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Experimental Brain Research

ISSN 0014-4819

Volume 234

Number 3

Exp Brain Res (2016) 234:721-731

DOI 10.1007/s00221-015-4492-5



 Springer

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The impact of extraversion on attentional bias to pleasant stimuli: neuroticism matters

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Received: 27 May 2015 / Accepted: 31 October 2015 / Published online: 19 November 2015
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Abstract The present study explored whether neuroticism modulates the impact of extraversion on attention orienting to pleasant and unpleasant pictures of diverse emotional intensities. We measured event-related potentials for highly emotional, mildly emotional, and neutral stimuli in both pleasant and unpleasant blocks, while subjects (16 stable ambiverts, 15 stable extraverts, 17 neurotic ambiverts, and 17 neurotic extraverts) were asked to perform a standard/deviant categorization task, irrespective of the emotionality of the deviants. The results revealed a modulation effect of neuroticism in the impact of extraversion on emotional attention. On the one hand, irrespective of extraversion, emotionally stable samples showed increased N200 amplitudes for highly unpleasant (HN) stimuli relative to mildly unpleasant (MN) and neutral stimuli, while these samples exhibited no significant emotion magnitude effect in the pleasant block. On the other hand, although neurotic samples, both extraverts and ambiverts, showed enhanced N2 amplitudes for HN stimuli than neutral stimuli, neurotic extraverts displayed increased N2 amplitudes for highly pleasant (HP) and mildly pleasant (MP) stimuli than neutral stimuli, which was absent in neurotic ambiverts. These results extend our understanding of the relationship

between extraversion and emotion by showing that neuroticism amplifies the positive emotional bias of extraverts.

Keywords Neuroticism · Extraversion · Attentional bias · Event-related potentials

Introduction

As a trait describing individual tendency to be optimistic, and to enjoy social contact (Ashton et al. 2002; Eysenck 1990), extraversion is closely related to subjects' positive emotion and happiness (DeNeve and Cooper 1998; Diener et al. 1992). Previous studies indicate that extraverts are linked with higher subjective well-being (Costa and McCrae 1980) and more positive emotional experiences (DeNeve and Cooper 1998). For example, researchers have reported a positive correlation between extraversion and the activation of limbic structures when viewing pleasant stimuli (Canli et al. 2001, 2002). Moreover, event-related potential (ERP) researches reported an enhanced sensitivity to positive stimuli and reduced responsiveness to negative stimuli in extraverts, compared to ambiverts (Yuan et al. 2009; Yuan et al. 2012b) or introverts (Lucas et al. 2000). A number of studies indicate that the correlation between extraversion and positive emotional experience might be partially explained by the extraverts' attentional bias toward positive stimuli, and attentional resistance to negative stimuli (Amin et al. 2004; Derryberry and Reed 1994; Yuan et al. 2012b).

However, there are evidences (Derryberry and Reed 1994; Gray 1987; Newman 1987; Wallace et al. 1991) showing that the impact of extraversion on the reactivity to pleasant and unpleasant stimuli may be modulated by emotional stability (neuroticism; Eysenck 1990). In Gray's

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Reinforcement Sensitivity Theory (RST; Gray 1987), he proposed two separable but interactive motivation systems for organizing emotional behaviors. One is the behavioral inhibition system (BIS), which is responsible for inhibiting behavior, increasing arousal, and directing attention to aversive events. The other is the behavioral activation system (BAS), responsible for activating approach behavior, increasing arousal, and directing attention to rewards. Furthermore, Gray (1987) mapped his work onto Eysenck's and maintained that extraversion reflects the relative balance of sensitivity in the reward and punishment systems. For example, high extraversion is associated with lower BIS and higher BAS activities, which in turn enhances individuals' reward sensitivity. By contrast, high introversion is associated with higher BIS and lower BAS activities, which in turn enhances individuals' punishment sensitivity (Gray 1987; Smillie et al. 2006). Gray (1987) also suggests that Eysenck's trait of neuroticism reflects the sum of the susceptibility to both reward and punishment systems. Also, Newman and Wallace (Newman 1987; Wallace et al. 1991) put forward that extraversion reflects the relative strengths of BAS and BIS, with a stronger BAS in extraverts and a stronger BIS in introverts, while neuroticism reflects the reactivity of a non-specific arousal system. This arousal system would amplify the positive stimulus processing of extraverts and the negative stimulus processing of introverts (Wallace et al. 1991). According to these theories, the relationship among BAS, BIS, and extraversion depends on the levels of neuroticism. In fact, the positive motivation reflected by BAS should be strongest in neurotic extraverts while the negative motivation reflected by BIS should be strongest in neurotic introverts, consequently leading to more pronounced emotion-related differences between extravert and introvert in neurotic relative to stable subjects (Gray 1987; Newman 1987; Wallace et al. 1991).

These theories were also supported by empirical evidences. Taylor and McFatter (2003) asked subjects different in extraversion and neuroticism to perform some cognitive tasks under sleep deprivation. The authors found that, the extraverts' performance in time estimation task was significantly worse than introverts, as they estimated earlier to the termination of a required time. This pattern of difference between extraverts and introverts was more pronounced for neurotic in comparison with stable samples. Consistent with Gray's and Newman's theories (Gray 1987; Newman 1987; Wallace et al. 1991), this finding suggests that the extraverts are more impulsive than introverts, and neuroticism even amplifies this personality difference. Apparently, due to the close correlation between impulsivity and BAS, this empirical evidence implies an interactive effect of neuroticism and extraversion on the BAS.

In another research, Derryberry and Reed (1994) required subjects different in extraversion and neuroticism to perform

a target detection task. The authors observed an attentional bias of introverts for negative locations, which was more pronounced in neurotic subjects. However, neuroticism did not amplify the positive bias of extraverts in this study (Derryberry and Reed 1994). This study just used response times as an index to examine attention orienting to emotionally relevant stimuli. Behavioral index, such as response time, was thought to reflect a composite emotion effect from both attention, cognitive, and response-decisional processes (Huang and Luo 2006). In this regard, the direct evidence is still lacking, for the interactive effects of extraversion and neuroticism on attention orienting to emotional stimuli.

