



## Original Articles

## Emotional processing is enhanced in peri-hand space

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## ABSTRACT

The space near the hands, or peri-hand space is a critical multisensory-motor interface between people and the environment. Recent studies have shown that visual processing near the hands is altered compared with stimuli far from the hands. Some results suggest that the changes may be mediated by brain mechanisms involved in evaluating emotional stimuli. Here we show direct evidence for that proposal: we found that both the emotional Stroop effect and the Late Positive Potential (LPP) to unpleasant visual stimuli were enhanced near the hands compared to far from the hands. The results reveal enhanced processing of unpleasant stimuli in peri-hand space, which may facilitate the response to potentially dangerous stimuli.

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## 1. Introduction

Recent studies have shown that human visual perception and attentional selection near the hands are substantially altered compared with stimuli far from the hands (Abrams, Davoli, Du, Knapp, & Paull, 2008; Davoli, Du, Montana, Garverick, & Abrams, 2010; di Pellegrino & Frassinetti, 2000; Wang, Du, He, & Zhang, 2014). For example, cued stimuli near the hand are detected faster (Reed, Grubb, & Steele, 2006) and near-hand stimuli are more likely to be assigned as foreground figures than those far from the hand (Cosman & Vecera, 2010). In addition, holding the hands near a display causes attention to dwell longer on individual elements during a search (Abrams et al., 2008), and increases the number of items that can be retained in visual working memory (Tseng & Bridgeman, 2011). It has been suggested that these and other changes in perception in the near-hand space serve the purpose of enhancing the information that would be needed for manipulation of nearby objects, or for performing defensive movements to protect against a threatening stimulus (Abrams et al., 2008; for a review see Abrams, Weidler, & Suh, 2015).

Emotionally significant stimuli receive attentional priority since they play a critical role in one's social interactions and defensive behaviors. For example, emotionally significant stimuli draw

attention faster than emotionally neutral stimuli (e.g. Öhman, Flykt, & Esteves, 2001), and hold attention longer (Fox, Russo, & Dutton, 2002). In addition, emotion-provoking stimuli can involuntarily capture attention and interfere with a concurrent task when they are irrelevant to the task. For instance, naming the color of an emotional stimulus takes longer than for a neutral stimulus (Williams, Mathews, & MacLeod, 1996). Similarly, when participants are required to discriminate the color border surrounding a picture without reporting the content of the picture, the response to emotional pictures is delayed relative to neutral pictures (Constantine, McNally, & Hornig, 2001; Kolassa, Musial, Mohr, Trippe, & Miltner, 2005)—a phenomenon that is known as the emotional Stroop effect. However, little is known about how emotionally significant stimuli are processed in peri-hand space. The present study aims to explore whether emotional stimuli near the hands would capture attention more than those far from the hands.

Researchers have proposed that visual stimuli in peri-hand space might induce a bias toward the action-oriented magnocellular visual pathway. Conversely, objects far from the hands bias vision toward the perception-oriented parvocellular visual pathway (Goodhew, Gozli, Ferber, & Pratt, 2013; Gozli, West, & Pratt, 2012). Consistent with this proposal, people show enhanced temporal acuity and impaired spatial resolution for stimuli near the hands compared with those far from the hands (Gozli et al., 2012). Furthermore, stimuli near the hand benefit from enhanced processing of low spatial frequency information at the expense of

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high spatial frequency information (Abrams & Weidler, 2014). It is also known that processing emotionally significant stimuli relies heavily on magnocellular mechanisms (Bocanegra & Zeelenberg, 2009, 2011). It has been shown that the amygdala, a brain area critical to the processing of emotional stimuli, receives direct inputs from the magnocellular pathway via the superior colliculus and pulvinar (Morris, Öhman, & Dolan, 1999; Vuilleumier, Armony, Driver, & Dolan, 2003). If objects near the hand truly evoke enhanced magnocellular processing, such bias toward magnocellular processing would also be expected to facilitate the processing of emotionally significant objects near the hands. As a result, emotionally significant pictures near the hands might receive more extensive processing compared with those far from the hands, leading to a larger emotional Stroop effect.

The processing of emotionally significant stimuli can be also measured by event related potentials (ERPs). Of particular interest is the Late Positive Potential (LPP)—an enlarged positive potential for high-arousing emotional pictures compared with low-arousing pictures, which starts from around 300–400 ms after picture onset and has a centroparietal maximum topography (Keil et al., 2002; Schupp et al., 2004). Additionally, the magnitude of the LPP to emotional pictures is correlated with BOLD activity in both visual cortices and emotion-processing structures including amygdala, orbitofrontal cortex and insula (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012). Thus, a larger LPP is believed to reflect enhanced processing of emotionally salient stimuli and the recruitment of more attentional resources (Lang & Bradley, 2010). If processing of emotionally significant objects in perihand space is truly enhanced (due to enhanced magnocellular processing near the hands), LPP to unpleasant pictures would also be enhanced near the hands compared with far from the hands. The present study provides evidence for this possibility.

