Fear recognition across the menstrual cycle

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Abstract

This study assesses the mediating role of stage of menstrual cycle in the recognition of emotional expressions. It was hypothesised that fear recognition ability would be stronger at high-oestrogen stages of the menstrual cycle. The accuracy of recognising emotional expressions was compared across 50 women who were at different stages of their menstrual cycle. It was found that accuracy to recognise emotions was significantly affected by the interaction between stages of the menstrual cycle and the emotion being displayed. Further analysis revealed that for the emotion expression of fear alone, participants were significantly more accurate at the preovulatory surge (highest oestrogen levels) than at menstruation (oestrogen levels at lowest point). The results have implications for the processes that underlie fear processing and a possible insight into the sexual dimorphism of this ability and conditions that show variations in fear recognition (e.g., autism, Turner syndrome).

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Introduction

Cognitions change across the menstrual cycle: for example, Penton-Voak and Perrett (2000) found that during the preovulatory and ovulatory phases of the cycle, women prefer more masculinised faces than at other stages. At these high oestrogen phases of the menstrual cycle, women are at their most fertile and, it can be argued, it makes evolutionary sense to have an enhanced sensitivity to reproductively relevant stimuli. Macrae et al. (2002) suggest that when conception risk is high, women are primed by hormones to make more efficient social cognitive judgements. They found that women made more categorical and stereotypical judgements about men at ovulation relative to menstruation. This implies that women are more efficient at, and may have a heightened ability for, person perception and social cognition at times when they are most fertile.

Social competence is itself a sexually dimorphic skill with women showing a superior empathizing ability according to Baron-Cohen’s (2003) definition of the female brain. Baron-Cohen states that women show earlier development and superior theory of mind abilities (i.e., the developed understanding that other humans have beliefs and a point of view different to one’s own). This ability may be linked to sexually dimorphic processing of facial expressions in which women generally show a superior ability (Hall et al., 1999). Women are both better encoders of basic emotions (Kilgore, 2000) and more complex emotions and mental states (Baron-Cohen, 2003). It is argued below that fear recognition is at the heart of this sexual dimorphism.

Responses to a threatening environment are often important to the survival of species and the amygdala is instantly activated when threat, such as a fearful face, is detected (Morris et al., 1998). Despite showing activation to all emotional stimuli, the amygdala shows preferential activation to fearful faces (Morris et al., 1996) and brain damage to this region results in the selective impairment of fear recognition (Adolphs et al., 1995). Calder et al. (2001) provide a review of the relationship between fear and the amygdala.

Skuse (2003) argues that the neural circuits based around the amygdala have adapted to enable higher social cognitive...
functions such as a theory of mind. Skuse proposes that the recognition of the facial expression of fear correlates with theory of mind ability. He further suggests that this is because, unlike the direct threat of anger, for example, understanding why a fearful face signals threat requires us to interpret the world through someone else’s perspective. To discover what the threat is, we need to look outside the person and see the subject of their fear. Successful interpretation of the meaning of a fearful face, thus, requires second-order representations and a theory of mind. It has been argued that these cognitive abilities separate humans from other species (Tomasello, 1999).

Fear recognition, unlike any of the other emotions, correlates with face recognition memory in women but not men (Campbell et al., 2002). This suggests that the specific neural mechanisms involved in fear recognition may be sexually dimorphic. Neuroimaging studies enable researchers to identify the pattern of structural and functional sexual dimorphism of the neural network. The main areas of sexual differentiation involve hemispheric lateralisation: ERP data show men to have greater right hemisphere activity when processing emotions (Everhart et al., 2001). Morris et al. (1998) demonstrated that the right amygdala is associated with automatic and even unconscious processing of fear whereas the left amygdala is involved in a full analysis of the face and has links to higher regions. A right amygdala advantage in men may therefore reflect the tendency to rely on an initial automatic response, perhaps reminiscent of the ancient fight-or-flight reaction.

