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Human face processing is tuned to sexual age preferences

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Human faces can motivate nurturing behaviour or sexual behaviour when adults see a child or an adult face, respectively. This suggests that face processing is tuned to detecting age cues of sexual maturity to stimulate the appropriate reproductive behaviour: either caretaking or mating. In paedophilia, sexual attraction is directed to sexually immature children. Therefore, we hypothesized that brain networks that normally are tuned to mature faces of the preferred gender show an abnormal tuning to sexual immature faces in paedophilia. Here, we use functional magnetic resonance imaging (fMRI) to test directly for the existence of a network which is tuned to face cues of sexual maturity. During fMRI, participants sexually attracted to either adults or children were exposed to various face images. In individuals attracted to adults, adult faces activated several brain regions significantly more than child faces. These brain regions comprised areas known to be implicated in face processing, and sexual processing, including occipital areas, the ventrolateral prefrontal cortex and, subcortically, the putamen and nucleus caudatus. The same regions were activated in paedophiles, but with a reversed preferential response pattern.

1. Introduction

The observation of caregiving behaviours in the context of mating led an ethological theorist to state a phylogenetic association between nurturing behaviour and sexual behaviour [1]. However, combining those behaviours can be problematic from an evolutionary perspective; and generally, the functional division between the two domains operates effectively. In rodents, the distinction between sexually mature and immature conspecifics is driven by pheromones [2]. Given the central role of faces in signalling internal states and providing feedback during social interactions in old-world primates [3], face-related age information constitutes powerful cues for mating and caregiving behaviour. In humans, child faces are powerful elicitors of caregiving behaviour in both men and women particularly when child faces closely correspond to the baby schema [4]. By contrast, adult faces are relevant stimuli in mate selection [5]. The human brain contains networks that are tuned to face processing [6], and these networks appear to activate different processing streams of the reproductive domain selectively: nurturing processing in the case of child faces [7] and sexual processing in the case of sexually preferred adult faces [8]. This implies that the brain extracts age-related face cues of the preferred sex that inform appropriate response selection in the reproductive domains: nurturing in the case of child faces and mating in the case of adult faces.

Some men, however, experience sexual attraction to prepubescent children (i.e. paedophilia [9]). The neural correlates of abnormal sexual age preference still

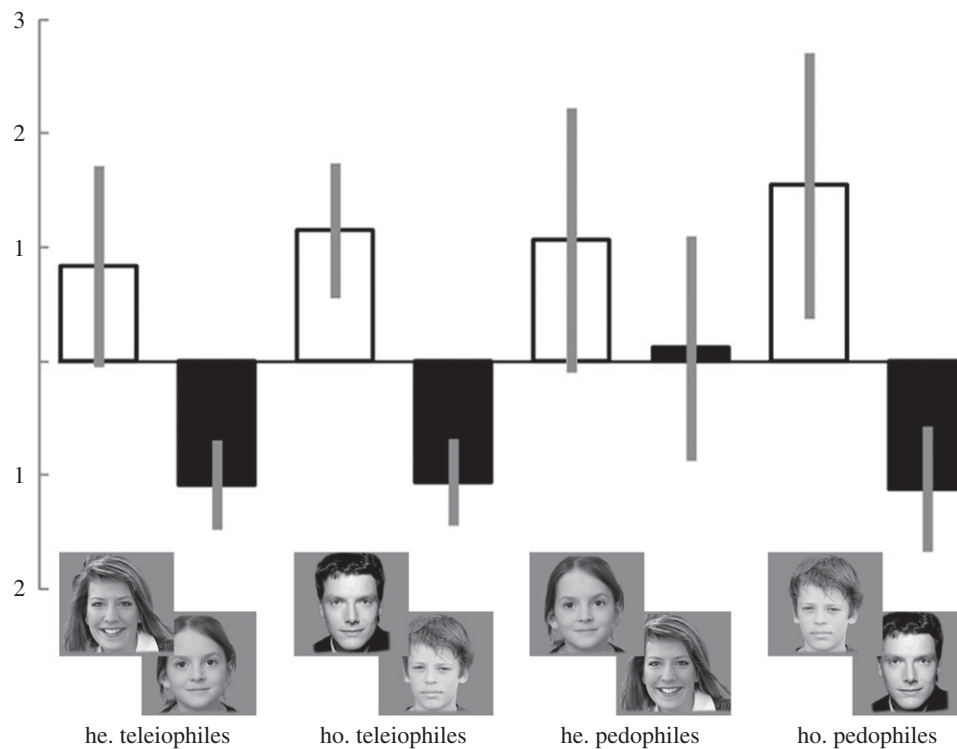


Figure 1. Subjective ratings of face stimuli in the four participant groups. Mean ratings and s.d. of the faces of the preferred age and gender (white bars) and of the non-preferred age of the same gender (black bars) were in accordance with the sexual preferences in the four groups (he., heterosexual; ho., homosexual). The face-rating scores were subtracted from the overall mean rating of the high-arousing IAPS pictures. The face images represent the stimulus type.