These theories and empirical evidences suggest that the impact of extraversion on attention orienting to emotional stimuli may depend on neuroticism. Probably, the extraversion effect in emotional attention to pleasant and unpleasant stimuli may be stronger in neurotic, relative to stable samples. To directly test the modulating role of neuroticism in the extraversion effect in attention orienting to emotional stimuli, the current study used a modified oddball task and ERP technique, by classifying subjects into different groups according to extraversion and neuroticism. We used the oddball task because prior studies have indicated that the oddball N200, which peaks over frontal sites in the 200–300 ms post-stimulus (Li et al. 2008; Nagy et al. 2003; Yuan et al. 2007, 2012b), is elicited by deviant stimuli (Muller-Gass et al. 2006; Nagy et al. 2003; Yuan et al. 2007; Carretié et al. 2004), and this component represents a frontier between automatic and controlled phases of attention orienting to salient stimuli (Carretié et al. 2004; Li et al. 2008; Nagy et al. 2003; Yuan et al. 2007). Therefore, the current study chose oddball N200, instead of other later components (e.g., P3) more relevant to cognitive processing (Ito et al. 1998; Huang and Luo 2006), as a direct index to investigate how extraversion and neuroticism interact to influence attention orienting to emotional stimuli. The attention orienting effect for emotional stimuli is defined by the N200 amplitude differences between the emotional and the baseline, neutral stimuli in the current study, in order to isolate the emotional attention from other non-emotional process indexed by oddball N2. To better understand the attention orienting to emotional stimuli, we varied the valence strength of emotional stimuli from highly unpleasant to highly pleasant (Lang et al. 1997). In addition, this study used a non-emotional, distracting task, in order to mask the true purpose of the experiment.

We hypothesize that, if neuroticism indeed amplifies the extraverts' attentional bias toward positive stimuli, the differences between people high and low in extraversion in attention to positive stimuli would be increased in neurotic relative to emotionally stable samples. And this effect would be manifested by the N200 amplitude differences between pleasant and neutral stimuli being more pronounced with increasing extraversion and neuroticism.

Table 1 Descriptive data for demographic variables and score distribution for all experimental groups

	Stable ambiverts <i>M</i> or <i>n</i> (SD)	Stable extraverts <i>M</i> or <i>n</i> (SD)	Neurotic ambiverts <i>M</i> or <i>n</i> (SD)	Neurotic extraverts <i>M</i> or <i>n</i> (SD)
Male	7	7	7	6
Female	9	8	10	11
Age	22.11 (1.85)	21.94 (1.73)	22.18 (1.67)	21.64 (2.06)
Extraversion	4.06 (10.61)	27.67 (11.09)	−0.35 (11.56)	27.53 (9.73)
Neuroticism	−25.38 (8.21)	−30.87 (10.12)	10.82 (15.31)	3.06 (14.02)

Materials and methods

Subjects

As paid volunteers, 65 right-handed undergraduate students with no history of major psychiatric or neurological disorders participated in this experiment (see Table 1). All the subjects completed the NEO Five-Factor Inventory (NEO-FFI, Chinese version; internal consistency coefficient = .878; Wang et al. 2010), a five-point (from −2 to 2), 240-item questionnaire that is widely used in personality assessments (Amin et al. 2004; Canli et al. 2001, 2002). The four experimental samples were determined by subjects' scores on the extraversion subscale (48 items; internal consistency coefficient 0.88; Wang et al. 2010) and the neuroticism subscale (48 items; internal consistency coefficient = .90; Wang et al. 2010) of the NEO-FFI. Participants whose extraversion scores were below the 50th percentile were categorized as ambiverts, while the rest were determined as extraverts. The ambiverts whose neuroticism scores were under the 50th percentile were classified into stable ambiverts, while the rest were classified into neurotic ambiverts. Using the same method, extraverts were classified into stable extraverts and neurotic extraverts by their neuroticism scores (see Table 1). *T* test showed no significant differences of extraversion scores between stable extraverts and neurotic extraverts ($t(30) = -.085$; $p = .93$) nor between the stable ambiverts and neurotic ambiverts ($t(31) = 1.14$; $p = .26$). Likewise, the neuroticism scores were not significantly different between stable extraverts and stable ambiverts ($t(29) = 1.66$; $p = .11$) nor between neurotic extraverts and neurotic ambiverts ($t(32) = 1.54$; $p = .13$). The study was approved by the local Review Board for Human Participant Research, and each subject signed an informed consent form before the experiment.

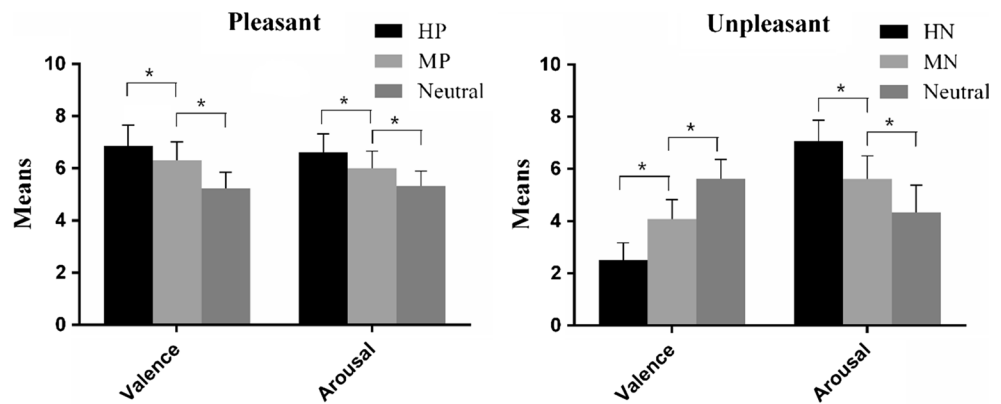
Stimuli

The present study included two modified oddball experimental blocks (pleasant block and unpleasant block). Each block consisted of four phases, with each phase including 55 standard pictures (a natural scene of a cup) and 45

