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Neurocognitive mechanisms underlying identification of environmental risks

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ABSTRACT

Environmental risks threaten a large population and are more dreadful than personal risks that bring physical or health problems to individuals. To assess the neurocognitive processes involved in environmental risk identification, we recorded brain activities, using event-related potential (ERP) and functional magnetic resonance imaging (fMRI), from human adults while they identified risky and safe environmental and personal events depicted in words. We found that, relative to safe environmental events, the identification of risky environmental events induced larger amplitudes of an early positive ERP component at 180–260 ms over the frontal area (P200) and of a late positive wave at 420–660 ms over the central–parietal area (LPP). fMRI results showed that the identification of environmental risks was associated with increased activations in the ventral anterior cingulate cortex (vACC) and posterior cingulate cortex (PCC). The amplitudes of the LPP/P200 and the PCC activity positively correlated with subjective ratings of risk degree of and emotional responses to the risky environmental events. However, the identification of personal risks induced positive shift of ERPs at 280–320 ms over the frontal and parietal areas and increased activity in the left inferior and medial prefrontal cortex. Our findings suggest that identification of dreadful environmental risks is subserved by an early detection in vACC and a late retrieval of emotional experiences in PCC.

1. Introduction

Natural disasters such as floods and earthquakes may induce serious damages to a large population and constitute severe risks to the public. After entering the 20th century, human beings are also confronted with potential artificial disasters such as nuclear explosion and chemical pollution that can damage the environment and lead to catastrophic consequences to human society. These environmental risks have increasingly dominated individual and collective consciousness (Denney, 2005; Laudan, 1994) since perception of these environmental risks is crucial for making decisions on both individual behaviors and public policies.

Psychometric studies showed that risk perceptions are highly domain specific (Blais & Weber, 2001; Weber, Blais, & Betz, 2002). For example, risks related to an individual can be decomposed into subcategories such as those related to personal health/safety and social decisions (Weber et al., 2002). Our recent functional magnetic resonance imaging (fMRI) study showed that distinct neural substrates engage in identifications of personal risks that arise from interpersonal interactions in social contexts (social risks) and that come from situations that may give rise to physical discomfort (physical risks) (Qin & Han, in press). Specifically, the identification of social risks induced increased activities in the medial prefrontal cortex (MPFC), the dorsal anterior cingulate cortex (dACC), and bilateral posterior insula, whereas the identification of physical risks resulted in activations in the MPFC, the ventral anterior cingulate cortex (vACC), the right cuneus/precuneus and bilateral amygdala. The fMRI findings suggest that identifications of risks in the social and physical domains are different in both cognitive processes and emotional responses.

Researchers also categorized risks into environmental and individual personal domains (Gattig & Hendrickx, 2007; Schütz, Wiedemann, & Gray, 2000). The environmental risks arise from the natural processes and the use of technology, lack direct control by individuals (Schütz et al., 2000), and may generate catastrophic consequences relevant to the survival of a large population (Böhm & Pfister, 2000). In contrast, personal risks result from individual activities (e.g., smoking, drinking, or car driving) that influence individual health and safety (Schütz et al., 2000). It has been shown that humans may discount the ponderance of the same personal risks that may happen in the far than near future (Chapman, 1996; Chapman & Elstein, 1995), whereas evaluation of the severity of

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environmental risks is less influence by the temporal delay of outcome (Böhm & Pfister, 2000; Hendrickx & Nicolaij, 2004). Following our previous research (Qin & Han, in press), the current work further investigated neurocognitive mechanisms that may distinguish between the identifications of environmental and personal risks.

Most of contemporary research on risk perception/evaluation emphasizes both probability and consequences of risks during decision making (Kahneman & Tversky, 1979; Sanfey, Loewenstein, McClure, & Cohen, 2006). Neuroimaging studies have shown evidence that the processing of probability and negative outcome are associated with the prefrontal cortex (ventral and medial prefrontal cortex: Longe, Elliott, & Deakin, 2001; ventral and dorsal prefrontal cortex: Casey et al., 2001; dorsal lateral prefrontal cortex: Huettel, Song, & McCarthy, 2005) and the ACC (Gehring & Willoughby, 2002; Yeung & Sanfey, 2004), respectively. However, memory of emotional experience and other factors may influence the way people evaluate risks in everyday life so that the probability of risky events may be ignored (Botterill & Mazur, 2004; Loewenstein, Weber, Hsee, & Welch, 2001; Sunstein, 2003). In this case, the evaluation of potential consequences or consequences that have already taken place may become extremely important for risk perception. The psychometric approach on risk perception showed that subjective rating of risks correlated with the severity and dreadfulness of hazards that reflect the consequences associated with risks (Slovic, 1987). These findings suggest that feelings of dread play an important role in risk perception (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, 1987) and risk perception may be associated with emotional reactions (Loewenstein et al., 2001; Slovic, Finucane, Peters, & MacGregor, 2004).

