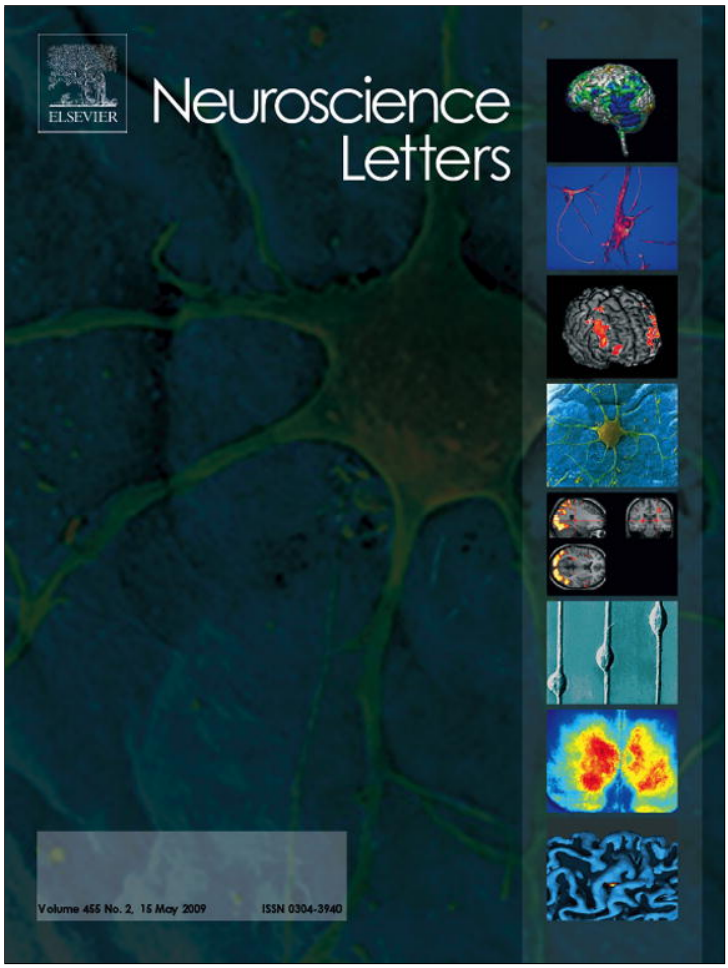
Provided for non-commercial research and education use.
Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright

Author's personal copy

Neuroscience Letters 455 (2009) 110–115

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Neural activities underlying environmental and personal risk identification tasks

Jungang Qin[a], Tatia M.C. Lee[b,c], Fan Wang[a], Lihua Mao[a], Shihui Han[a,*]

[a] Department of Psychology, Peking University, 5 Yiheyuan Road, Beijing, 100871, PR China
[b] Laboratory of Neuropsychology, The University of Hong Kong, Hong Kong, PR China
[c] Laboratory of Cognitive Affective Neuroscience, The University of Hong Kong, Hong Kong, PR China

ARTICLE INFO

Article history:
Received 18 November 2008
Received in revised form 16 February 2009
Accepted 3 March 2009

Keywords:
ERP
fMRI
Risk
Cingulate
Late positive potential

ABSTRACT

The present study examined domain specific neural activities associated with the identification of environmental and personal risks. We recorded neural activities from subjects, using functional magnetic resonance imaging and event-related brain potential, when they identified risky and safe environmental and personal events. We found that, relative to the semantic control task, both environmental and personal risk identification tasks were associated with increased sustained activities in the medial frontal and supramarginal gyrus. Moreover, relative to the personal risk identification task, the environmental risk identification task resulted in greater transient activity in the posterior cingulate cortex and precuneus. ERPs recorded over the parietal area associated with the environmental risk identification task occurred earlier than that linked to the personal risk identification task. Our findings suggest that the extent of involvement and temporal courses of retrieval of emotional experiences may distinguish between the environmental and personal risk identification tasks.

© 2009 Elsevier Ireland Ltd. All rights reserved.

Risk perception is an important prerequisite for decision making in everyday life. The underlying neural mechanisms, however, remain unresolved. Recent neuroimaging studies have investigated neural substrates underlying risk assessment/estimation during risk decision making. It has been shown that increased activations in the insula, the medial prefrontal cortex (MPFC), and the anterior cingulate cortex (ACC) were involved in the assessment and action selection during the Rock Paper Scissors computer game [17]. The activities in the orbitofrontal cortex, ACC and dorsolateral prefrontal cortex also engaged in risk estimation in a gambling task [26]. Others investigated the neural substrates associated with risk perception by comparing a risk rating task with a letter detection task [27] and found increased activity in the MPFC, left inferior frontal gyrus, cerebellum, and left amgydala in association with risk rating.