deviant pictures, which were grouped into three experimental conditions (highly emotional, mildly emotional, and neutral). All the deviant pictures were taken from the CAPS,¹ which included three categories: emotionally positive, emotionally negative, and neutral (see the “Appendix” for the specific pictures used in each condition). In the pleasant block, a natural scene of a cup served as the standard picture, and 45 deviant pictures were grouped as highly positive (HP), mildly positive (MP), and neutral (Neu). The deviant pictures used in the pleasant block covered a variety of contents, such as highly pleasant, mildly pleasant, or neutral animals (e.g., puppies, pandas or wolfs), natural scenes (e.g., landscapes, seashores, or mountains), and human activity (e.g., cheers, sports, or conversation). In the unpleasant block, the same natural scene of a cup served as the standard picture, and 45 deviant pictures were categorized into highly negative (HN), mildly negative (MN), and neutral (Neu). Also, the pictures used in the unpleasant block covered varieties of contents, such as highly unpleasant, mildly unpleasant, or neutral animals (e.g., snakes, bugs, or eagles), natural scenes (e.g., fire disaster, flood, clouds) and human activity (e.g., homicide, violence, or sports). In addition, the validity of the three picture sets was verified by our prior study (Yuan et al. 2012a). The means of valence and arousal ratings for each of the three sets in both blocks are presented in Fig. 1. All pictures were identical in size and resolution (15 × 10 cm, 100 pixels/in.),

¹ The standardized CAPS was developed in Key Laboratory of Mental Health, Chinese Academy of Sciences in order to avoid the cultural bias of emotional inducement found in Chinese participants when IAPS was used. The CAPS introduced a number of pictures characterized by oriental objects, humans and natural scenes. The development method of this native emotional picture system is similar to that of IAPS, using the same Self-Assessment Manikin procedure (SAM; Lang et al. 1997). For the CAPS development, originators first collected over 2000 pictures of various contents for the system development and finally kept 852 pictures most of which are typical of Chinese cultures for the normative ratings. Chinese college students ($n = 156$, gender-matched) were recruited to rate the valence, arousal, and dominance by a self-report 9-point rating scale for the 852 pictures of the system. The pretest for this system showed that CAPS is reliable across individuals in emotional inducement (the between-subjects reliability scores were 0.982 for valence and 0.979 for arousal).

Fig. 1 The valence ratings and arousal ratings for highly emotional, mildly emotional, and neutral picture sets during pleasant and unpleasant blocks. Error bars represent standard errors. $*p < .001$



and the contrast and luminance levels among photographs were also controlled. The sequence of standard and deviant pictures was randomized in both blocks.

Behavioral procedures

Subjects were seated in an acoustically isolated room at approximately 150 cm from the computer screen, with their horizontal and vertical visual angles below 6° . All the subjects were naïve to the experimental purposes, and they were told before the experiment that this study was to investigate their abilities to make a fast response selection. To avoid fatigue, subjects had 2–3 min to take a rest after each phase. During the resting period, the subject's accuracy rates for both the standard and deviant stimuli were provided as a feedback of their performance. Each trial started with a 300 ms presentation of a small black cross on the white computer screen. Then, a blank screen was presented for 500–1500 ms whose offset was followed by a picture stimulus. Each subject was asked to press the “F” key as accurately and quickly as possible when they saw a standard picture, and to press the “J” key if the deviant picture appeared. The stimulus presentation was terminated by a key-pressing. Each response was followed by 1000 ms of a blank screen (see Fig. 2). Ten practice trials were used before the experiment to familiarize subjects with the procedure. The order of the pleasant and unpleasant blocks was counterbalanced across the subjects. After EEG recording, subjects were required to assess the valence (ranging from 1, extremely unpleasant; to 9, extremely pleasant) and arousal (ranging from 1, extremely relaxed; to 9, extremely excited) of all the pictures using a self-reported nine-point rating scale.

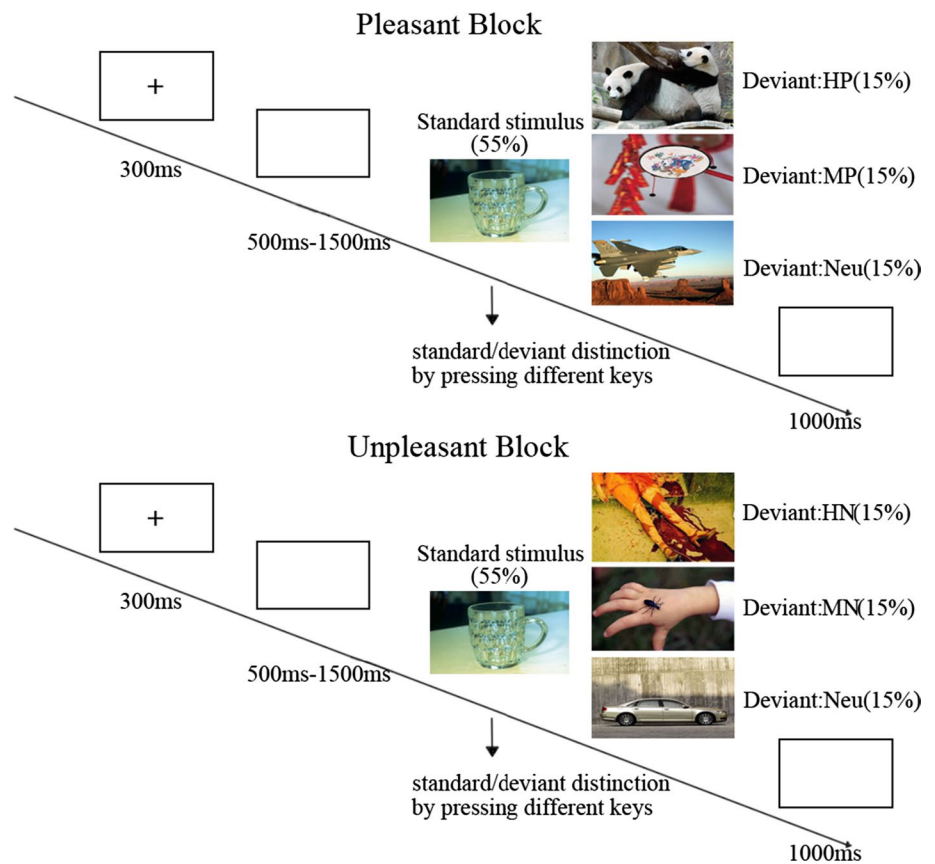
ERP recording and analysis

The EEG was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Products, Munich, Germany), with the reference electrodes on the left and