Previous studies suggested that strong feelings of dread are induced by the risks that lack control by individuals and may induce severe consequences (Slovic, 1987). Environmental risks are out of control in most cases (Schütz et al., 2000) and may produce catastrophic consequences to the survival of a large population (Böhm & Pfister, 2000). In these senses, environmental risks are more dreadful than personal risks (Slovic, 1987). This is consistent with the stress-related theory of risk perception, which claims that perception of high risk or anticipation of serious negative consequences may elicit intense emotions such as dread or fear (Stallen & Tomas, 1985). Moreover, Böhm (2003) suggested that prospective consequence-based feelings such as dread and fear are the most intense emotion associated with the consequence-based evaluation of environmental risks. Based on these studies, we hypothesized that, relative to the process of personal risks, the identification of environmental risks may result in enhanced emotional processing. In addition, the identification of environmental risks may occur earlier than that of personal risks in order to avoid harms to humans. To test these hypotheses, we combined event-related potential (ERP) and fMRI to record neural activities from subjects who were asked to perform a risk identification task. The task required judgment of risky or safe environmental and personal events depicted in words or phrases. Personal risk identification task was employed in the current work in order to estimate the specificity of the neurocognitive processes linked to the identification of environmental risks. Both risky and safe items were included in risk identification tasks. The neural substrates underlying risk identifications were defined by contrasting the risky events with the safe ones, which ruled out any confounds such as semantic processing and motor responses.

ERPs with high temporal resolution were recorded to examine the time course of environmental risk identification. Previous research showed that a fronto-central positive ERP component peaking at about 200 ms after sensory stimulation (P200) is sensitive to presence of threatening images or angry faces (Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001; Carretié, Mercado, Tapia, & Hinojosa, 2001; Eimer, Holmes, & McGlone, 2003). A late positive potential (LPP) over the centro-parietal area is engaged in evaluative categorizations (Cacioppo, Crites, & Gardner, 1996; Crites & Cacioppo, 1996; Ito & Cacioppo, 2000) and could differentiate emotional from neutral stimuli during active evaluation (Cacioppo et al., 1996; Schupp et al., 2000). We assessed whether the ERP component such as P200 and LPP could differentiate identification of environmental and personal risks by comparing risky and safe events in each domain. Blood oxygen level dependent (BOLD) signals with high spatial resolution were recorded using fMRI to localize neural substrates engaged in the identification of environmental and personal risks. Our recent research showed the vACC activity was greater to physical than social risks, parallel to the higher rating scores of physical than social risks (Qin & Han, in press). Moreover, the neural activity in the posterior cingulate cortex (PCC) positively correlated with subjective evaluations of the degree of physical risks. The higher subjective ratings of the physical risk degree, the greater activations were observed in this brain region. Thus the current study tested if, compared with processing of personal risks, identification of environmental risks may enhance neural activities in brain regions such as vACC and PCC since environmental risks induce higher dread than personal risks (Slovic, 1987).

2. Materials and methods

2.1. Subjects

Seventeen undergraduate and graduate students (7 males and 10 females) from Peking University participated in the ERP study. Three of the female subjects were excluded from data analysis because of excessive artifacts during EEG recording. The behavioral and EEG data were reported from 14 subjects (7 males and 7 females, aged between 20 and 29 years, mean age ± S.D. = 24.64 ± 2.68, values are given as mean ± S.D. throughout). An independent group of 14 undergraduate and graduate students (7 males and 7 females, 19–25 years of age, mean age ± S.D. = 22.79 ± 1.58) from Peking University participated in the fMRI study as paid volunteers. All subjects were paid for their participation. All were right-handed, had normal or corrected-to-normal vision, and had no neurological or psychiatric history. Subjects gave informed consent prior to the study. This study was approved by a Local Ethic Committee at the Department of Psychology, Peking University.