Women, however, exhibit a differential pattern of activation in the left amygdala and subsequent regions such as the prefrontal cortex and the hippocampus when presented with fearful faces. Women, relative to men, exhibit increased habituation in the left amygdala followed by increased activity in the hippocampus (Campbell et al., 2002; Kilgore, 2000). The neural differences may reflect an adaptive female differentiation of the ancient neural “warning system”. Increased habituation may reflect an inhibitory mechanism controlling the initial fight-or-flight response and evaluating the social context. Successfully attributing salience and value to the emotional stimuli requires careful balance of the amygdala and higher cortical regions (Skuse, 2003). This involves accessing emotional memory (the hippocampus) and the evaluative capabilities of the left prefrontal cortex (Leducx, 1995). As discussed above, these regions show more activation in women’s response to fear and women only show an association of fear recognition with memory for faces placing a special role for the hippocampus in women.

Women compared to men take more notice of, and assign more meaning to, emotions in others (Baron-Cohen, 2003). This may reflect the specific evolutionary pressures on women. For example a fight-or-flight response would not be an appropriate reaction to a young child’s fearful expression; a mother needs to evaluate meanings so that she can distinguish realistic and unrealistic fears in the child, as she is responsible for teaching them about the world. As hunters, men would primarily meet fearful expressions in situations where a rapid fight-or-flight reaction provides the most promising survival tactic.

It is hypothesised that oestrogen may play a mediating role in this female adaptation and may explain the structural and functional differences discussed above. Oestrogen receptors have been identified in the amygdala (Osterlund and Hurd, 2001) and more prominently in the hippocampus and the corpus callosum (Fitch and Denenberg, 1998). Oestrogens acting on these sites can change the neurochemical and physical structures of cells (McEwen et al., 1997) and cycling estrus hormones in the female rat are known to remodel hippocampal cells (Woolley et al., 1990). It appears then that oestrogen facilitates increased functioning of these areas. As discussed before, the transient effects of hormones on these brain regions may explain the female brain acting more “female” at high oestrogen stages of the menstrual cycle.

Further evidence of the link between hormones and fear recognition comes from clinical disorders, such as autism, that appear to have very specific impairments in fear recognition (Howard et al., 2000). Autism is a predominantly male disorder and has been conceptualised by Baron-Cohen (2003) as the extreme male brain. Part of his biological theory behind masculinisation or feminisation of the brain is the level of male and female hormones the brain is exposed to. Autism can be characterised as a severe lack of active female hormones in the central nervous system.

This theory is further supported by evidence from studies into Turner’s syndrome. Patients with this syndrome suffer from ovarian dysgenesis and the subsequent failure of endogenous oestrogen production (Collear et al., 2002). Individuals with Turner’s syndrome are at an increased risk of having autism (at least 200 times, Creswell and Skuse, 1999) and show impaired social abilities (Lawrence et al., 2003). Like individuals with autism, individuals with Turner’s syndrome have a specific deficit in fear recognition (Lawrence et al., 2003). It would appear that without oestrogen, the brains of individuals with Turner’s syndrome fail to ‘feminise’ resulting in some extreme-male or autistic-like characteristics. Further evidence for oestrogen’s key role in fear recognition is that emerging evidence suggests that individuals who have received early oestrogen replacement are less likely to show this fear recognition deficit which appears to be so key in social cognition (Lawrence et al., 2003).

While we have focused on the possible effect of oestrogen here, it must be considered that an effect of menstrual stage could also be accounted for in terms of other female hormones such as progesterone. Such an effect would be supported by work conducted by Smith et al. (1998), who demonstrated how progesterone’s metabolite allopregnanolone is active in the hippocampus area.

The current experiment explored how accuracy of recognition of six basic facial expressions of emotions
varies across four stages of the menstrual cycle. It was hypothesised that, specifically, fear-recognition ability will be at its most accurate during high oestrogen phases, particularly the preovulatory phase where oestrogen is at its highest, and the ability will be at its lowest at low oestrogen phases, particularly at menstruation when oestrogen is at its lowest.