right mastoids (average mastoid reference; Luck 2005), and the ground electrode was on the medial of frontal aspect. Vertical electrooculograms (EOGs) were recorded below the right eye, and the horizontal EOGs were recorded on the right-hand of the right eye. The EEG and EOG were amplified using a DC ~ 100-Hz band-pass filter and continuously sampled at 500 Hz/channel. All interelectrode impedances were maintained below 5 k Ω . The averaging of ERPs was computed offline, and EOG artifacts (blinks and eye movements) were corrected by using a 24-Hz low-pass filter offline. The Vision Analyzer software used an automatic ocular correction procedure to eliminate EOG artifacts. And then, trials with a mean EOG voltage that exceeded $\pm 100 \mu\text{V}$ or contaminated with artifacts due to amplifier clipping of peak-to-peak deflection that exceeded $\pm 100 \mu\text{V}$ were excluded from the averaging. Since the rejected rate of each condition was very low ($< 8\%$), enough trials were obtained for ERP averaging. The EEGs for correct responses during each emotion condition were averaged separately. The ERP waveforms were time-locked to the onset of the stimuli, and the time-window included a 200 ms pre-stimulus baseline and a post-stimulus duration of 800 ms.

It could be seen by the grand average map that each emotion condition elicited apparent N2 activity in both blocks (see Figs. 4, 5), regardless of participants' extraversion and neuroticism. Therefore, the amplitudes and peak latencies of the N2 (210–270 ms) were measured and analyzed. Since the prior studies reported a central and frontal distribution of N2 component (Carretié et al. 2004; Nagy et al. 2003; Yuan et al. 2007), the following nine electrode sites were selected for the statistical analysis of the N2 component: F3, Fz, F4, FC3, FCz, FC4, C3, Cz, and C4. Emotion valence (two levels: pleasant and unpleasant), emotion magnitude (three levels: highly emotional, mildly emotional, and neutral), frontality (three levels: frontal, fronto-central, and central), and laterality (three levels: left, midline, and right) were used as repeated factors in a repeated measures ANOVA of the amplitudes and peak

Fig. 2 Schematic illustration of the experimental procedure and the stimulus examples



latencies of N2 component. Extraversion (two levels: extraverts and ambiverts) and neuroticism (two levels: neurotic and stable) was used as between-subjects factors. Since the present study focused on the modulation effect of neuroticism on attention orienting of extraverts and ambiverts to pleasant and unpleasant stimuli of diverse emotional intensities, we focused the statistical analysis on the four-way interaction of emotion valence, emotion magnitude, neuroticism, and extraversion. The degrees of freedom of the F -ratio were corrected for violation of spherical assumption according to the Greenhouse-Geisser method, and Bonferroni correction method was used for post hoc comparisons if significant main or interaction effects were found.

Results

Behavioral data

Errors were rare (<3 %), as all the subjects achieved a ceiling accuracy for both standard and deviant stimuli in each experimental block. The ANOVA of the reaction time (RT) data, with emotion valence and emotion magnitude as repeated factors, and extraversion and neuroticism as between-subjects factors, showed neither a significant

interaction of valence, magnitude, extraversion, and neuroticism [$F(2, 101) = 0.67, p = .49$] nor a significant interaction of extraversion and neuroticism [$F(1, 60) = 0.41, p = .53$]. Also, the main effects of valence [$F(1, 60) = 0.47, p = .50$], magnitude [$F(1, 88) = 3.39, p = .052$], extraversion [$F(1, 60) = 1.48, p = .23$], and neuroticism [$F(1, 60) = 3.18, p = .08$] were not significant. The mean RTs and standard errors for each of the three conditions during both blocks are presented in Table 2. In fact, the influence of extraversion and neuroticism on brain activity to emotional stimuli was not significant in the measure of RTs.

Emotion assessment

Valence assessment

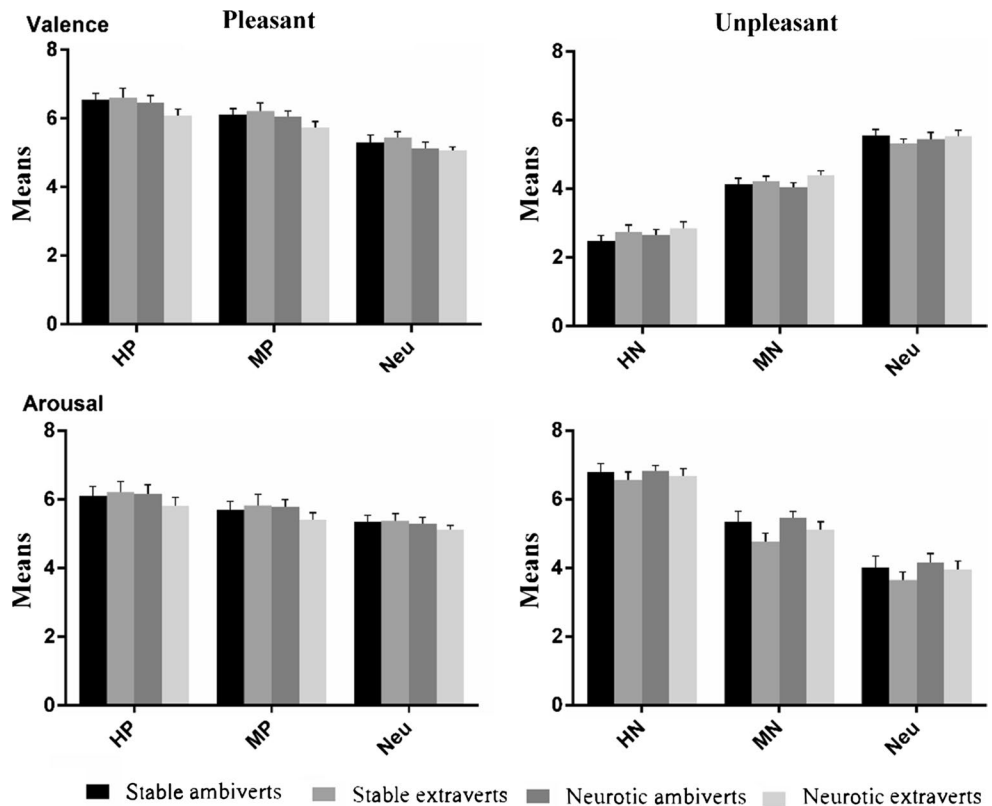
The repeated measures ANOVA of valence scores, with emotion valence and emotion magnitude as repeated factors, extraversion, and neuroticism as the between-subjects factors, showed significant main effects of valence [$F(1, 59) = 375.61, p < .001$] and magnitude [$F(2, 98) = 103.64, p < .001$], but not of extraversion [$F(1, 59) = 0.04, p = .84$] or neuroticism [$F(1, 59) = 0.69, p = .41$]. The analysis showed no other significant interactions except for the interaction of valence and