2.2. Stimuli

The stimuli were Chinese words or phrases (each consisting of two to four Chinese characters), which described either a potentially risky or a safe event that may occur in everyday life. Each stimulus subtended a visual angle of $1.28^\circ \times 0.51^\circ \sim 2.61^\circ \times 0.51^\circ$ (2.0 cm × 0.8 cm ∼ 4.1 cm × 0.8 cm, width × height) at a viewing distance of 90 cm. 52 phrases describing risky environmental events and 52 phrases describing safe environmental events were selected for initial screening procedure. Environmental risky events refer to those that may produce catastrophic consequences to the health and living conditions of human beings and animals in a local area or around the world, such as “tsunami”, “earthquake”, “nuclear warfare”, “volcanic eruption” or “air pollution”. Safe environmental events refer to those that would not induce damage to the health and living conditions of people, such as “appropriate rainfall”, “virescence”, “railway construction”, “using solar energy”, or “recycling garbage”. There were also 52 words or phrases describing potentially risky personal events and 52 words or phrases describing safe personal events. Risky personal events refer to those that would bring harmful consequences (e.g., physical injury or health problems) to an individual, such as “smoking”, “taking in heroin”, “bungee jumping”, “surfing” or “swimming in the ocean”. Safe personal events refer to those that would not induce potential physical injury or health problems, such as “playing piano”, “reading”, “jogging”, “watching cinema” or “wearing sunglasses”. Some of the risky environmental and personal events were derived from the materials used by Slovic (1987) and Weber et al. (2002). The length of stimuli was balanced among each stimuli category. The same stimuli and stimulus duration were used in both the ERP and fMRI experiments.

The risk degree of each word/phrase describing potentially risky/safe environmental/personal event was initially rated by an independent group of 11 subjects using a seven-point Likert scale (0 = safe, 6 = extremely risky). Based on this initial screening procedure, we selected subsets of the stimulus items (40 words or phrases for each category) for the ERP and fMRI study, which were further rated by an independent group of 24 subjects. Paired t-test on rating scores from these subjects showed that rating scores were higher for environmental than personal items (risky events: 3.60 ± 0.48 vs. 2.84 ± 0.57, $t(23) = 11.81$, $p < 0.001$; safe events:

0.59 ± 0.44 vs. 0.38 ± 0.35, $t(23) = 4.27$, $p < 0.001$). The coefficient alpha values were calculated to assess the internal consistency of the items within each stimulus category. The coefficient alpha was 0.95 and 0.94 for the risky and safe environmental items, respectively, and 0.96 and 0.95 for the risky and safe personal items, respectively.

2.3. ERP experiment

2.3.1. Procedure

Each subject participated in eight blocks of trials, in which the stimuli and tasks varied. In each two blocks of trials, subjects either (1) were presented with words/phrases depicting environmental events (half safe and half risky) and were asked to judge risky vs. safe environmental events (environmental risk identification task); (2) were presented with half words/phrases depicting environmental events and half pseudo words/phrases, and were asked to judge real vs. pseudo words/phrases (semantic control task); (3) were presented with words/phrases depicting personal events (half safe and half risky) and were asked to judge risky vs. safe personal events (personal risk identification task); or (4) were presented with half words/phrases depicting personal events and half pseudo words/phrases, and were asked to judge real vs. pseudo words/phrases (semantic control task).[1] Subject pressed one of the two buttons to indicate risky/safe in the risk identification task or real/pseudo words/phrases in the control task using the index or middle finger. The responding hand corresponding to 'yes' and 'no' responses was counterbalanced across subjects. Each block of trials began with the presentation of instructions for 2000 ms, which defined the task (i.e., risk identification or semantic control tasks) for each block. There were 80 trials in each block. On each trial a word/phrase was

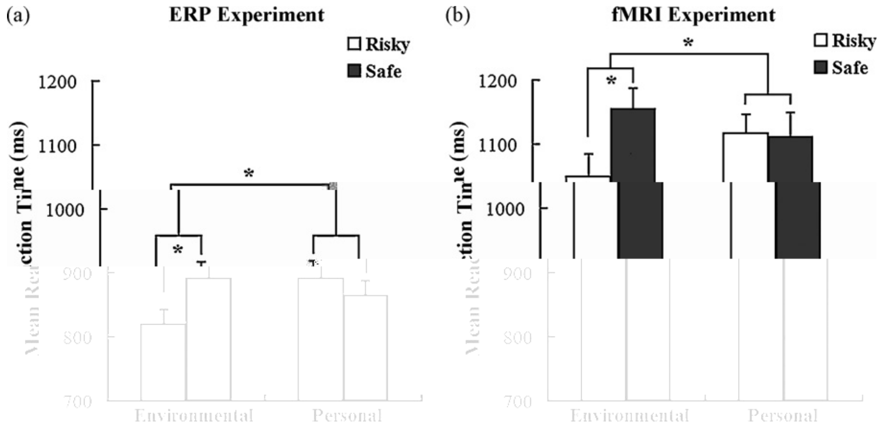

Fig. 1. Mean reaction times to risky and safe environmental and personal items in (a) ERP and (b) fMRI experiments. Error bars indicate standard errors of the mean.

from each individual participant to allow population inference. Areas of significant activation were identified at the voxel level for values exceeding an uncorrected *p*-value of 0.0005, voxel number >50. MNI coordinates were reported in the current work.