As psychometric research has categorized risks into different domains (e.g., social and physical [28]), our recent work examined whether distinct neural mechanisms are involved in the identification of risks in different domains [18]. We found that, relative to an autobiographical control task, the social risk identification task induced increased activities in the MPFC, the dorsal ACC, and bilateral posterior insula, whereas the physical risk identification task resulted in activations in the right cuneus/precuneus and bilateral amygdala [18]. Our results suggest that both cognitive processes and emotional responses are involved to differentiate between social and physical risk identification tasks, providing neuroimaging evidence for the view that risk perception is domain specific [28].

Psychometric studies also suggest domain specific perception of environmental and personal risks in that the former induce more serious damages to a large population and are more dreadful because of their uncontrollability and global catastrophic consequences [23]. In accord with the psychometric research, our recent neuroimaging studies found distinct neural substrates underlying the identification of environmental and personal risks, i.e., the former was characterized by increased activations in the ventral anterior cingulate cortex and posterior cingulate cortex whereas the latter was linked to increased activities in the left inferior and medial prefrontal cortex [19]. The current work further assessed whether distinct neural processes were associated with the tasks to identify environmental or personal risks. We had subjects identify risky and safe environmental/personal events depicted in words or phrases or identify real or pseudo words/phrases to control for semantic processing and response selection/execution. Neural activities in association with the risk identification task and the control task were recorded using functional magnetic resonance imaging (fMRI) and event-related potentials (ERPs). The fMRI experiment adopted a mixed design [6] in order to isolate the neural activities related to the ongoing task demands (sustained activities) and the trial-specific processes (transient activities) involved in environmental and personal risk identification tasks. The ERP measurement examined the time courses of the neurocognitive

* Corresponding author. Tel.: +86 10 6275 9138; fax: +86 10 6276 1081.
E-mail address: shan@pku.edu.cn (S. Han).

0304-3940/$ – see front matter © 2009 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.neulet.2009.03.008

Author's personal copy

processes involved in environmental and personal risk identification tasks.

Fourteen healthy adults (seven males, 19–25 years of age, mean ± SD = 22.8 ± 1.58) participated in the fMRI experiment. An independent group of fourteen healthy adults (seven males, 20–29 years of age, mean ± SD = 24.6 ± 2.68) participated in the ERP experiment. All were undergraduate or graduate students from Peking University in Beijing, China. All were right-handed and had normal or corrected-to-normal vision. Subjects gave informed consent prior to the study. This study was approved by a local ethics committee. Both fMRI and ERP data were collected in Beijing in 2007.

The stimuli were Chinese words or phrases (each consisting of 2–4 Chinese characters), which described potentially risky or safe events. There are 40 phrases describing risky environmental events (i.e., "tsunami", "earthquake"), 40 phrases describing safe environmental events (i.e., "appropriate rainfall", "tree planting"), 40 phrases describing risky personal events (i.e., "smoking", "bungee jumping"), and 40 words or phrases describing safe personal events (i.e., "playing piano", "reading"). Each stimulus subtended a visual angle of $1.28^\circ \times 0.51^\circ$–$2.61^\circ \times 0.51^\circ$ (width × height) at a viewing distance of 90 cm.

The fMRI experiment consisted of four functional scans. Each scan consisted of eight sessions. Each session began with the presentation of an instruction for 2.0 s, which defined the task (i.e., risk identification or semantic control tasks). Subjects pressed one of the two buttons to indicate risky/safe events in a risk identification task or real/pseudo words/phrases in the control task (half words/phrases depicting environmental events and half pseudo words/phrases) using the right index or middle finger. Each session consisted of five risky and five safe events or five real and five pseudo words/phrases. Each item was presented for 1.5 s followed by an interstimulus interval that varied randomly among 0.5, 1.0, 1.5, 2.0 and 2.5 s. Two adjacent sessions were intervened with a fixation of 8.0 s. The order of risk identification and semantic control tasks was counterbalanced using the Latin-square design.