Table 2 Averaged reaction times (RTs) and standard errors (SE) for each of the three conditions in the pleasant and unpleasant blocks (in milliseconds)

	Stable ambiverts		Stable extraverts		Neurotic ambiverts		Neurotic extraverts	
	<i>M</i>	SE	<i>M</i>	SE	<i>M</i>	SE	<i>M</i>	SE
HP	569	19	615	38	546	16	572	16
MP	570	18	609	39	541	16	564	16
Neu (P)	582	21	611	36	553	17	574	17
HN	565	16	616	38	549	15	551	10
MN	571	18	611	38	551	17	553	10
Neu (N)	586	21	608	31	549	17	557	9

Neu (P), neutral condition in the pleasant block; Neu (N), neutral condition in the unpleasant block

Fig. 3 Schematic illustration of the valence ratings and arousal ratings for highly emotional, mildly emotional, and neutral picture sets during pleasant and unpleasant blocks. Error bars represent standard errors



magnitude [$F(1, 81) = 491.02, p < .001$]. The breakdown of this interaction showed a significant emotion magnitude effect [$F(2, 106) = 138.79, p < .001$] in the pleasant block. Subjects rated HP ($M \pm SE: 6.42 \pm 0.11$) pictures as more pleasant than MP ($6.03 \pm 0.10; p < .001$) pictures, and MP pictures were rated as more pleasant than neutral ($5.23 \pm 0.09; p < .001$, see Fig. 3) pictures. Also, there was a significant emotion magnitude effect [$F(1, 78) = 421.372, p < .001$] in the unpleasant block. HN (2.69 ± 0.09) pictures were rated as more unpleasant than MN ($4.21 \pm 0.07; p < .001$) pictures, which, in turn, were rated as more unpleasant than neutral ($5.47 \pm 0.09; p < .001$, see Fig. 3) pictures.

Arousal assessment

The analysis of arousal scores showed significant main effects of valence [$F(1, 59) = 6.20, p < .05$] and magnitude [$F(1, 81) = 221.22, p < .001$], but not of extraversion [$F(1, 59) = 2.57, p = .11$] or neuroticism [$F(1, 59) = .001, p = .98$]. There were no other significant interactions except for a valence by magnitude interaction [$F(2, 109) = 123.39, p < .001$]. The sub-analysis of this interaction showed a significant emotion magnitude effect [$F(1, 82) = 31.89, p < .001$] in the pleasant block. Subjects rated HP pictures (6.08 ± 0.14) as more arousing than MP ($5.68 \pm 0.13; p < .001$) pictures, and MP pictures were