To exclude the effect of task and search for the specific activations linked to environmental and personal risks, we conducted the exclusive masking analysis that

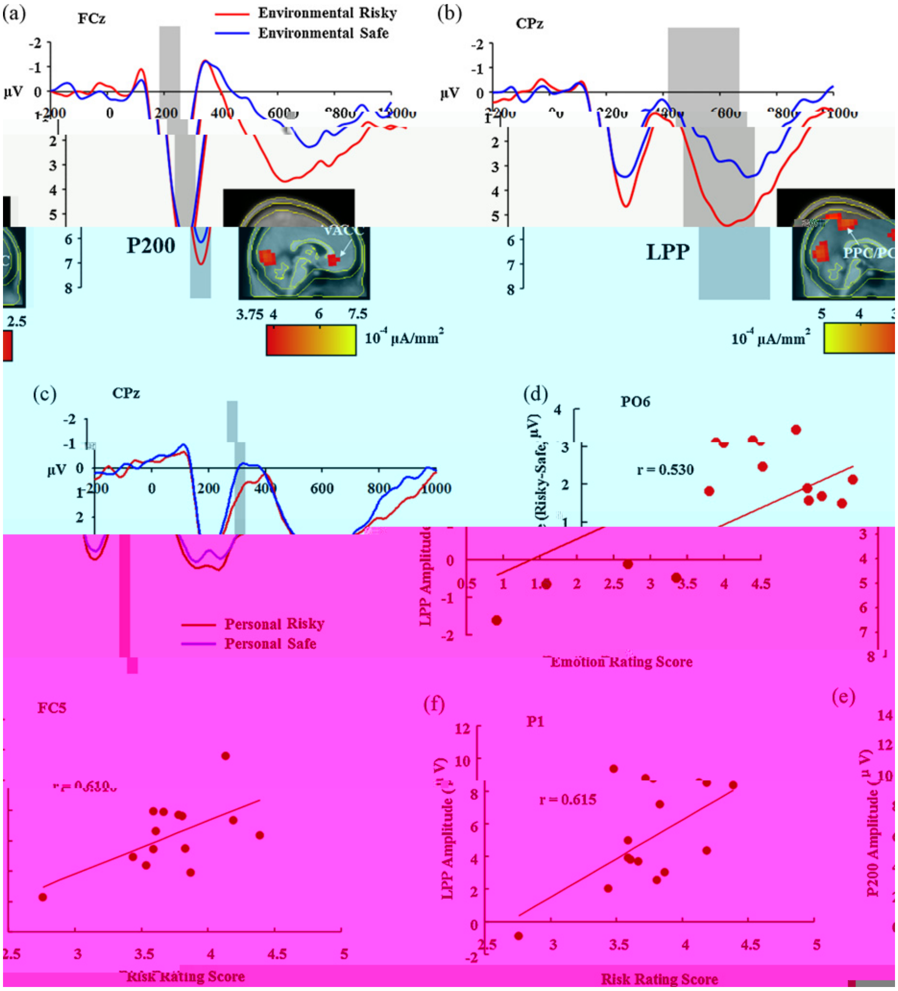

Fig. 2. ERP results in the environmental and personal risk identification tasks. (a) P200 associated with risky environmental events relative to safe ones and its representative current sources identified in the vACC and medial occipital cortex at 228 ms; (b) LPP associated with risky environmental events relative to safe ones and its representative current sources identified in the PPC and PCC at 560 ms; (c) ERPs recorded at CPz differentiated between risky and safe personal events at 280–320 ms after stimulus delivery; (d) correlation between the difference of LPP amplitudes between risky and safe environmental events and the corresponding subjective rating scores of emotional impact; (e) correlation between the P200 amplitudes evoked by risky environmental events and the corresponding subjective rating scores of risk degree; (f) correlation between the LPP amplitudes evoked by risky environmental events and the corresponding subjective rating scores of risk degree. The mean rating score and ERP amplitude of each subject are indicated by a single disk. The lines represent the linear best fit; r refers to the correlation coefficient. LPP: late positive potential; PPC: posterior parietal cortex; PCC: posterior cingulate cortex; vACC: ventral anterior cingulate cortex.

eralized processing of negative information (Anderson et al., 2003; Cunningham, Espinet, DeYoung, & Zelazo, 2005).

The current sources of the P200 and LPP were estimated using LORETA. We found that two current sources, one located at the vACC and one at the medial occipital cortex (Fig. 2a), were able to account for over 90% of the variance of the topography at the time window corresponding to the P200. At a latter time window corresponding to the LPP, the LORETA analysis showed an additional current source at the posterior parietal cortex and the PCC (Fig. 2b).

