

Analysis:

Questionnaire

A questionnaire was conducted to ensure that the participant's ratings were in agreement with our categorization of fame. Only 6 pictures out of the total 68 were not rated as either 10 or 1 on scale ranging from 1 to 10. These 6 pictures were rated 8, 3, 2, 2, 2, 2 which rendered no cause of concern. Thus, no subjects were excluded.

Behavioral analysis

A short analysis of the behavioral data was conducted in R studio. An investigation of the reaction time and correct button presses in terms of familiarity across sessions was conducted. The participant's reaction time got significantly faster across sessions ($\beta = -.08$, ($SE = 0.01$), $t = -10.9$, $p<.001$), however no significant difference in amount of correct button presses was found which indicates a stable focus across all sessions.

Statistical analysis

After the fMRI data collection, the analysis was conducted in MatLab using the package SPM12. As part of preprocessing of the fMRI data the collected files were realigned, coregistered, segmented, normalised and smoothed. After preprocessing the model was specified and estimated to gain the full model. To conduct the model specification the onsets of each condition from each session was extracted from the log files. Finally, the contrasts of interest were conducted including a contrast focusing on activation during pictures of humans and another contrast for pictures of characters. Moreover, a contrast looking at the main effect of fame. To investigate whether or not there was an interaction between 'type of subject' and 'degree of fame', a contrast looking for interaction effects was created. No interaction was observed in the area of interest.

Results:

The contrast looking at activation during human pictures showed significant activation using a family-wise-error corrected p-value in the right fusiform gyrus at MNI coordinate: [38, -6, -36] cf. figure 2.

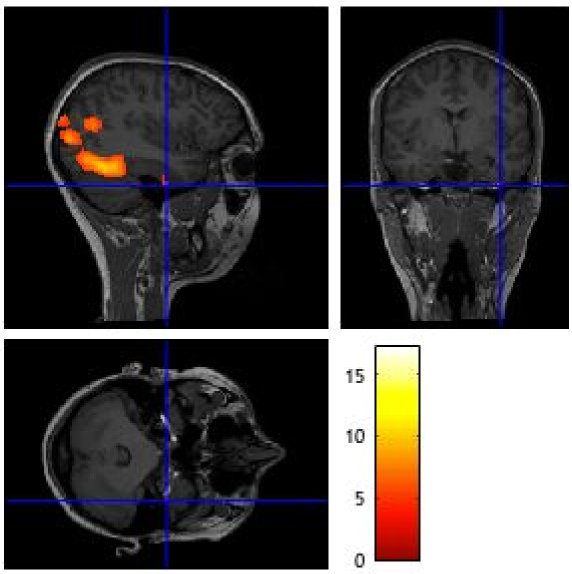


Figure 2: Voxel activation within right fusiform gyrus (at the blue cross) for the human pictures contrast

The contrast looking at activation during character pictures showed significant activation using a family-wise-error corrected p-value in the right fusiform gyrus at MNI coordinate: [32, -24, -24] cf. figure 3.

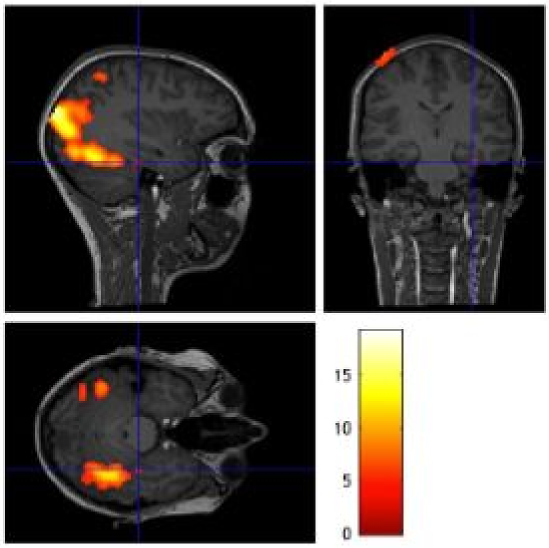


Figure 3: Voxel activation within right fusiform gyrus (at the blue cross) for the character pictures contrast

Our results also found increased significant activation in the right fusiform gyrus when presenting famous humans and characters using an uncorrected p-value of 0.001. Figure 4 shows the amount of activation at the MNI coordinate: [22, -50, -22]. The non-famous conditions (bar 2 and 4) caused less activation than famous conditions (bar 1 and 3).

