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Distinct brain activity in processing negative pictures of animals and objects — The role of human contexts

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ABSTRACT

Previous studies have shown that the amygdala is important in processing not only animate entities but also social information. It remains to be determined to what extent the factors of category and social context interact to modulate the activities of the amygdala and cortical regions. In this study, pictures depicting animals and inanimate objects in negative and neutral levels were presented. The contexts of the pictures differed in whether they included human/human parts. The factors of valence, arousal, familiarity and complexity of pictures were controlled across categories. The results showed that the amygdala activity was modulated by category and contextual information. Under the nonhuman context condition, the amygdala responded more to animals than objects for both negative and neutral pictures. In contrast, under the human context condition, the amygdala showed stronger activity for negative objects than animals. In addition to cortical regions related to object action, functional and effective connectivity analyses showed that the anterior prefrontal cortex interacted more with the amygdala for negative objects (vs. animals) in the human context condition, by a top-down modulation of the anterior prefrontal cortex to the amygdala. These results highlighted the effects of category and human contexts on modulating brain activity in emotional processing.

Introduction

In our daily lives we may fear different kinds of things, e.g., snakes, plane crashes, or blood. Some people develop as phobia to excessively fear certain classes of objects or contexts. Among the specific phobias, animal phobia has the highest prevalence (Damsa et al., 2009; Pull, 2008), but its neural mechanisms remain unclear. One influential hypothesis, the preparedness theory, posits that fear of snakes and spiders may be associated with prepared networks because ancient humans faced attacks from these animals (Ohman and Mineka, 2001; Seligman, 1970). Compared to ontogenetic fear stimuli (e.g., guns), phylogenetic fear stimuli (e.g., snakes) are more attended to (e.g., New et al., 2007; Ohman et al., 2001a,b), and lead to stronger physiological responses (e.g., Cook et al., 1986; Hugdahl and Karker, 1981).

Specifically the preparedness theory proposes that the enhanced response to phylogenetic fear stimuli is associated with activity in the amygdala. This result is supported by the evidence that the amygdala is more responsive to animate stimuli compared to inanimate objects, in addition to being extensively involved in processing threatening stimuli. In a previous study the neurons in the right amygdala were more responsive to animal pictures, which were independent of emotional valence and arousal (Mormann et al., 2011). The medial temporal region, including the amygdala, was preferentially responsive to personally relevant images (vs. unfamiliar people) (Viskontas et al., 2009). The animate advantage is also shown in fMRI studies. In one study, Yang et al. (2012a) compared brain activation in American participants for faces, nonhuman animals and inanimate objects in negative, positive and neutral levels. The results demonstrated that activation in the right amygdala was the strongest for human faces, less strong for animals, and weakest for inanimate objects. This pattern was clear for negative and neutral pictures and suggested that the amygdala is more involved in processing animate (vs. inanimate) entities.

Various studies have also revealed that the amygdala is important for processing social information (e.g., Norris et al., 2004; Sakaki et al., 2012; Wheatley et al., 2007. For reviews, see Adolphs, 2010; Frith and Frith, 2012). In the Wheatley et al. (2007) study, subjects viewed moving shapes in two different backgrounds biased towards animate or inanimate interpretations. Because the shapes were the same, the interpretation was determined by the contextual background. The results showed that animate interpretation significantly activated the amygdala, insula, medial prefrontal cortex (mPFC) and posterior cingulate cortex (PCC) relative to inanimate interpretation. Sakaki et al. (2012) divided the pictures into survival-related (e.g., threats, food) and social life-related categories (e.g., trust, friendship) with the two types of pictures matched in their valence and arousal levels. The results showed that the left amygdala and the left mPFC were activated for both survival- and social-related

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pictures. The amygdala also had addictive effects when pictures were negative and included social contents (i.e., pictures containing human information) (Norris et al., 2004).

Although the factors of emotion, category and context are important for amygdala activation, to what extent they interact to influence the activation of the amygdala and other brain regions is unclear. Some studies found comparable emotional responses to living and nonliving entities under some conditions. For example, pointed guns and pointed snakes had comparable resistance to extinction (Hugdahl and Johnsen, 1989) because guns with sounds are more likely to be associated with threatening situations. Indeed, when seeing a gun handled by a human hand, one likely finds the gun more threatening than a gun on the table and as threatening as a snake biting a man. A recent eye-tracking study showed that, although animal pictures attract more attention than inanimate objects (New et al., 2007), they had comparable numbers of gaze fixations and gaze durations when human contexts were included in both types of pictures (Yang et al., 2012b). This result suggested that contextual information is important for understanding how people react to negative inanimate objects. Processing pictures with human contextual information may critically depend on that context and is associated with top-down modulation and executive control of social information (Frith and Frith, 2012). Neural recordings of rats found that the prefrontal cortex encoded contextual information to form rich contextual representations and alter the interpretations or meanings of stimuli (Hyman et al., 2012). Thus, the amygdala and the prefrontal cortex possibly interact to process emotional pictures with human contexts, but more evidence is needed to confirm the prediction.