To assess whether the ERP effects were specific to the identification of environmental risks, the ERPs to personal items were analyzed similarly. Relative to safe personal items, risky personal items elicited a positive shift of ERPs at 280–320 ms, resulting in significant main effects of Valence over frontal–central (F3–F4: $F(1, 13) = 6.28$, $p < 0.05$; FC3–FC4: $F(1, 13) = 8.76$, $p < 0.05$; C3–C4: $F(1, 13) = 6.98$, $p < 0.05$; Fig. 2) and central–parietal electrodes (CP3–CP4: $F(1, 13) = 6.67$, $p < 0.05$; P3–P4: $F(1, 13) = 8.45$, $p < 0.05$, Fig. 2c). However, neither the P200 nor the LPP was modulated by stimulus valence of personal items ($p > 0.05$). This was further confirmed by the significant interaction of Risk × Valence at 200–220 ms over frontal–central areas (FC3–FC4: $F(1, 13) = 5.52$, $p < 0.05$; C3–C4: $F(1, 13) = 6.74$, $p < 0.05$) and at 460–580 ms over central–parietal areas (CP3–CP4: $F(1, 13) = 7.62$, $p < 0.05$; P3–P4: $F(1, 13) = 5.37$, $p < 0.05$).

To evaluate to what degree the ERP effects linked to identification of environmental risks could predict subjective ratings of risky events, we calculated the correlation between subjective ratings and the magnitudes of the ERP effect. We found marginally significant correlation between the emotional rating scores of risky environmental items and the differential ERP amplitudes to risky and safe environmental items recorded at the parietal electrodes at 540–580 ms (P6: $r = 0.530$, $p = 0.051$; P4: $r = 0.515$, $p = 0.06$; PO6: $r = 0.519$, $p = 0.057$, Fig. 2d). In addition, the mean ERP amplitudes associated with the risky environmental items recorded at frontal–central electrodes at 200–240 ms positively correlated with the risk rating scores of risky environmental items (FC5: $r = 0.610$, $p < 0.05$; FC3: $r = 0.541$, $p < 0.05$; FC2: $r = 0.538$, $p < 0.05$, Fig. 2e). The mean ERP amplitudes linked to risky environmental items recorded at the parietal electrodes at 580–620 ms also positively correlated with the risk rating scores of risky environmental items

Table 1
Brain activations associated with risky items relative to safe items

Brain region	BA	X	Y	Z	Z-Value	Voxel no.
Environmental$_{\text{risky}}$ > environmental$_{\text{safe}}$						
Posterior cingulate gyrus/precuneus	BA31/5/7	−4	−40	38	4.94	1889
Ventral anterior cingulate	BA10/32	−2	52	−2	3.44	176
Personal$_{\text{risky}}$ > personal$_{\text{safe}}$						
Inferior frontal gyrus (L)/insula (L)	BA13/45	−40	24	8	3.43	166
Medial frontal gyrus (L)	BA9/10	−18	54	20	3.83	154

BA: Brodmann area; R: right hemisphere; L: left hemisphere; cluster survived under voxel-level uncorrected p-value of 0.0005, voxel number >50.

(P1: $r = 0.615$, $p < 0.05$; PO3: $r = 0.546$, $p < 0.05$; PZ: $r = 0.545$, $p < 0.05$, Fig. 2f).

3.3. fMRI results

Our ERP results suggest that two neural structures, i.e., vACC and PCC, may be engaged in the identification of environmental risks. To further localize the neural substrates differentiating between risky and safe environmental events, we conducted a whole-brain statistical parametric mapping (SPM) analysis to contrast risky and safe items correctly identified by the subjects inside the scanner. Relative to safe environmental events, risky environmental events induced increased activations in the PCC and vACC (Table 1; Fig. 3a). The time courses (hemodynamic responses) within the PCC and vACC for risky and safe environmental items were computed and illustrated in Fig. 3b. Similar analysis of the fMRI data associated with risky and safe personal events showed increased activation in the left inferior frontal gyrus/insula and MPFC (Table 1; Fig. 3c).