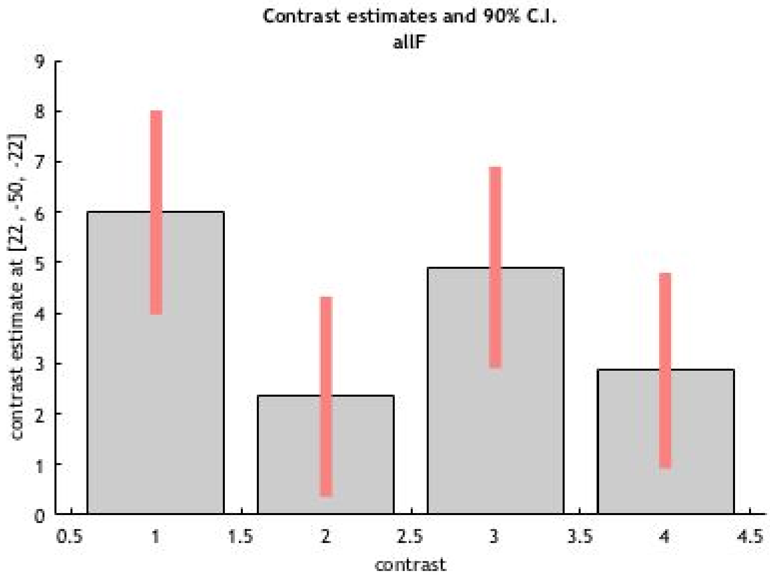


Figure 4: Bar plot of the activation for the four different conditions at MNI coordinate [22, -50, -22]. Bar 1 represent famous humans, bar 2 represents non-famous humans, bar 3 represents famous characters and bar 4 represents non-famous characters.

Discussion

Within the scope of the present study, we set out to investigate FFA activity for cartoon and human faces, which both delivered significant right lateralized FFA activity levels. Moreover, a p-value uncorrected for multiple comparisons showed a significant positive increase in FFA activity for famous stimuli compared to non-famous ($P < 0.0001$). Before reviewing what this tells us in a broader sense, we will walk through some of the limitations of this study.

Error Sources

First and foremost; using an uncorrected p-value makes the results of hp2 unreliable as it may be a false-positive. Secondly, the experiment included only one participant meaning we can't average any random effects away, lending itself to little statistical power. As important as these two things are, they have a clear solution: don't use an uncorrected measure and include more participants. So instead we'll look into some other demanding questions, like with the

experimental design. The stimuli pictures presented to the participant were not thought through. Some pictures had limited detail, the colour saturation and backgrounds were varying, facial expressions weren't alike, one picture included a watermark, and maybe most pressingly, not all pictures had a frontal view, as have been shown to alter FFA activity. (Tong et al., 2000) How all this adds up to affect the FFA activity is impossible to predict.
Moreover, this study used three different voxels to locate the Fusiform Gyrus in the neuromorphometric labelling system in SPM 12, instead of first having functionally localised the subject's FFA on independent localiser scan, as has been done in other studies using a baseline to compare the effects of face-stimuli with. (Tong et al., 2000) As such, it is uncertain if it's really the FFA activity we picked up in each of the three contrasts since the anatomic location of the FFA is highly individual (Tong et al., 2000).

The experiment and beyond

Keeping all this in mind, hp2 was confirmed, offering us new questions to explore: Does the FFA hold the ability to learn to recognise distinct faces, hence the heightened activity of familiar stimuli? Supporting the findings made in the (Axelrod and Yovel, 2015) study.
Or does this indicate that the FFA is an expertise center based in familiar pattern recognition? The current experimental setup can't answer these questions, but with a few alterations, it might be able to accommodate some interesting conclusions.

Between-category stimuli

Beyond just fixing the stimuli, one could add a third variable to the 'type of subject' dimension. This third variable should be a between category item, meaning it shouldn't be a face but instead a stimulus like chess positions. Having this third variable, still in the dimensions of 'degree of fame' with e.g. chess experts and novices, would allow one to put the Face-specificity Hypothesis and the Expertise Hypothesis head to head. Where the Face Specificity Hypothesis would assume that chess positions render little activity in the FFA compared to a face, the Expert Hypothesis would assume that the participants showed a somewhat heightened FFA activity to those chess positions that had become familiar through meaningful training.

Between-subject differences

The questionnaire that the participant filled in showed that she arguably was an expert in the 'famous face' category of both 'Types of subjects'; the majority of her ratings being 10 on a scale to 10. But no novices were to be compared, which leaving the study unable to draw conclusions about the expert hypothesis. Correspondingly, it would be enlightening to include more participants with different levels of familiarity to the famous "type of subjects". This would allow one to see if the FFA activity was correlated to gradual expertise or if heightened FFA activity manifested abruptly as a face was not novel anymore, linking the FFA clearly to face-specific recognition.

In regard to this, one could also change the backbone of the experimental design from "degrees of fame" to "degree of received training", as has been done before in a similar study correlating FFA activity with practice on recognition of novel objects called greebles. (Gauntier et al., 1999) This would allow the study to avoid problems related to participant introspection, when rating the knowness of the stimuli.

Baseline

Unlike other experimental designs (Tong et al., 2000), this study did not hold the FFA activity for faces up against a baseline of objects. But for further research with new 'Between category stimuli' and more subjects, it could be beneficial to establish a baseline to see to what degree different categories of stimuli increase or decrease FFA activity. One way to do this could, for example, be to include objects as a third or fourth variable, e.g. having an unknown utensil as a non-famous object and a 'pokeball' from the animated Pokemon-series as a famous object.

New Paths

Alternatively one could also explore the tendencies seen in figure 4. Do we find a starker difference in activation between famous and non-famous human faces than cartoon faces, as tendencies in the plot might suggest in the slightest sense, and if so - why?

One could also do an exploratory analysis of what other voxels are active during face recognition, and let that guide new investigations into the connections between FFA activity and higher-level theory of mind, as has been done in a study on car fronts and anthropomorphism. (Kühn et al., 2014) Likewise it could be interesting to investigate, if and how the FFA is connected to the memory system with its recognition abilities.

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