In the work presented here, we aimed to explore whether emotional stimuli near the hands reveal greater attentional allocation and enhanced emotional processing compared with stimuli far from hands. The results demonstrated both a larger emotional Stroop effect (Experiments 1 and 2) and enhanced LPP amplitudes (Experiment 3) for unpleasant pictures when they are near the hands compared with far from the hands. These results suggest a processing bias toward emotionally significant stimuli near the hands, thus facilitating the evaluation of objects that may be important for survival.

## 2. Experiment 1

The present experiment used a pictorial emotional Stroop task (Constantine et al., 2001; Kolassa et al., 2005). Participants were required to discriminate the color of the border surrounding a picture without a need to process the emotional content of the picture. The pictorial emotional Stroop effect refers to the response delay typically observed for unpleasant pictures relative to neutral pictures, presumably reflecting automatic processing of the emotionally significant stimuli. If processing of emotionally significant pictures is enhanced near the hands, a larger pictorial emotional Stroop effect should occur near the hands compared with far from the hands.

### 2.1. Materials and methods

#### 2.1.1. Participants

Forty-eight students (19 male; 19–29 years old) participated in the experiment for cash payment. All participants were naïve with respect to the hypotheses under investigation, and had normal or corrected-to-normal vision. The experimental procedure was approved by the institutional review board of the Institute of Psy-

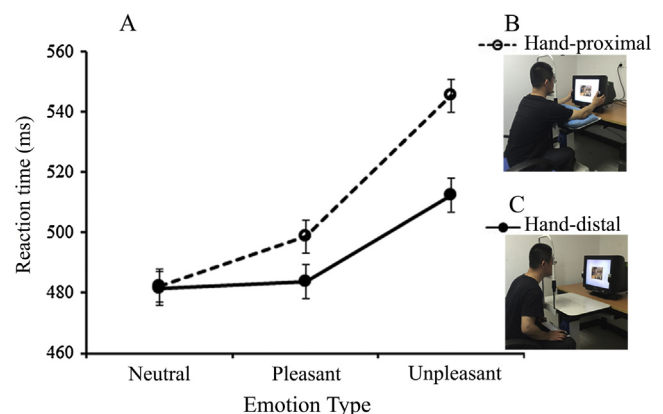
chology, Chinese Academy of Sciences. Informed consent was obtained from all participants before the experiment.

#### 2.1.2. Apparatus, stimuli and procedure

All stimuli were presented on a 17 in CRT monitor operating at a refresh rate of 85 Hz. Participants were seated at a viewing distance of 43 cm and steadied their head by resting on a chinrest. The two hand-stimulus proximity conditions are shown in Fig. 1B and C. In the hands-proximal condition, participants placed their hands on mini-mouses attached to each side of the monitor, with their elbows resting on cushions. In the hands-distal condition, participants placed their hands on the same two mini-mouses on a lightweight 38-cm-long board on their laps. The distance between the mini-mouses was the same in both conditions with 32 cm separation.

Twenty pleasant, twenty neutral, and twenty unpleasant pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). The mean pleasure ratings (valence) for pleasant, neutral and unpleasant pictures were 7.72, 5.05, and 2.83, respectively. The mean arousal ratings were 5.508 for pleasant pictures, 2.98 for neutral pictures, and 6.57 for unpleasant pictures. All pictures were adjusted to a width of 20° and a height of 14°, and were surrounded by either a red or blue border with a width of 0.4°. Under each hand-proximity condition participants served in three blocks of trials—one block each of neutral, pleasant or unpleasant pictures. A blocked design was used because it is more effective for eliciting emotion-related interference than event-related designs (Compton et al., 2003). Since emotional pictures might have a residual effect on subsequent neutral pictures, the neutral block was presented first to avoid such influence and it was followed by either a pleasant or unpleasant block. The order of the pleasant and unpleasant blocks was counterbalanced across participants. Each participant received the same sequence of the three blocks for the two hand-proximity conditions. The order of the hand-proximity conditions was also counterbalanced across participants. In each block, each picture was presented twice—once with a red border and once with a blue border, resulting in 40 trials in each block, which were presented in a random order. Over the six blocks, there were a total of 240 trials. Participants completed 18 practice trials with a different set of neutral pictures before testing.

Each trial began with a black fixation cross at the center of the screen on a white background. The fixation duration varied ran-



**Fig. 1.** The experimental methods and results from Experiment 1. (A) Mean reaction time to three types of emotional pictures for the two hand-stimulus proximity conditions. (B) The hands-proximal condition; participants placed their hands on mini-mouses attached to each side of the monitor, with their elbows resting on cushions. (C) The hands-distal condition; participants placed their hands on the same two mini-mouses on a lightweight 38-cm-long board on their laps. Error bars represent the within-subjects standard errors.

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