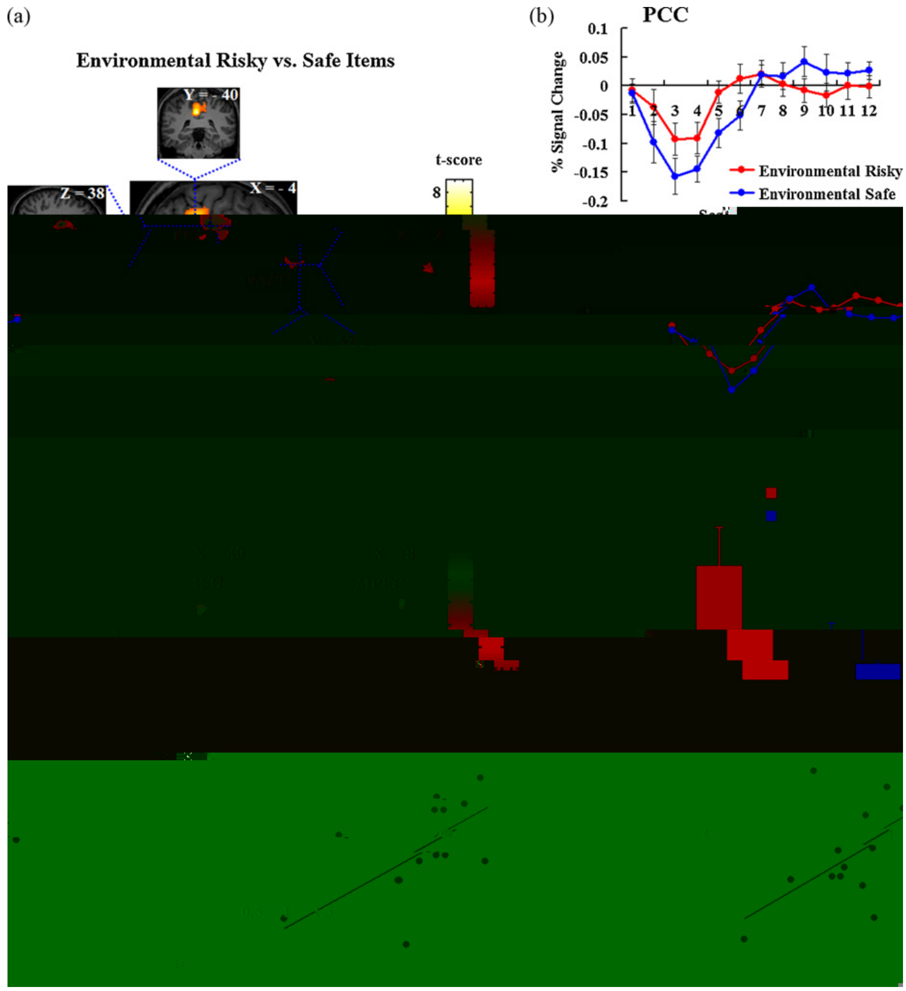

Fig. 3. fMRI results in the environmental and personal risk identification tasks. (a) Increased brain activations associated with risky environmental events relative to safe environmental events; (b) time courses (hemodynamic responses) were computed for each condition within PCC and vACC identified from the contrast of risky vs. safe environmental events, bars indicate standard error of the mean; (c) increased brain activations associated with risky personal events relative to safe personal events; (d) percent signal changes in the PCC differentiating identification of risky environmental (or personal) items relative to safe environmental (or personal) items, bars indicate standard error of the mean; (e) correlation between the percent signal changes observed within the PCC related to risky relative to safe environmental events and the corresponding subjective rating scores of emotional impact; (f) correlation between the percent signal changes observed within the PCC related to risky environmental events and the corresponding subjective rating scores of risk degree. The mean rating score and fMRI signal change of each subject are indicated by a single disk. The lines represent the linear best fit; r refers to the correlation coefficient. PCC: posterior cingulate cortex; vACC: ventral anterior cingulate cortex; IFG: inferior frontal cortex; MPFC: medial prefrontal cortex.

In addition, we exclusively masked the contrast of risky vs. safe environmental items with the contrast of environmental vs. personal items and found increased PCC/precuneus activation ($x = -4/y = -32/z = 52$, $Z = 4.50$, cluster size = 1018 voxel). However, masking the contrast of risky vs. safe personal items with the contrast of personal vs. environmental items failed to show any activation. Moreover, we conducted ROI analysis by calculating percent signal changes in the PCC and vACC (defined by the mean percent signal changes of two successive time points around the peak of the BOLD signals extracted from the PCC and vACC clusters). We found that a marginally significant interaction of Risk × Valence for the PCC activity ($F(1, 13) = 4.303$, $p = 0.058$, Fig. 3d) and the vACC activity ($F(1, 13) = 3.302$, $p = 0.092$).

Similarly, we calculated the correlation between subjective rating scores of the risky environmental events and the magnitude of the neural activities associated with identification of risky environmental events (defined by the mean percent signal changes of two successive time points around the peak of the BOLD signals extracted from the PCC and vACC clusters). Interestingly, we found that the difference in PCC activity between risky and safe environmental events positively correlated with the emotional rating scores of the risky environmental events ($r = 0.665$, $p < 0.05$, Fig. 3e). In addition, the PCC activity elicited by risky environmental events positively correlated with the risk rating scores of the risky environmental events ($r = 0.601$, $p < 0.05$, Fig. 3f).