The scanning was performed on a 3-T Siemens Trio system using a standard head coil. Thirty-two transversal slices of functional images that covered the whole brain were acquired using a gradient-echo echo-planar pulse sequence ($64 \times 64 \times 32$ matrix with 3.4 mm × 3.4 mm × 4.4 mm spatial resolution, TR = 2000 ms, TE = 30 ms, FOV = 220 mm, flip angle = 90°). Anatomical images were obtained using a standard 3D T1-weighted sequence ($256 \times 256 \times 176$ matrix with 0.938 mm × 0.938 mm × 1.3 mm spatial resolution, TR = 1600 ms, TE = 3.93 ms). SPM2 (Wellcome Department of Cognitive Neurology, London, UK) was used for imaging data processing and analysis. The preprocessing and most second-level analysis procedure is identical to our previous study [18]. Main differences between these are the construction of design matrix. Specifically, a general linear model (GLM, $y = \beta x + \varepsilon$, where the response y is equal to a linear sum of weighted (β) variables (x) plus an error or residual value (ε)) was used to construct the multiple time series regression design matrix, which included weighted parameter estimates (βx) for both the event-related and block-based components of the design and a common error term (ε) and the head motion parameters for capturing residual movement related artifacts (the three rigid-body translations and rotations determined from the realignment stage). To identify sustained activities of each task, positive or negative contrasts were applied to the parameter estimates for each block-based component and zero weights were applied to all parameter estimates of the event-related component; to identify transient activities for all tasks, positive or negative contrasts were applied to the event-related parameter estimates with zero weights being applied to the block-based parameter estimates. Random effect analyses were conducted based on statistical parameter maps from each individual participant to allow population inference. Areas of significant activation were identified at the cluster level for values exceeding a p-value of 0.05 (corrected for multiple comparisons). To confirm possible different activities associated with environmental and personal risk identification tasks, we calculated the percent signal change in the regions of interests (ROIs) defined as spheres (7 mm diameter) around the peak voxel of specific activated brain areas identified in the contrast of environmental risk identification versus semantic task in the random effect analysis for both environmental and personal conditions. The results were then subjected to repeated analysis of variance (ANOVAs) with Risk (environmental vs. personal) and Task (risk identification vs. semantic) as independent variables. The percent signal change was calculated using MarsBaR 0.38 (http://marsbar.sourceforge.net).

The same stimuli and tasks were used in the ERP experiment. Each subject conducted eight blocks of trials (two blocks for each stimulus condition). Each block began with the presentation of instructions for 2.0 s, which defined the task (i.e., risk identification or semantic control task). There were 80 trials in each block. On each trial a word/phrase was presented for 1500 ms at the centre of a screen, which was followed by a fixation cross with a duration varying randomly between 800 and 1200 ms. The stimuli in each block of trials were presented in a random order and the order of risk identification and semantic control tasks was counterbalanced.

The electroencephalogram (EEG) was continuously recorded from 60 scalp electrodes. The electrodes at the right mastoid were used as reference. Eye blinks and vertical eye movement were monitored with electrodes located above and below the left eye. The horizontal electro-oculogram was recorded from electrodes placed 1.5 cm lateral to the left and right external canthi. The electrode impedance was kept less than 5 kΩ. The EEG was amplified (band pass 0.01–100 Hz) and digitized at a sampling rate of 250 Hz. The ERPs in each condition were averaged separately offline with an epoch beginning 200 ms before stimulus onset and continuing for 1000 ms. Trials contaminated by eye blinks, eye movements, or muscle potentials exceeding ±50 μV at any electrode were excluded from the average. ERPs at each electrode were re-referenced to the algebraically computed average of the left and right mastoids before further analysis. The baseline for ERP measurements was the mean voltage of a 200 ms pre-stimulus interval and the latency was measured relative to the stimulus onset. Statistical analysis of the mean ERP amplitudes were conducted at midline single electrode or each pairs of electrodes selected from the anterior frontal (AF3-AF4, AF7-AF8), frontal (Fz, F3-F4), frontal-central (FCz, FC3-FC4), central (Cz, C3-C4), central-parietal (CPz, CP3-CP4), parietal (Pz, P3-P4), temporal (T7-T8, TP7-TP8, P7-P8), parieta-occipital (POz, Oz, PO3-PO4) regions. The mean ERP amplitudes were subjected to repeated measure analysis (ANOVAs) with Task (risk identification vs. semantic) and Hemisphere (electrodes over the left or right hemisphere) as within-subjects independent variables.

Percent agreement with ours ex-ante classification to the risky and safe environmental and personal events were over 84.0% and 88.0% in the fMRI and ERP experiments, respectively. Response accuracy to the identification of real and pseudo words were over 80.0% and 86.0% in the fMRI and ERP experiments, respectively. ANOVAs of reaction times (RTs) in the fMRI experiment confirmed faster responses to the phrases depicting environmental than personal events (1111 vs. 1145 ms, $F(1,13) = 8.19$, $p < 0.05$) and to the risk identification than the control tasks (1108 vs. 1149 ms, $F(1,13) = 6.36$, $p < 0.05$). As there was a significant interaction of Risk × Task ($F(1,13) = 6.38$, $p < 0.05$), post-hoc analyses were conducted. RTs were shorter in the environmental risk identification task than in the semantic control task ($t(13) = 3.303$, $p < 0.05$) but did not differ between the personal risk identification and the control tasks ($t(13) = 1.405$, $p > 0.05$). Similarly, responses recorded in the ERP experiment were faster to the phrases depicting environ-