remain poorly understood [10]. Possibly, the detection of age-related face cues functions appropriately in these men, but age cues indicating sexual immaturity elicit aberrant sexual arousal and attraction. In this study, we wished to identify networks in the human brain which are tuned to age cues of faces and explore the impact of sexual preference. Using the blood-oxygen-level-dependent (BOLD) signal as an index of regional brain activity, we performed functional magnetic resonance imaging (fMRI) to delineate the brain regions processing the sexually preferred age cues of faces. To this end, we exposed adult participants to pictures of adult and child faces of both genders during an fMRI session. We were interested in identifying regional brain responses related to the sexual attractiveness of a face in terms of its age, independent of whether it is a child or adult face and independent also of its gender. We also had to exclude the possibility that response differences in brain activity between adult and child faces simply reflect different object categories. Therefore, we included four groups of adult men sexually attracted to one of the following: adult females (heterosexual teleiophiles), adult males (homosexual teleiophiles), prepubescent girls (heterosexual paedophiles) or prepubescent boys (homosexual paedophiles).

2. Material and methods

Fifty-six men (11 heterosexual paedophiles, 13 homosexual paedophiles, 18 heterosexual teleiophiles and 14 homosexual teleiophiles) were briefly exposed to pictures of men's, women's, boys' and girls' faces, and to high-arousing pictures from the International Affective Picture System (IAPS [11]) (35 images per stimulus type) in a random order during an fMRI session. Participants rated the attractiveness of each individual face after the fMRI session. For each participant, we estimated the parameters of a generalized linear model for the fMRI data that describes how the stimulus type affects

the BOLD signal. We then contrasted the brain response elicited by face stimuli *showing the sexually preferred gender and age group* with the response elicited by face stimuli showing the sexually preferred gender but not the sexually preferred age group (e.g. women's faces versus girls' faces in heterosexual controls) of each group separately and submitted the resulting t-maps to a conjunction analysis using the conjunction null option of the SPM software with a threshold of $p < 0.01$ (see the electronic supplementary material for details).

3. Results

Post-scan ratings consistently reflected the sexual preference of the participants. Repeated-measures analyses of variance revealed main effects of face stimuli (with sexually preferred faces being rated as the most arousing) in all of the four participants (all F -tests: $p < 0.001$; figure 1). Conjunction analysis revealed a common pattern of brain activity covering the inferior occipital gyrus (IOG) (bilaterally), the fusiform gyrus (FFG) (bilaterally), the left nucleus caudatus (NC) (head and tail), the putamen, the sulcus calcarinus (bilaterally) and the left ventrolateral prefrontal cortex (VLPFC) (figure 2 and table 1).

4. Discussion

The detected network comprises face- and sex-sensitive areas. Sulcus calcarinus activity indicates enhanced processing at an early visual processing stage [12], providing input to the IOG and the FFG, which constitute the core areas of the human face perception system [6]. Previous research has found that the VLPFC is face and gaze sensitive [13] and that it receives input from the high-level visual cortex of the occipito-temporal area through the inferior front-occipital fasciculus [14]. Moreover, the VLPFC appears to be a site of convergence not only of high-order facial representations, but also

Table 1. Areas of common brain activity elicited by sexually preferred faces according to the conjunction analysis. (Significant clusters only (uncorrected threshold: $p < 0.01$). MNI, Montreal Neurological Institute; pref., preferred; non-pref., non-preferred; R, right; L, left. Cluster sizes are only given for the voxel showing peak activity. Numbers in parentheses indicate the cluster correspondence of subpeaks.)

| | | | | MNI coordinates (mm) | | |
|-------------------------------|------|----------------------|----------------|----------------------|-----|-----|
| brain area | side | cluster size, voxels | z score maxima | x | y | z |
| pref. faces > non-pref. faces | | | | | | |
| Sulcus calcarinus | R | 45 | 2.72 | 10 | −76 | 8 |
| Sulcus calcarinus | L | 22 | 2.70 | −10 | −78 | 12 |
| IOG | R | 69 | 2.78 | 42 | −66 | −6 |
| IOG | L | 362 (1) | 3.16 | −40 | −64 | −10 |
| FFG | R | 104 | 2.69 | 34 | −50 | −20 |
| FFG | L | (1) | 3.05 | −40 | −56 | −18 |
| NC tail | L | 32 | 2.87 | −22 | −12 | 18 |
| putamen | L | 28 | 2.73 | −20 | 6 | 16 |
| VLPFC | L | 7 | 2.55 | −44 | 44 | 8 |