4. Discussion

The current work combined ERP and fMRI to assess neurocognitive mechanisms underlying the identification of environmental and personal risks depicted in words or phrases. Our ERP results first showed evidence that the identification of environmental risks induced modulation of the neural activities at two successive time windows. Both the early P200 with maximum amplitudes over the frontal–central cortex and the following LPP with a central–parietal scalp distribution were enlarged by the identification of risky relative to safe environmental events. In addition, the P200 and LPP amplitudes positively correlated with subjective ratings of risky environmental events. Consistent with the ERP results, our fMRI results showed evidence that two distinct brain areas subserved the identification of environmental risks because risky environmental events generated increased brain activations in the vACC and PCC relative to safe environmental events. In addition, the PCC activity elicited by risky environmental events was positively correlated with subjective ratings of risky environmental events. Interestingly, all the neural activities associated with the identification of environmental risks were not observed in the identification of personal risks.

The P200 modulation by environmental risk identification reflected an initial neural differentiation between risky and safe environmental events. The P200 was localized to the vACC in the current source analysis, which was reinforced by our fMRI results. Previous ERP studies have shown that the P200 was associated with detection of threats such as fearful faces (Correll, Urland, & Ito, 2006; Thomas, Johnstone, & Gonsalvez, 2007). fMRI research also found that vACC was associated with the processing of emotional distrators and involved in resolving emotionally laden conflict (Vuilleumier, Armony, Driver, & Dolan, 2001; Whalen et al., 1998) and was activated by the presence of infrequent threat-related distrators such as fearful faces (Bishop, Duncan, Brett, & Lawrence, 2004). These findings suggest that vACC plays a key role in monitoring emotion-related conflict between the functional state of the organism and any new information that has potential affective or motivational consequences (Dalgleish, 2004). Although the environmental risks were depicted in words or phrases in our study, the detection of threat generated by risky environmental events may occur as early as the detection of threat shown in images. We suggest that the P200 and vACC activation observed in our study subserve an early detection of environmental risks by monitoring of the conflict between affective consequences of risky environmental events and the survival of a population. In addition, because vACC activity is involved in the processing of all types of emotional stimuli (Bush, Luu, & Posner, 2000; Phan, Wager, Taylor, & Liberzon, 2002) and can be enhanced when anticipating painful stimuli (Ploghaus, Becerra, Borras, & Borsook, 2003) or aversive pictures (Nitschke, Sarinopoulos, Mackiewicz, Schaefer, & Davidson, 2006), it may be proposed that early detection of environmental risks is accompanied with emotional response. These neural activities, to a certain degree, contributed to the subjective ratings of environmental risk degree because the P200 amplitude correlated with the risk rating scores of risky environmental events.

In a latter time window, we found that identification of risky environmental events invoked enlarged centro-parietal LPP. The current source analysis indicates that the LPP originated from the PCC. The PCC activation was further supported by the fMRI results. Previous research has shown evidence that the LPP is an index of evaluation process of emotional stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2000; Schupp, Junghöfer, Weike, & Hamm, 2003, 2004). It has been suggested that increased PCC activity mediates the evaluation of emotional stimuli and reflects the interaction between memory retrieval and emotion (Maddock, 1999; Maddock, Garrett, & Buonocore, 2003). Comparing with safe environmental events, identification of risky environmental events may induce enhanced retrieval of previous self-related emotional experience. The correlation analysis indicates that the LPP and PCC activity also contributed to subjective ratings of risky environmental events. The more emotional experiences are retrieved, the greater the risk degree and the emotional impact would be given to the risky environmental event. Taken these with the earlier activities, our ERP and fMRI results consistently support that the identification of environmental risks is underpinned by an early detection process and a late process of emotional experiences retrieval. There has been increasing evidence that the cortical midline structures such as PCC and vACC are involved in self-referential processing such as self-experience based memory retrieval (Fossati et al., 2003; Johnson et al., 2002) and self trait judgment (Han et al., 2008; Kelley et al., 2002; Zhu, Zhang, Fan, & Han, 2007; also see Northoff et al., 2006 for review). As most evaluative judgments are self-referential (Zysset, Huber, Ferstl, & von Cramon, 2002), it is not surprising that the neural activations observed in our current work overlapped with the cortical midline structures that were demonstrated to engage in self-related processing.