Method

Participants

Fifty-three female undergraduate students from Cardiff University volunteered to take part in the study in return for course credit. The ages ranged from 18 to 22 and the mean age was 20. All the participants that were included had a regular menstrual cycle and were not taking any form of the contraceptive pill. Three participants were excluded from the study: two because of ambiguous menstrual cycles and one due to computer failure. The participants were assigned to one of four groups depending on the stage of their menstrual cycle they were experiencing on the date of testing. In order to track the stages of the menstrual cycle, two key events from each participant were noted. If the female reported she was currently menstruating or had been in the last 2 days, she was automatically assigned to the menstruation group \( (N = 12) \). The three remaining groups were calculated by obtaining information via email from the individuals of their subsequent onset of menses in return for further course credit. This enabled calculation of ovulation, which is taken to have occurred 14 days prior to menstruation. Participants who were tested the day before and 3 days after ovulation were assigned to the ovulating group (i.e., 15 days to 11 days before the onset of subsequent menses; \( N = 11 \)). Participants who were tested before ovulation were assigned to the preovulatory group \( (N = 13) \) and participants who were tested after ovulation were assigned to the luteal group \( (N = 14) \).

Stimuli

The stimuli consisted of 6 practice and 60 test faces. These were taken from the Ekman and Friesen (1976) set, which has been used in emotion recognition studies as a valid measure for over 20 years. The test consisted of 11 fearful, 11 sad, 11 happy, 11 angry, 11 disgusted and 11 surprised faces. One of each was presented in the practice and the remaining 60 were presented on the screen in randomised order.

Procedure

Participants were initially given a consent form and then instructed to fill out the menstrual cycle questionnaire. They were then told that several faces would appear on the screen and that they had to decide how they thought the person was feeling from the six options, which were on the keyboard. Keys on a keyboard were labelled with stickers with capital print of the six emotions. The position of each emotion sticker on the keyboard was counterbalanced across participants. They were told there would be six practice faces followed by a break and then they would enter the test phase. They were instructed to make their response as soon as they had come to a decision. There was an interstimulus interval of 1000 ms and each test item was presented until the participant made a keyboard response. After completion of the computerised test, the participants were instructed to email to confirm the date of their next set of menses.

Design

This was a two-way mixed design. The within-subject independent variable was emotion and has six levels: fear, happy, disgust, sad, surprise and anger. The between-subjects independent variable is menstrual cycle stage and has 4 levels: menses, preovulatory, ovulating and luteal. There were two dependent variables. The first is accuracy scores for correct recognition of each emotion out of a maximum of 10. The second dependent variable was the mean reaction time to make correct responses to each of the emotional stimuli sets.

Results

The results for the accuracy scores for the six emotions are shown in Fig. 1. This shows that variations in accuracy for emotions over cycle stages are greatest for fear recognition. Accuracy for fear recognition is greatest during the pre-ovulation stage and at its lowest during menses.
A two-way mixed design ANOVA was performed on the accuracy data. There was a significant main effect for emotion \( F(5,230) = 36.764; P < 0.001 \). The emotion-by-stage interaction was also significant \( F(15,230) = 2.379; P < 0.01 \). Simple main effects analysis was performed with planned pairwise comparisons. Effects of stage of cycle were found for fear where performance at menses was significantly \( (P < 0.05) \) poorer than at pre-ovulation or ovulating stages. Other comparisons were nonsignificant.

Although hormone levels were not assessed directly for the participants, it is possible to have a general idea as to the approximate level of oestrogen for each of the four groups based on their stage of cycle reported. Using charts such as that produced by Alliende (2002), a rough measure of estrone glucuronide for participants in each of the four groups can be estimated. Participants would be likely on average to have the following averages: the menses group would have 29.8 nmol/l/day; the pre-ovulatory group would have 62.4 nmol/l/day; the ovulation group would have 53.7 nmol/l/day and luteal group would have 42.9 nmol/l/day. These values for the four groups can be correlated with the accuracy obtained for the fear faces. This correlation reveals a strong positive relationship between performance on the fearful faces and the level of estrone glucuronide \( (r = 0.987; P < 0.01) \).

A mixed-design ANOVA was conducted for mean reactions. Although this revealed that happy faces could be categorised faster than any other emotion faces \( (P < 0.05) \), no other effects or interactions were significant.