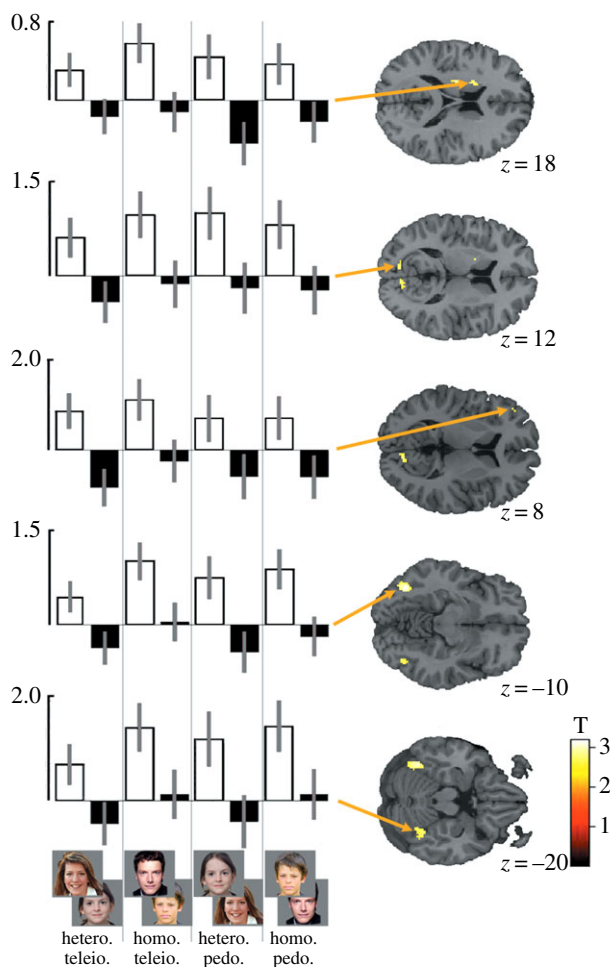


Figure 2. Brain areas that selectively respond to faces of the sexually preferred age. Parameter estimates show the relative BOLD signal changes (%) for faces of the preferred age and gender (white bars) and of the non-preferred age of the same gender (black bars) in the four participant groups as revealed by the general linear model (group means and 95% confidence interval). Signal changes revealed activity profiles that were similar to the profiles of the ratings at several voxels with maximal peak activation. hetero. teleio., heterosexual teleiophiles; homo. teleio., homosexual teleiophiles; hetero. pedo., heterosexual paedophiles; homo. pedo., homosexual paedophiles.

of a series of cognitive processes [15] and emotional regulation [16]. We therefore suggest that the common activity detected by this study in the IOG, FFG and VLPFC reveals the core areas of a brain network that is tuned to detect face cues of sexual maturity. We also found elevated activity in the putamen and NC, which have also been found to be involved in both emotional face processing [4,8] and sexual processing [17]. Several researchers have highlighted the relevance of the dorsal striatum for reward anticipation [18] and inhibitory control [19–21]. It remains, therefore, an open question whether the increased activity in the dorsal striatum is related to the incentive value of the sexually preferred faces or to the participants' efforts in withholding actions.

The present findings confirm previous reports in which they show that human faces were processed according to the sexual gender orientation of the observer [8]. The critical new finding is that face processing is also tuned to face cues revealing the developmental stage that is sexually preferred. We found no evidence to suggest that paedophiles recruit a different brain network when exposed to faces of the preferred sex and age than individuals showing a normal preference for adults do. In both teleiophilic and paedophilic men, the same network is activated by the sexually preferred face, but the main difference is that in paedophiles that network is abnormally tuned to sexual immaturity. The cross-sectional nature of this study provides no clues as to which mechanisms triggered this abnormal conversion in age sensitivity. Possibly, neurodevelopmental disturbances [22] might have contributed to a response confusion within the reproductive domain.

The sensitivity of the paedophilic men to the age-related face cues indicates a potential clinical benefit of the present findings. Recent fMRI research has demonstrated that paedophiles can be reliably classified according to their brain responses to pictures of naked children and naked adults [23]. Because showing paedophiles pictures of naked children sometimes raises ethical concerns, it should be tested whether paedophilia could be diagnosed using brain responses to facial stimuli as well. Furthermore, using face stimuli would allow for cross-sectional and longitudinal studies of younger participants. However, the usefulness of face stimuli remains an open question, firstly,

because the present data provide no information about how consistent the effects were in individual subjects and secondly, because increased responses to child faces may also result from increased familiarity and attention [24].

The study was approved by the local ethics committee of the Medical Faculty of Christian-Albrechts University.

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