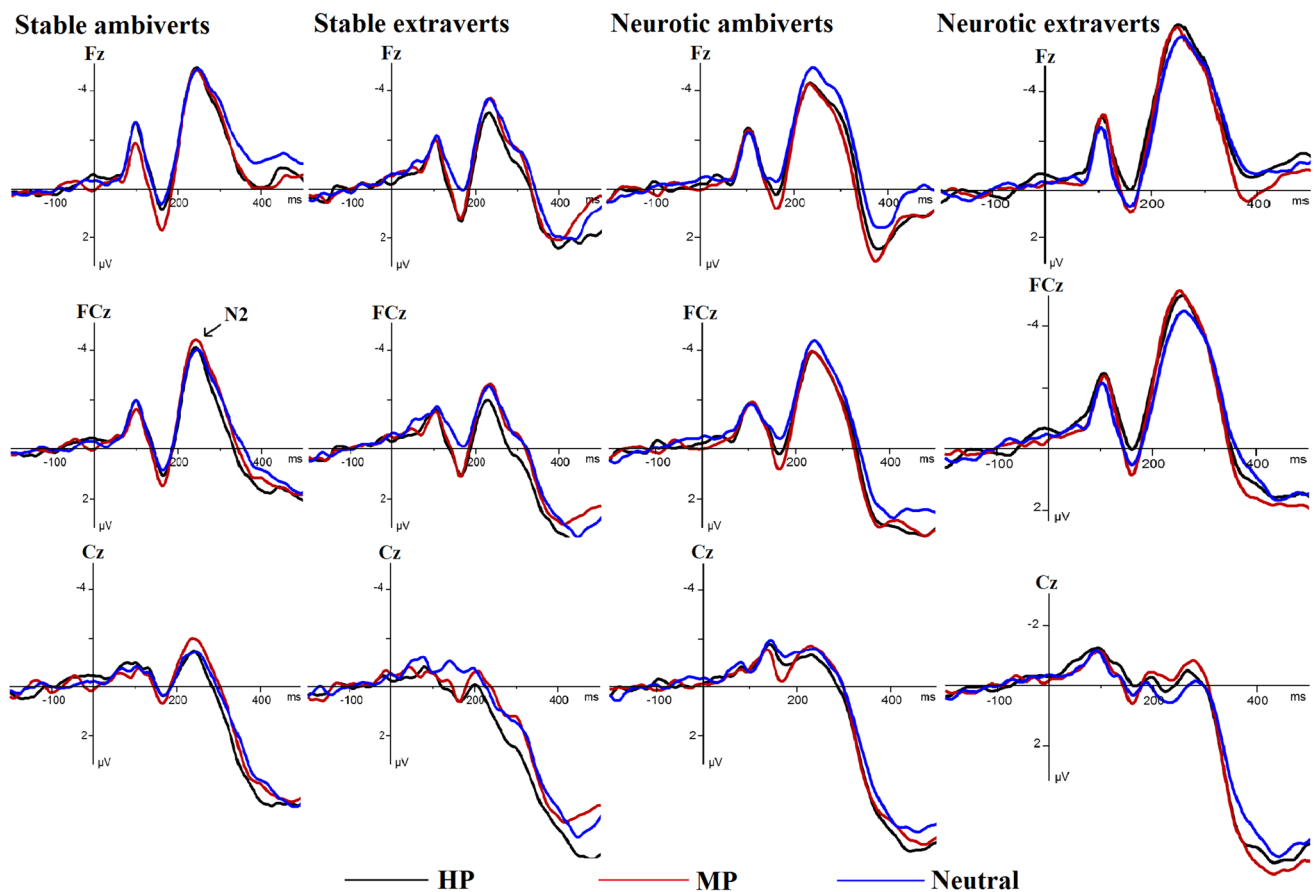


Fig. 4 Averaged ERPs for stable ambiverts, stable extraverts, neurotic ambiverts, and neurotic extraverts subjects during the highly positive (HP; black lines), mildly positive (MP; red lines), and neutral (blue lines) conditions in the pleasant block. (color figure online)

rated as more arousing than neutral (5.28 ± 0.09 ; $p < .001$, see Fig. 3) pictures. There was also an emotion magnitude effect [$F(1, 84) = 308.97$, $p < .001$] in unpleasant block. HN (6.72 ± 0.10) pictures were rated as more arousing than MN (5.17 ± 0.12 ; $p < .001$) pictures, which, again, were rated as more arousing than neutral (3.94 ± 0.14 ; $p < .001$, see Fig. 3) pictures.

ERP results

N2 The repeated measures ANOVA of N2 amplitudes, with emotion valence and emotion magnitude as the repeated factors, and extraversion and neuroticism as the between-subjects factors, demonstrated a significant main effect of valence [$F(1, 61) = 44.78$, $p < .001$], with unpleasant stimuli eliciting larger amplitudes ($-2.43 \pm 0.26 \mu\text{V}$) than pleasant stimuli ($-1.71 \pm 0.26 \mu\text{V}$). In addition, there were significant main effects of frontality [$F(2, 122) = 103.77$, $p < .001$] and laterality [$F(2, 122) = 39.45$, $p < .001$]. Mid-lines sites ($-3.16 \pm 0.32 \mu\text{V}$) recorded more pronounced amplitudes than did the left ($-1.45 \pm 0.25 \mu\text{V}$; $p < .001$) and right sites ($-1.61 \pm 0.27 \mu\text{V}$; $p < .001$). Consistent

with previous evidences for N2 distribution (Carretié et al. 2004; Nagy et al. 2003; Yuan et al. 2007), frontal regions recorded larger N2 amplitudes than central sites.

More importantly, there was a significant main effect of emotion magnitude [$F(2, 122) = 12.13$, $p < .001$], a valence by magnitude interaction [$F(2, 122) = 22.49$, $p < .001$], and a significant four-way interaction of valence, magnitude, extraversion, and neuroticism [$F(2, 122) = 4.77$, $p = .01$]. In order to sub-analyze these interactions, the present study tested the interaction of valence, magnitude, and extraversion in neurotic and stable subjects, respectively. In the stable group, the valence \times magnitude \times extraversion interaction [$F(2, 58) = 1.29$, $p = .28$] was not significant, while there was a significant two-way interaction of valence and magnitude [$F(2, 58) = 18.76$, $p < .001$]. This suggests that the emotion valence by magnitude interaction in stable groups was not influenced by extraversion level in N2 amplitudes. The subsequent analysis of this two-way interaction showed a significant emotion magnitude effect in the unpleasant block [$F(2, 58) = 15.86$, $p < .001$] but not in the pleasant block [$F(2, 58) = 2.75$, $p = .083$]. Regardless of extraversion, emotional stable subjects showed larger