Author's personal copy

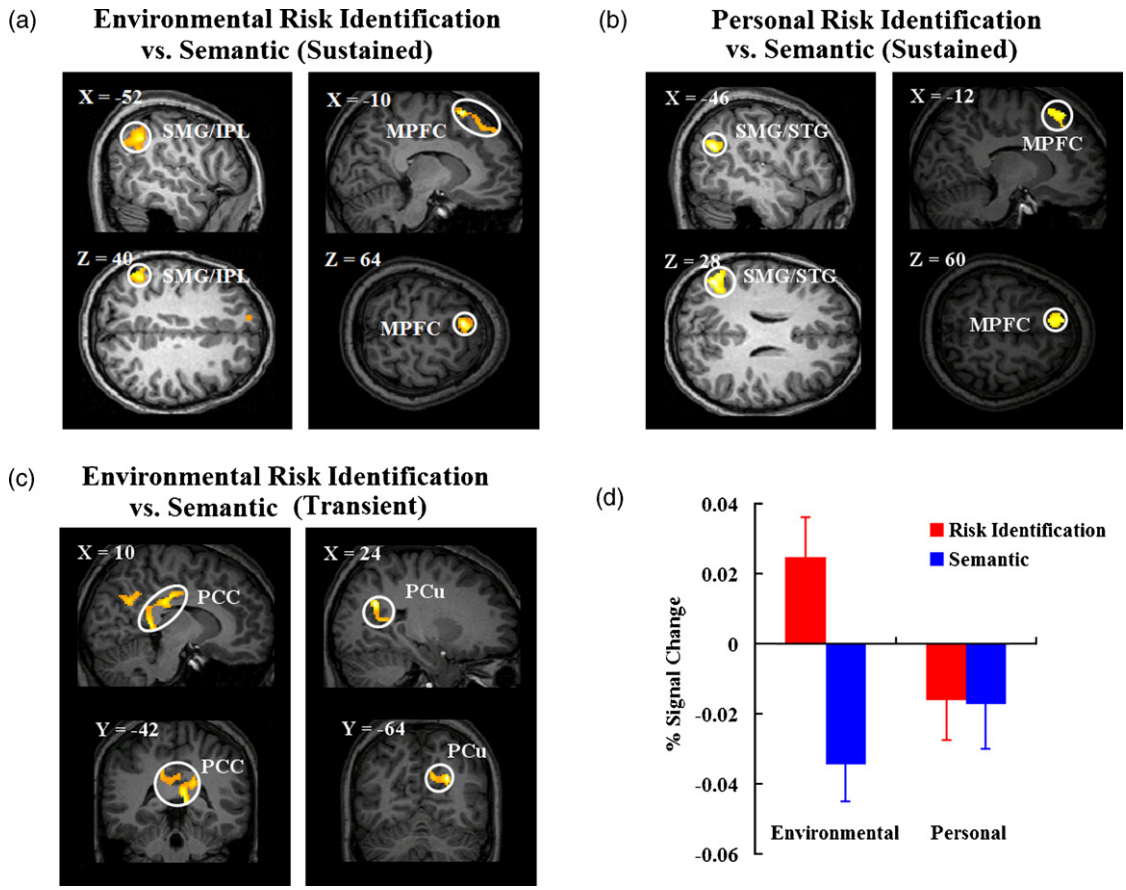


Fig. 1. fMRI results associated with risk identification tasks. (a) Sustained activities shown in the contrast of the environmental risk identification task versus the semantic task. (b) Sustained activities shown in the contrast of the personal risk identification task versus the semantic task. (c) Transient activities shown in the contrast of the environmental risk identification task versus the semantic task. (d) Percent signal changes of the ROI in the PCC linked to environmental and personal items during the risk identification and semantic tasks. Bars indicate standard error of the mean. SMG = supramarginal gyrus; IPL = inferior parietal lobules; MPFC = medial prefrontal cortex; STG = superior temporal gyrus; PCC = posterior cingulate cortex; PCu = precuneus.

mental than personal events (902 vs. 921 ms, $F(1,13) = 5.79$, $p < 0.05$) and were faster to the risk identification than the control tasks (867 vs. 956 ms, $F(1,13) = 7.65$, $p < 0.05$).

Analysis of the fMRI data showed that, relative to the semantic control task, the environmental risk identification task induced increased sustained activations in the left MPFC and supramarginal gyrus/inferior parietal lobule (SMG/IPL) (Fig. 1a, Table 1) and the personal risk identification task generated enhanced sustained activation in the left SMG/superior temporal gyrus (STG) (Fig. 1b). Increased transient neural activities related to the onset of individual items were observed in the right posterior cingulate (PCC) and precuneus in association with environmental risk identification task compared to the semantic control task (Fig. 1c). However, the contrast between the personal risk identification and semantic tasks failed to show any increased transient activation.