In addition, our results indicate that the identification of dreadful environmental risks depicted in words is different from the detection of evolutionary prepared threats to individuals (e.g., angry fearful faces, snakes, or spiders), because threats to individuals usually induce activation in subcortical structure such as amygdala (Carlsson et al., 2004; Carretié, Hinojosa, Mercado, & Tapia, 2005; Morris et al., 1996; Pissiota et al., 2003). This further suggests that cognitive processing of consequences associated with risky environmental events rather than salient emotional responses such as fear subserves identification of environmental risks depicted in words or phrases. A recent fMRI study investigated the neurobiological substrates of dread using delay-conditioning paradigm and found the subjective experience of dread comes from the attention devoted to the expected physical response (SI, SII, the caudal ACC, and the posterior insula) and not simply a fear or anxiety response (Berns et al., 2006). Similar to this, our results suggest that the identification of the dread depicted in words may require cognitive processes such as detection and retrieval rather than pure emotional response.

Are the neurocognitive processes of environmental risks different from the identification of signals that indicate negative utility? Utility is computed as the product of the value and probability of each potential outcome (Kahneman & Tversky, 1979; von Neumann & Morgenstern, 1947), and the neural mechanisms underlying the processing of utility has been studied extensively (Sanfey et al., 2006). Specifically, negative utility results in increases in ACC activity that correlates with the magnitude of anticipated consequences (Gehring & Willoughby, 2002; Yeung & Sanfey, 2004). The vACC activation associated with environmental risks observed in the current work suggests an important role of ACC in detection of negative utility in different domains such as environmental and financial. However, the identification of environmental risks is also characterized with increased PCC activity, which has not been observed in association with negative utility in the previous neuroeconomic studies. The PCC activity reveals the unique function of retrieval of previous emotional experiences in the process of environmental risks depicted in words, which may not be required for evaluation of instantaneous outcome when making economic decisions. Moreover, our results suggest that the probability of risky events might be neglected during the identification of environmental risks, because the neural activities associated with processing of probability, such as prefrontal cortex (Casey et al., 2001; Huettel et al., 2005; Longe et al., 2001), were not observed in our results.

Most importantly, our ERP and fMRI results failed to find evidence for modulations of the P200/LPP and vACC/PCC by stimulus valence of personal risks. The results of identification of personal risks rule out the possibility that ERP and fMRI results linked to identification of environmental risks arose from the specific task utilized in the current study. Moreover, the results indicate that the neural processes such as early detection and late emotional experiences retrieval may be specific to the identification of environmental risks, as indexed by the P200/vACC effects and the LPP/PCC effects. This could be due to that environmental risks can lead to more serious catastrophic consequences and stronger emotional reactions relative to personal risks. The enhanced PCC activation and LPP amplitudes may also reflect ethical considerations involved in environmental risk identification since more ethical concerns may be involved in identification of risky environmental than risky personal events (Böhm, 2003; Böhm & Pfister, 2000). This should be assessed in future work.

Together with our previous fMRI study (Qin & Han, in press), the current ERP and fMRI findings provide further evidence for domain specific neurocognitive processes in risk perception. Our previous fMRI study found distinct neural mechanisms underlying social and physical risk identifications and thus provided neural bases for the categorization of personal risks into social and physical domains (Qin & Han, in press). The findings of the current study indicate the existence of distinct neural and cognitive mechanisms underlying identification of risks in environmental and personal domains, providing neuroimaging evidence for the categorization of risks into environmental and personal risks (Gattig & Hendrickx, 2007; Schütz et al., 2000). Both our previous (Qin & Han, in press) and the current work found increased MPFC activation to risky than safe personal events, suggesting that the MPFC mediates intensive evaluation of stimulus valence in terms of the safety of human behaviors. However, the vACC and PCC activity was increased to risky than safe personal physical events in the previous work (Qin & Han, in press) but not the in the current study. A key difference between the two studies is that the personal physical risk identification task was intermixed with the identification of personal social risks assigned with lower rating scores in the previous work but with the identification of environmental risks assigned with higher rating scores in the current work. Apparently, the relative risk salience of personal physical events was lower in the current than previous studies although the risky and safe items were similar in the two studies. It appears the neural substrates underlying risk identification are not only domain specific but are modulated by the context in which the risks were identified as well.

In conclusion, our ERP and fMRI results provide consistent evidence that the identification of environmental risks consists of an early detection process mediated by vACC and a late process of retrieval of emotional experiences subserved by PCC. These neurocognitive processes are more salient for the identification of environmental risks in comparison with that of personal risks. These results indicate that the neural substrates of environmental risk identification are different from those of personal risk identification and possibly reflecting the consequences of evolution on human risk processing. It should be noted that ethnic cultural and socioeconomic background (Vaughan & Nordenstam, 1991) and personal variables such as profession (Barke, Jenkins-Smith, & Slovic, 1997; Slovic, 1987) affect risk perception. As our study only recruited college students, future research should investigate whether the neurocognitive processes identified in the current work could be modulated by individual knowledge of risks in specific fields.

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