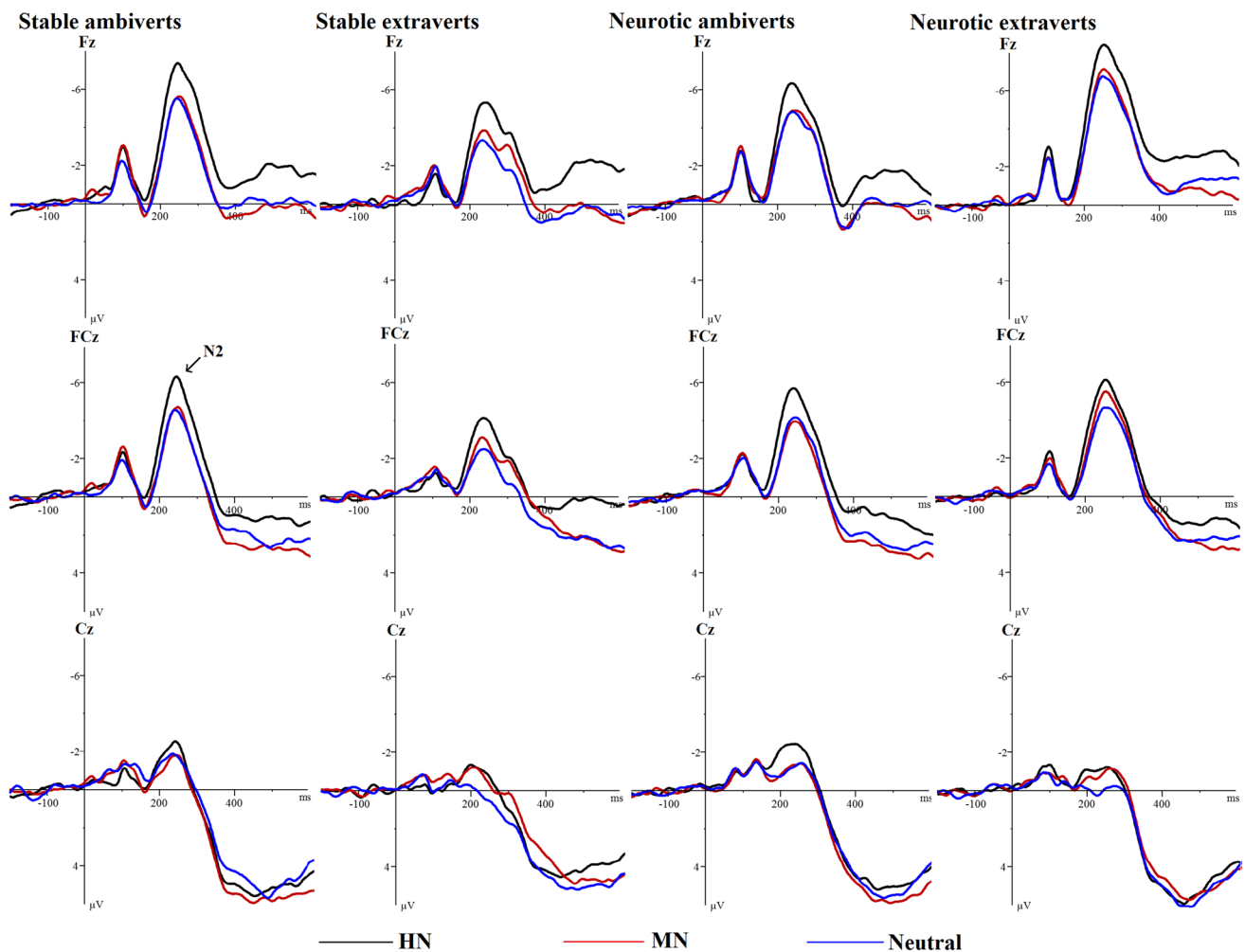


Fig. 5 Averaged ERPs for stable ambiverts, stable extraverts, neurotic ambiverts, and neurotic extraverts subjects during the highly negative (HN; black lines), mildly negative (MN; red lines), and neutral (blue lines) conditions in the unpleasant block. (color figure online)

amplitudes for HN ($-2.74 \pm 0.43 \mu\text{V}$) stimuli than for MN ($-1.98 \pm 0.43 \mu\text{V}$; $p < .001$) and neutral ($-1.67 \pm 0.34 \mu\text{V}$; $p < .001$) stimuli; while the latter two conditions showed no significant differences [$F(1, 29) = 1.99$, $p = .17$].

On the other hand, there was a significant three-way interaction of valence, magnitude, and extraversion [$F(2, 62) = 3.74$, $p < .05$] in neurotic samples. To breakdown this three-way interaction, we tested the valence \times magnitude interaction in neurotic ambiverts and neurotic extraverts, respectively. The two-way interaction of valence and magnitude was not significant [$F(2, 32) = .41$, $p = .66$] in neurotic extraverts, but there was a significant main effect of emotion magnitude [$F(2, 32) = 10.84$, $p < .001$] in this sample. Highly emotional ($-3.05 \pm 0.60 \mu\text{V}$; $p < .001$) and mildly emotional ($-2.91 \pm 0.61 \mu\text{V}$; $p < .01$) stimuli elicited larger amplitudes than neutral ($-2.30 \pm 0.58 \mu\text{V}$) stimuli, irrespective of whether the stimulus was positive or negative. However, there was a significant

valence \times magnitude interaction in neurotic ambiverts [$F(2, 32) = 13.01$, $p < .001$]. Neurotic ambiverts showed a significant emotion magnitude effect in unpleasant [$F(2, 32) = 10.88$, $p < .001$], but not in pleasant [$F(2, 32) = 2.72$; $p = .09$] valence. HN stimuli ($-3.07 \pm 0.43 \mu\text{V}$; $p < .001$) elicited more pronounced amplitudes than MN ($-2.24 \pm 0.40 \mu\text{V}$; $p < .01$) and neutral stimuli ($-1.90 \pm 0.41 \mu\text{V}$, $p < .001$; see Figs. 4, 5), while the latter conditions showed no significant differences ($p = .21$).

In addition, the analysis of N2 latencies showed no other significant main or interaction effects but a significant main effect of frontality [$F(1, 73) = 8.29$; $p < .01$], with N2 latencies increasing from central to frontal sites.

The comparison of the emotional effect in N200 amplitudes

As described above, breaking down the four-way interaction showed that neurotic extraverts displayed a significant

emotion effect for both HP and MP stimuli in N200 amplitudes, which was absent in neurotic ambiverts and stable subjects. This suggests that neuroticism amplified the extraversion effect in attention to pleasant stimuli. To confirm these results, we computed an index of emotional effect by subtracting neutral condition from each emotional condition. Then, the size of the emotion effect was directly compared between ambiverts and extraverts in each neurotic and each emotional level. The results showed that the size of the emotion effect was significantly larger for neurotic extraverts than for neurotic ambiverts for both HP ($t(32) = 3.17, p < .005$) and MP ($t(32) = 2.16, p < .05$) stimuli, while this pattern of difference was absent for stable samples for HP ($t(29) = -1.52, p = .14$) and MP stimuli ($t(29) = -.40, p = .69$).

In addition, the size of the emotion effect was not significantly different between stable ambiverts and stable extraverts, whether HN ($t(29) = .38, p = .71$) or MN ($t(29) = .63, p = .53$) condition was concerned. Similarly, the size of the emotion effect was not significantly different between neurotic extraverts and neurotic ambiverts, for HN ($t(32) = -.63, p = .54$) and MN ($t(32) = .62, p = .54$) stimuli.

Discussion

The behavioral data of the current study showed no significant interactive effect of extraversion and neuroticism in attention to emotional stimuli, whether RTs or emotion ratings were used as an index. However, this interaction was clearly observed, when oddball N2 was taken as an index of attention orienting to emotional stimuli. The oddball N2 has been accepted as a direct index of attention orienting in previous studies (Carretié et al. 2004; Li et al. 2008; Nagy et al. 2003; Yuan et al. 2007, 2012b). We observed a prominent N2 peaking about 240 ms post-stimulus, and its amplitudes increased from central to anterior regions, fitting well with the oddball N2 archetype (Carretié et al. 2004; Li et al. 2008; Yuan et al. 2007, 2012b). This verifies that oddball N2 is a more sensitive index than behavioral measures in detecting individual differences in attention to emotional stimuli.

Consistent with previous studies, we observed increased N2 amplitudes in unpleasant versus pleasant blocks, reflecting enhanced attention alerting for negative, threatening stimuli (Carretié et al. 2004; Yuan et al. 2007). In addition, there was a significant four-way interaction of valence, magnitude, extraversion, and neuroticism in N2 amplitudes.