To further examine the difference between environmental and personal risk identification tasks, we conducted ROI analysis of percent signal changes in the MPFC but did not find significant difference in the MPFC activation between environmental and personal risk identification tasks ($F(1,13) = 2.82$, $p > 0.05$). However, similar ROI analysis confirmed the differential transient PCC and precuneus activity between the two risk identification tasks. Relative to the personal risk identification task, the environmental risk identification task produced greater signal intensity in the right PCC ($F(1,13) = 4.69$, $p < 0.05$; Fig. 1d) and the precuneus ($F(1,13) = 4.24$, $p = 0.06$).

Analysis of the ERP data showed that, relative to the semantic control task, the environmental risk identification task elicited early positive deflection at 260–300 ms over the central-parietal-occipital electrodes ($F(1,13) = 5.02$ to 20.85; $p < 0.05$). The late positive potentials (LPP) were also enlarged to the environmental risk identification task at 340–620 ms over the frontal-parietal-temporal electrodes ($F(1,13) = 5.79$–24.45, $p < 0.05$, Fig. 2a). ANOVAs also showed reliable interactions of Task × Hemisphere at 380–460 ms over the frontal-central ($F(1,13) = 5.53$–6.32, $p < 0.05$) and at 540–780 ms over the temporal-parietal-occipital electrodes ($F(1,13) = 6.19$–12.05, $p < 0.05$), suggesting that the difference in the anterior positivity between the environmental risk identification and semantic control tasks was larger over the right than over the left hemispheres whereas the difference in the LPP between the environmental risk identification and semantic control tasks was larger amplitudes over the left than over the right hemispheres.

Relative to the semantic control task, the personal risk identification task elicited enlarged LPP at 340–620 ms over the frontal-central-parietal electrodes ($F(1,13) = 5.81$–20.82, $p < 0.05$, Fig. 2b). Similarly, ANOVAs showed reliable interactions of Task × Hemisphere at 420–460 ms over the frontal area ($F(1,13) = 5.70$, $p < 0.05$) and at 580–780 ms over central-parietal-occipital areas ($F(1,13) = 6.80$–7.52, $p < 0.05$), suggesting that the difference in the anterior positivity between the personal risk identification and semantic tasks was larger over the right than over the left hemispheres whereas the difference in the LPP between the personal risk identification and semantic tasks was larger amplitudes over the left than over the right hemispheres.

Author's personal copy

Table 1
Sustained and transient activities associated with risk identification tasks.

Brain region	BA	*X*	*Y*	*Z*	*Z*-value	Voxel number
Sustained activities						
Environmental risk identification > semantic						
Supramarginal gyrus (L)/inferior parietal lobule (L)	BA40/39	−52	−52	40	3.85	456
Medial frontal gyrus (L)	BA8/6	−10	18	64	4.36	458
Personal risk identification > semantic						
Supramarginal gyrus (L)/superior temporal gyrus (L)		−48	−64	28	3.90	279
Medial frontal gyrus (L)	BA6/8	−12	36	60	3.36	223
Transient activities						
Environmental risk identification > semantic						
Posterior cingulate (R)	BA31	10	−42	10	3.59	663
Precuneus (R)		24	−64	30	4.21	344
Personal risk identification > semantic						
Null						

BA: Brodmann area; R: right hemisphere; L: left hemisphere; Voxels survived an uncorrected p-value of 0.005, cluster size > 30, $p < 0.05$ corrected (except for [−12 36 60], $p_{uncorrected} < 0.005$, voxel number > 50).

To further verify if specific ERPs were associated with the environmental risk identification task, the mean ERP amplitudes were subjected to ANOVAs with Risk, Task, and Hemisphere as within-subjects independent variables. There was a significant interactions of Risk × Task at 420–460 ms over parietal areas ($F(1,13) = 4.77$ to 4.81, $p < 0.05$) and at 540–580 ms over the frontal-central area ($F(1,13) = 5.24$, $p < 0.05$, Fig. 2c), indicating that the environmental risk identification task induced larger LPP over the parietal areas compared to the personal risk identification task at 420–460 ms but smaller anterior late positivity over frontal-central area at 540–580 ms.