The question addressed in this study was to explore the extent to which the activities of the amygdala and cortical regions were modulated by contextual information when subjects processed animals and objects in different emotional levels. In a pilot experiment (Supplementary material), we adopted the design of Yang et al. (2012a); Chinese subjects viewed pictures of facial expressions, animals and manipulable objects in different emotional levels (i.e., negative, neutral and positive). In this study, we further included pictures with human or human body information as contexts for nonhuman animals and inanimate objects in negative and neutral dimensions. To dissociate the factors of emotion and category, we matched valence and arousal levels across categories and controlled for complexity and familiarity levels. We hypothesized that factors of emotion, category and context interact to influence the amygdala activation (e.g., Hyman et al., 2012; Yang et al., 2012b). We predicted that the amygdala activation was stronger for negative (vs. neutral) pictures, and stronger for animals than objects, as shown in previous studies. In addition, the category effect is expected to interact with that of emotion and context. For pictures without human contexts, nonhuman animals elicit stronger activation in the amygdala than inanimate objects. For the pictures with human contexts, the animate advantage in negative dimensions may attenuate or disappear in the amygdala due to top-down processing of the prefrontal cortex.

Materials and methods

Subjects

Sixty healthy, right-handed subjects (28 males) participated in the study, with the mean age 22.54 ± 2.75 yrs. Of these subjects, 21 participated in emotional rating (10 male), 18 participated in familiarity and complexity rating (7 males), and the other 21 subjects participated in the fMRI experiment (11 males). All subjects were native Chinese speakers, and gave written informed consent in accordance with procedures and protocols approved by the Institutional Review Board of the Department of Psychology, Peking University.

Stimuli

The stimuli setup was the same as Yang et al. (2012b) (Fig. 1). Three within-subject factors were included in the study with a $2 \times 2 \times 2$ structure: context (with or without human contexts), emotion (negative, neutral) and category (nonhuman animals, inanimate objects). The factorial combination of the three factors made up eight experimental conditions. The stimuli in the fMRI experiment consisted of 240 colorful, nameable experimental pictures (30 per condition) with a resolution of $640 * 480$ pixels. Each of the 30 concepts was depicted as different pictures in contexts with and without human (or human parts). Low-level visual features, stimulus saliency, picture size, position of focal object and context were also analyzed and matched across categories (Yang et al., 2012b). Both small and large sizes of animals and inanimate objects were included to match their actual size. The orientation of the pictures was also matched across categories.

fMRI procedure

Pictures were clustered into blocks by context, emotion and category, with each of the $2 \times 2 \times 2$ conditions having 2 blocks. In each block, there were 19 pictures (15 different items and 4 repeats). Each picture was presented for 1 s, followed by a fixation for 500 ms, which yielded a duration of 28.5 s for each block. Subjects were asked to pay attention to all the stimuli, and to perform a repetition detection task. The 16 picture blocks and 16 scrambled blocks were pseudo-randomly assigned to 4 runs; the picture conditions, concepts and backgrounds were balanced

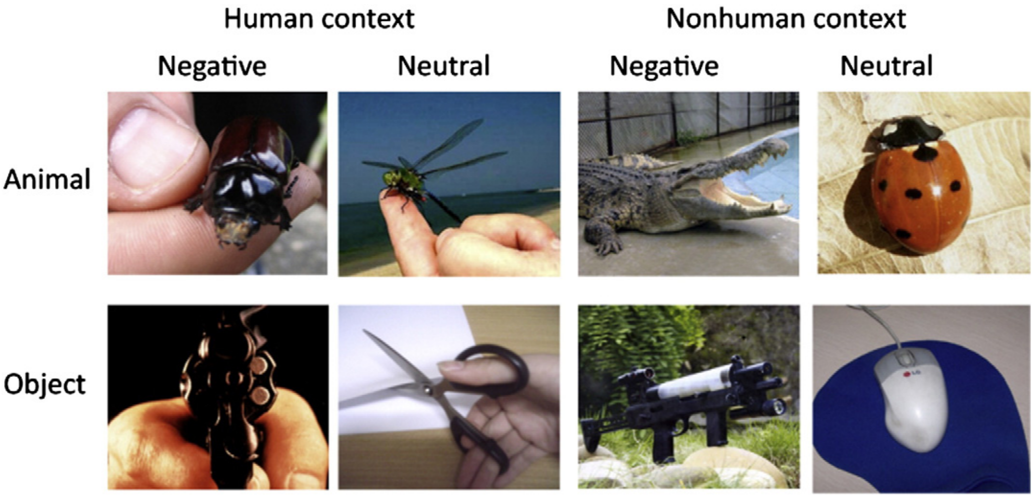

Fig. 1. Stimulus example.
Cited from Yang et al. (2012b).