Stable subjects, irrespective of extraversion, presented the same pattern of brain activity to negative stimuli, with HN stimuli eliciting larger amplitudes than MN and neutral

stimuli (see Figs. 4, 5). This suggests that stable subjects showed significant attentional alerting for HN stimuli, regardless of extraversion. This may be because it is biologically significant for humans, irrespective of personality, to be vigilant for salient negative events (Bradley et al. 2001; Cacioppo and Berntson 1994), such as HN stimuli in the present study. This also explains why neurotic subjects, irrespective of extraversion, showed more pronounced N200 amplitudes for HN pictures relative to MN and neutral pictures. However, the current study did not observe increased N2 amplitudes for either HP or MP stimuli in stable extraverts, while prior studies showed enhanced brain activity for pleasant versus neutral stimuli in stable extraverts (Yuan et al. 2012b). A most likely explanation is that the current study used a 50th percentile to split subjects as extraverts or ambiverts. As a result, the stable extravert samples (mean extraversion = 27.67) were not extraverted enough to show an attentional bias for positive stimuli, as they had lower extraversion scores than our prior study (e.g., mean extraversion = 39.7 in Yuan et al. 2012b).

On the other hand, there were pronounced emotion electrophysiological effects for both HP and MP stimuli in neurotic extraverts, but not in neurotic ambiverts (see Figs. 4, 5). Consistent with prior evidences of the relationship between emotion and extraversion (Canli et al. 2001, 2002; Yuan et al. 2012a, b), neurotic extraverts displayed enhanced attention orienting to pleasant stimuli, which was absent in neurotic ambiverts. This may be due to the stronger BAS of neurotic extraverts that enhanced their attentional bias toward pleasant stimuli than neurotic ambiverts (Gray 1987). It is worth noting that the extraversion scores were similar for neurotic and stable extravert samples. Thus, it is neuroticism that increased the attentional bias of extraverts to pleasant stimuli, consistent with the predictions by Gray and Newman's theories.

In addition, neurotic extraverts observed enhanced N200 amplitudes for MN relative to neutral stimuli, while this effect was not significant in stable subjects, regardless of extraversion. This suggests that neurotic extraverts allocated more attention resources to MN stimuli than stable extraverts. It may be because the stronger BIS of neurotic subjects has enhanced their negative bias than stable subjects (Gray 1987). However, one may question that the neuroticism not only amplifies the emotion effect for positive stimuli but also tends to amplify the effect for negative stimuli, as neurotic extraverts displayed a significant emotion effect for MN stimuli which, however, was non-significant across the other three groups. It is worth noting that our analysis of the magnitude of the emotional effect to negative stimuli, whether HN stimuli or MN stimuli, showed no significant differences between extraverts and ambiverts, regardless of neuroticism. By contrast, in the present study, both the decomposition of the three-way interaction and the

direct comparison of the emotion effect for pleasant stimuli showed converging evidences that neuroticism amplified the extraversion effect in attention to pleasant stimuli, irrespective of whether the emotion intensity is highly or mildly pleasant. Thus, our conclusion that neuroticism amplifies the extraversion effect in emotional attention should be most likely specific to pleasant stimuli, instead of being general to both positive and negative stimuli.

In conclusion, using oddball N200 as a direct index of attention orienting, the current study observed significant differences of positive bias between extraverts and ambiverts in neurotic samples, while this extraversion effect was absent in stable samples. These results suggest that neuroticism amplifies the attentional bias of extraverts for positive stimuli, which supports Gray's (1987) and Newman's (1987) theories. These theories posit that extraverts have a higher positive motivation than ambiverts due to increasing BAS activity, and the positive motivation and BAS activity of extraverts are amplified with increasing neuroticism. Consequently, the differences of attentional bias toward pleasant stimuli between extraverts and ambiverts become larger in neurotic than stable subjects. It has to be noted that, firstly, the present study used subjects whose extraversion scores are below 50th percentile of the distribution as the baseline sample, and the extraversion score of this sample is centered around zero, as shown by Table 1. Thus, these samples are ambiverts instead of introverts, and caution needs to be taken when applying the current findings to introverts.

Conclusions

The impact of extraversion in attention orienting to pleasant stimuli is moderated by neuroticism. Neuroticism amplifies the positive attention bias of extraverts, such that the differences between extraverts and ambiverts in attention to positive stimuli increase with emotional instability.

Acknowledgments This research was funded by the National Natural Science Foundation of China (NSFC31170989, 31371042, and 61472330) and the Natural Science Foundation of Chongqing (No. cstc2012jjA40063).

Appendix

Identification numbers of CAPS pictures used in present study

Unpleasant block:

HN: 173, 185, 191, 194, 196, 205, 206, 232, 240, 243, 244, 246, 248, 254, 255, 256, 270, 273, 280, 284, 471, 533, 541, 569, 573, 577, 580, 583, 584, 629.

MN: 585, 212, 617, 618, 150, 220, 247, 251, 252, 264, 265, 267, 272, 285, 507, 547, 553, 557, 565, 563, 228, 249, 154, 155, 157, 161, 169, 171, 621, 592.

Neutral (unpleasant): 89, 294, 306, 388, 454, 482, 538, 521, 523, 547, 614, 619, 696, 716, 722, 850, 308, 309, 321, 326, 328, 357, 377, 402, 634, 645, 719, 810, 363, 300.

Pleasant block:

HP: 1, 2, 5, 6, 8, 9, 21, 23, 24, 25, 33, 34, 36, 38, 41, 44, 46, 49, 50, 53, 56, 59, 60, 66, 79, 82, 83, 85, 87, 99.

MP: 4, 7, 10, 11, 12, 13, 14, 16, 18, 20, 28, 29, 45, 40, 52, 72, 73, 77, 78, 88, 94, 84, 39, 57, 32, 98, 27, 65, 663, 819.

Neutral (pleasant): 840, 841, 843, 547, 89, 306, 454, 482, 538, 521, 523, 614, 722, 848, 308, 321, 326, 328, 377, 402, 634, 645, 810, 363, 300, 291, 816, 818, 838, 839.

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