Our fMRI and ERP results indicate that, relative to the semantic control task, both environmental and personal risk identification tasks induced enhanced sustained activities in the MPFC

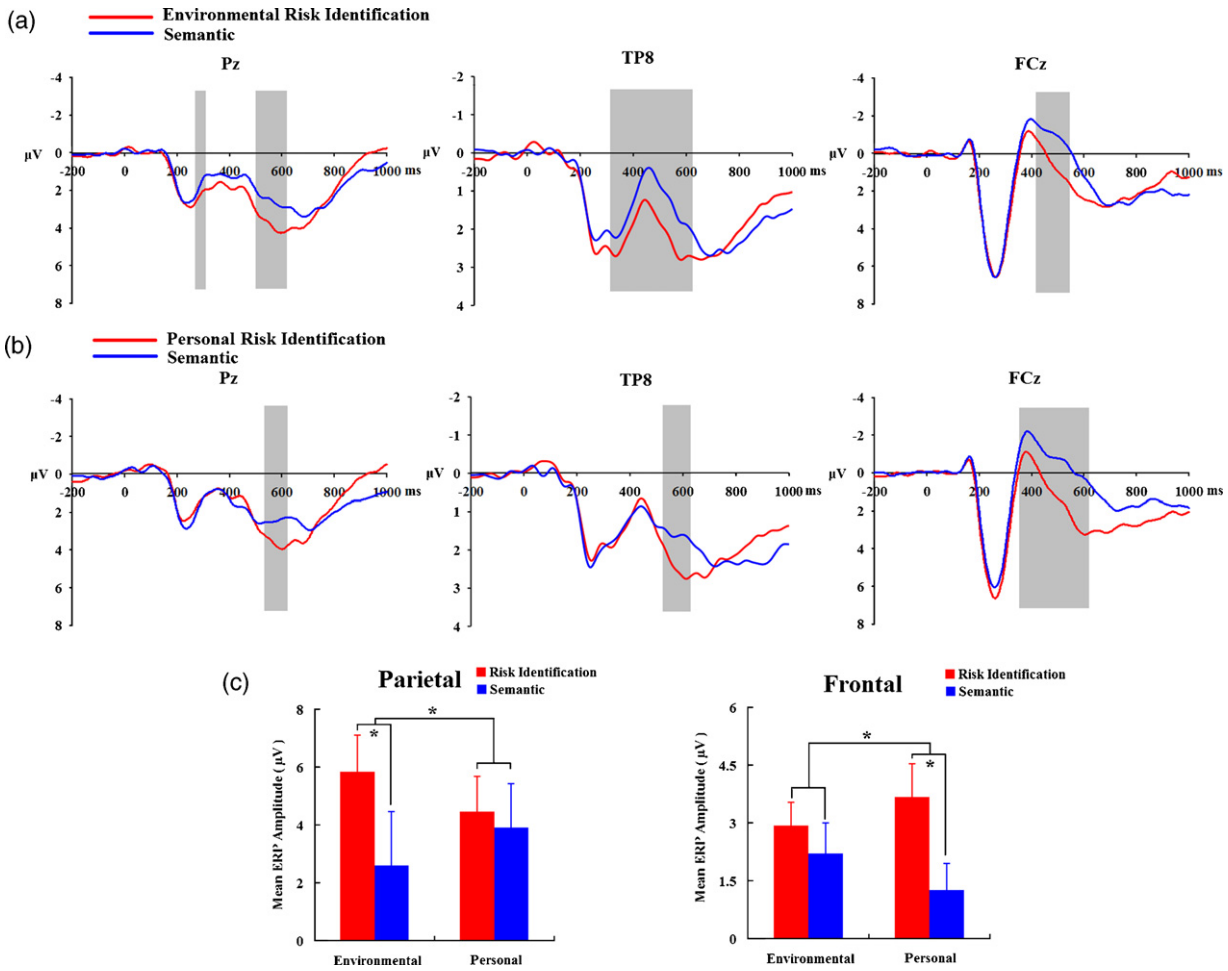


Fig. 2. ERP results associated with the risk identification tasks. (a) ERPs associated with the environmental risk identification and semantic tasks at Pz, TP8 and FCz electrodes. (b) ERPs associated with the personal risk identification and semantic tasks at Pz, TP8 and FCz electrodes. (c) Mean ERP amplitudes for each condition at electrodes over the parietal and frontal areas. The grey areas indicate the time window in which the ERP amplitudes differed significantly between the risk identification task and the semantic control task.

Author's personal copy

and enlarged LPP. Both the MPFC activity [3,4,8,10] and the LPP are involved in evaluative processes during social judgment [1,9]. The MPFC activity also engages in risk rating [27]. Our results suggest that the evaluative process plays a key role in both the environmental and personal risk identification tasks. The risk identification tasks also invoked enhanced activations in the left para-supramarginal gyrus (environmental risk identification: left SMG/IPL; personal risk identification: left SMG/STG). Given that the para-supramarginal gyrus is involved in semantic processing [11,15], we suggest that enhanced semantic processing is required during risk identification independently of risk domains.