Discussion

It can be concluded that there is a relationship between fear recognition and stage of the menstrual cycle. This finding supports the hypothesis regarding the level of oestrogen accuracy and encoding of fearful faces. Accuracy for fearful faces was highest during their highest oestrogen phase (preovulatory surge) and was lowest at the lowest oestrogen phase (menstruation). In fact, the pattern of accuracy scores across all four stages matches the pattern of oestrogen fluctuations across these stages as indicated by the strong correlation. The fact that fear recognition is differentially affected by stage of cycle suggests that there is a distinct neural processing of fear. The pattern of results also provides strong evidence for oestrogen’s (or some other hormone’s) mediating role in this system.

It is, however, possible that the mechanism behind the difference in performance can be explained in terms of mood changes and associated cognitive differences during the menstrual cycle (e.g., Davydov et al., 2004). If the participants were suffering from premenstrual dysphoric disorder or premenstrual syndrome, then it would be expected that performance would be better during the preovulatory and ovulation periods than during the menses period as has been shown in a variety of tasks (e.g., Mans et al., 1999). This explanation, however, would not explain why it is that the recognition of the fear emotion specifically is affected by the menstrual cycle.

Previous studies have shown that, at menstruation, women’s cognitive abilities shift slightly towards a male ‘type’ brain (Sanders et al., 2002). The experiment above has demonstrated that, at menstruation, participants show a significant decrease in fear recognition. Impairments at this skill at an extreme level characterise the proposed extreme male brain and are said to shape autistic individuals (Baron-Cohen, 2003). The relationship demonstrated here between this ability and hormones provides a new direction in research into autism. Is extreme lack of oestrogen or progesterone a potential cause? Could early oestrogen replacement act as a protective factor as it appears to in Turner’s syndrome?

The association between hormones and fear recognition also poses another question: if lack of oestrogen produces the extreme male brain, it would follow that excess levels will result in the extreme female brain. In his recent book, Baron-Cohen (2003) leaves open the question: What is the nature of the extreme female brain? Fear recognition may provide the answer to this, just as individuals with an extreme male brain deviate below the norm on this ability, individuals with an extreme female brain may deviate above the norm. Such individuals have been identified in a recent study that shows that individuals with a history of a major depressive episode show a selectively greater recognition of fear (Bhagwager et al., 2004). The authors also demonstrate that this abnormality was normalised through treatment with selective serotonin reuptake inhibitors. Previously, emotion recognition abilities have been found to correlate with depression (Gur et al., 1992). Could oestrogen play a role in the chemical imbalance of depressive disorder as has been suggested by, for example, Angold et al. (1999)? Is the predominantly female disorder of depression (2:1 female to male ratio, Hammen, 1997) a characteristic of the extreme female brain? This speculation requires further inquiry but one potential outcome from this line of research would be a test that could screen for depression (perhaps postnatal depression) without having to ask explicitly about feelings. Such a test could be administered as a test of hormonal imbalance and require people to make judgements about emotions expressed.

An implication of the current study for the normal female population concerns the effects of methods of contraception that alter levels of hormones might have. The present findings would suggest that altering one’s hormonal levels may subtly but significantly alter fear recognition ability. When fear recognition has such strong associations with social competence, interfering with such a process could have negative implications. No individuals who were taking the contraceptive pill were included in this study but an important future direction would be to assess the ability of those on different pills with the prediction that pills reducing oestrogen levels would be associated with lower fear recognition abilities.


**Conclusion**

What can be concluded from the present findings is that fear recognition, unlike recognition of other emotions, is associated with hormone levels. Previous research has placed fear recognition as a key social cognitive task. Oestrogen or progesterone then may find its role in the feminisation of the brain, which may have been particularly significant for the evolution of social cognition out of simple instinctive responses to threat. Moreover, the transient effects of these hormones across the menstrual cycle affirm them as an active chemical in the adult female brain. Seemingly, hormones’ active role in the brain not only shape between-sex variations but within-sex variation. Extreme variations may underlie cognitive and emotional disorders. Further understanding of the complex relationship between hormones, the brain and behaviour may aid understanding into these disorders as well as the biologically caused differences between the emerging ‘feminine’ and ‘masculine’ cognitive sets.

**References**


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