More importantly, we found increased transient PCC and precuneus activations associated with the environmental relative to the personal risk identification tasks. The parietal LPP was also of larger amplitudes to the environmental than personal risk identification tasks. In addition, we found that the ERPs differentiating the environmental risk identification and semantic control tasks occurred earlier than that differentiating the personal risk identification and semantic control tasks, consistent with subjects' behavioural performances. It has been shown that PCC activity mediates the interaction between memory retrieval and emotion [13,14]. The precuneus underpins the process of episodic memory retrieval [2,16]. The posterior LPP is also involved in evaluation of emotional stimuli [5,20–22] and retrieval processing [25]. Given these neuroimaging findings, our fMRI and ERP results imply that, relative to the personal risk identification task, the environmental risk identification task requires enhanced and earlier retrieval of more emotional experiences. This proposal is consistent with the notion that evaluative judgments associated with strongly held attitudes (e.g., higher rating scores for environmental than personal risks [19]) depend more on the retrieval process (Nayakankuppam and Priester, submitted for publication). In contrast to the environmental risk identification task, the personal risk identification task may employ more cognitive control processes as the personal risk identification task induced larger LPP over the frontal area compared to the environmental risk identification task. Such time-consuming cognitive processes then result in slow responses in the personal than the environmental risk identification tasks.

A "dual process" theory of risk evaluation has been used to explain the dramatic distinct behavioral performances associated with risks in different domains [7]. For example, Loewenstein et al. [12] argued that risk perception based on two fundamentally different psychological mechanisms: risk-related feeling ("emotion-driven" strategy) and cognitive evaluations ("consequentialist" evaluation strategy). On a similar line of thoughts, Slovic et al. [24] proposed two fundamental systems or two modes of thoughts for risk comprehension, i.e., the slow, effortful, and conscious controlled "analytic system" and the fast, intuitive, and mostly automatic "experiential system". With regard to the domain-specific risk perception, these theories imply that people comprehend and evaluate risks in different domains using distinct strategies. The enhanced activations in PCC/precuneus and increased amplitudes of LPP over the parietal area linked to the environmental risk identification task are in line with the "dual process" model in that a more "emotion-driven" strategy or "experiential system" may be involved during the environmental risk identification task than during the personal risk identification task. In agreement with this, our previous study [19] showed that, relative to the identification of safe environmental events, the identification of risky environmental events enhanced emotional conflict subserved by ACC and an early positivity (P200) and retrieval of emotional experiences underpinned by the PCC and LPP. The identification of risky personal events, however, is characterized by enhanced cognitive evaluative processes in the inferior frontal gyrus and medial frontal cortex.

In sum, our neuroimaging findings indicate that evaluation and semantic processes are involved in both the environmental and personal risk identification tasks. The enhanced retrieval of emotional experiences may distinguish between the environmental and personal risk identification tasks in the extent of involvement as well as the temporal courses. However, there are several limitations of the current study. First, as the examples of environmental and personal risk differ in severity, with the former having the potential for devastating effects on lives and property and the latter having only much more limited, distal adverse outcomes, the differential risk severity and the immediacy of threat may also contribute to the difference in behavioral responses and brain imaging results. Second, previous studies have shown that females perceive some risks to be larger and are less willing to take them than males [28]. Future work should investigate the gender effects on the neural correlates linked to perception of risks in different domains. Finally, as psychometric studies on risk perception have defined several psychological dimensions of risks such as controllable, voluntary, dread, catastrophic to investigate the characteristic for specific risk/hazard [23], further works may investigate the relationship between the neural activations associated with risk perception and the rating scores on each psychological risk dimension.

Acknowledgement

This research was supported by the National Natural Science Foundation of China (Project 30630025, 30828012).

References

[1] J.T. Cacioppo, S.L. Crites, W.L. Gardner, Attitudes to the right: evaluative processing is associated with lateralized late positive event-related brain potentials, Pers. Soc. Psychol. Bull. 22 (1996) 1205–1219.
[2] A.E. Cavanna, M.R. Trimble, The precuneus: a review of its functional anatomy and behavioral correlates, Brain 129 (2006) 564–583.
[3] W.A. Cunningham, M.K. Johnson, J.C. Gatenby, J.C. Gore, M.R. Banaji, Neural components of social evaluation, J. Pers. Soc. Psychol. 85 (2003) 639–649.
[4] W.A. Cunningham, C.L. Raye, M.K. Johnson, Implicit and explicit evaluation: fMRI correlates of valence, emotional intensity, and control in the processing of attitudes, J. Cogn. Neurosci. 16 (2004) 1717–1729.
[5] B.N. Cuthbert, H.T. Schupp, M.M. Bradley, N. Birbaumer, P.J. Lang, Brain potentials in affective picture processing: covariation with autonomic arousal and affective report, Biol. Psychol. 52 (2000) 95–111.
[6] D.I. Donaldson, Parsing brain activity with fMRI and mixed designs: what kind of a state is neuroimaging in? Trends Neurosci. 27 (2004) 442–444.
[7] A. Gattig, L. Hendrickx, Judgmental discounting and environmentalal risk perception: dimensional similarities, domain differences, and implications for sustainability, J. Soc. Issues 63 (2007) 21–39.
[8] J.D. Greene, R.B. Sommerville, L.E. Nystrom, J.M. Darley, J.D. Cohen, An fMRI investigation of emotional engagement in moral judgment, Science 293 (2001) 2105–2108.
[9] T.A. Ito, J.T. Cacioppo, Electrophysiological evidence of implicit and explicit categorization processes, J. Exp. Soc. Psychol. 36 (2000) 660–676.
[10] T. Jacobsen, I. Ricarda, R.I. Schubotz, L. Höfel, D.Y. Cramon, Brain correlates of aesthetic judgment of beauty, Neuroimage 29 (2006) 276–285.
[11] T.L. Jernigan, A.L. Ostergaard, I. Law, C. Svarer, C. Gerlach, O.B. Paulson, Brain activation during word identification and word recognition, Neuroimage 8 (1998) 93–105.
[12] G.F. Loewenstein, E.U. Weber, C.K. Hsee, E.S. Welch, Risk as feelings, Psychol. Bull. 127 (2001) 267–286.
[13] R.J. Maddock, The retrosplenial cortex and emotion: new insights from functional neuroimaging of the human brain, Trends Neurosci. 22 (1999) 310–316.
[14] R.J. Maddock, A.S. Garrett, M.H. Buonocore, Posterior cingulate cortex activation by emotional words: fMRI evidence from a valence decision task, Hum. Brain Mapp. 18 (2003) 30–41.
[15] A. Matsumoto, T. Iidaka, K. Haneda, T. Okada, N. Sadato, Linking semantic priming effect in functional MRI and event-related potentials, Neuroimage 24 (2005) 624–634.
[16] H.R. Naghavi, L. Nyberg, Common fronto-parietal activity in attention, memory, and consciousness: shared demands on integration? Conscious Cogn. 14 (2005) 390–425.
[17] M.P. Paulus, J.S. Feinstein, D. Leland, A.N. Simmons, Superior temporal gyrus and insula provide response and outcome-dependent information during assessment and action selection in a decision-making situation, Neuroimage 25 (2005) 607–615.
[18] J. Qin, S. Han, Parsing neural mechanisms of social and physical risk identification, Hum. Brain Mapp. (in press).

Author's personal copy

[19] J. Qin, S. Han, Neural mechanisms underlying identification of environmental risks, Neuropsychologia 47 (2009) 397–405.
[20] H.T. Schupp, B.N. Cuthbert, M.M. Bradley, J.T. Cacioppo, T. Ito, P.J. Lang, Affective picture processing: the late positive potential is modulated by motivational relevance, Psychophysiology 37 (2000) 257–261.
[21] H.T. Schupp, M. Junghöfer, A.I. Weike, A.O. Hamm, Emotional facilitation of sensory processing in the visual cortex, Psychol. Sci. 14 (2003) 7–13.
[22] H.T. Schupp, M. Junghöfer, A.I. Weike, A.O. Hamm, The selective processing of briefly presented affective pictures: an ERP analysis, Psychophysiology 41 (2004) 441–449.
[23] P. Slovic, Perception of risk, Science 236 (1987) 280–285.
[24] P. Slovic, M.L. Finucane, E. Peters, D. MacGregor, Risk as analysis and risk as feelings: some thoughts about affect, reason, risk, and rationality, Risk Anal. 24 (2004) 311–322.
[25] A.P.R. Smith, R.J. Dolan, M.D. Rugg, Event-related potential correlates of the retrieval of emotional and nonemotional context, J. Cogn. Neurosci. 16 (2004) 760–775.
[26] L. van Leijenhorst, E.A. Crone, S.A. Bungea, Neural correlates of developmental differences in risk estimation and feedback processing, Neuropsychologia 44 (2006) 2158–2170.
[27] V. Vorhold, C. Giessing, P.M. Wiedemann, H. Schütz, S. Gauggel, G.R. Fink, The neural basis of risk ratings: evidence from a functional magnetic resonance imaging (fMRI) study, Neuropsychologia 45 (2007) 3242–3250.
[28] E.U. Weber, A. Blais, N.E. Betz, A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors, J. Behav. Decis. Making 15 (2002) 263–290.