Event-related potential correlates of the extraverts' sensitivity to valence changes in positive stimuli

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This study investigated whether the human sensitivity to valence intensity changes in positive stimuli varies with extraversion. Event-related potentials were recorded for highly positive, moderately positive, and neutral stimuli while participants (extraverts and nonextraverts) performed a standard/deviant categorization task, irrespective of the emotionality of deviants. The results of extraverts showed larger P2 and P3 amplitudes during highly positive condition than during moderately positive condition which, in turn, elicited larger P2 than neutral condition. Conversely, nonextraverts showed no differences at both P2 and P3 components. Thus, extraverts, unlike less extraverted individuals, are sensitive to valence changes in positive stimuli, which may be underlain by certain biogenetic mechanism. ***NeuroReport*** **20:1071–1076 © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Considerable research has been conducted on the biological dimensions of personality, which indicates that differences in personality traits play a significant role in the individual variability of human emotional activity [1,2]. Extraversion, a trait that describes the degree to which a person is outgoing, sociable, and interactive with other people [2,3], was shown by numerous studies to correlate with individuals' susceptibility to positive emotions [1,4]. Under Jeffrey Gray's [5] theoretic constructs, the behavioral approach system, which mediates one's approach to signals of positive emotion values, is hypothesized to be more sensitive in extraverted individuals. This implies that extraverts are more susceptible to signals of positive values than less-extraverted individuals. Similarly, in Eysenck's theory, the behavioral approach system is considered to be primarily associated with high extraversion, which predicts that extraverts are characterized by reward expectancies and positive emotions [1,6]. The hypothesized linkage of extraversion with levels of positive emotions was supported by many correlational studies [2,4].

In early studies, highly extraverted individuals were reported to experience more positive emotions in everyday life than less-extraverted individuals [2]. This association proved effective in predicting levels of positive effects 10 years later [2]. In addition, extraverts are reported to be slow in shifting attention away from locations of positive incentive values compared with less-extraverted individuals, suggesting an attentional bias of extraverts for emotionally positive stimuli [7]. Consistent with these behavioral studies, using functional magnetic resonance imaging measures, Canli and coworkers [8,9] observed that the magnitude of brain reactions to positive pictures correlated significantly with participants' extraversion scores in numerous cortical and subcortical regions. More recently, using an emotional dot-probe task, Amin and colleagues [10] replicated the finding that neural activations elicited by positive stimuli increased with extraversion.

In life settings, the emotional events are often varying in valence intensity, even within the same emotional polarity (positive or negative) [11]. In fact, stimuli of varying valence conditions have different effects on cognitive processes [11]. Although extraverts are known for increased sensitivity to positive stimuli, whether their sensitivity increases with the intensity of positive stimuli, and how they differ from less-extraverted individuals in processing valence differences in positive stimuli remains unclear. Specifically, several studies consistently revealed a valence intensity effect that the human brain is sensitive to valence intensity differences in negative stimuli, whereas the brain is insensitive to those in emotionally positive stimuli [11,12]. However, it is likely that the conclusion for the insensitivity of the brain to valence intensity changes in positive stimuli is suitable only for less-extraverted individuals, as extraverted individuals are susceptible to positive stimuli [7].

Therefore, this study investigated whether extraverts are different from nonextraverted individuals in cerebral sensitivity to valence intensity changes in positive stimuli. It was hypothesized that (i) extraverted indivi-

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duals are more susceptible to positive stimuli than nonextraverts, irrespective of the valence intensity; (ii) extraverts are sensitive to valence changes in positive stimuli; (iii) nonextraverted individuals react similarly to positive stimuli of diverse valence conditions, just as that reported by previous studies [11,12]. In more detail, if dense array ERP technique is used, it is possible to observe that the amplitudes of attention-related components, such as frontal P2, are modulated by the valence intensity of positive stimuli in extraverts. In addition, as elaborated evaluative processes are central to human emotional processing and experience [13], valence effects at amplitude or latency of P3 are likely to occur in extraverts. In contrast, nonextraverted controls may exhibit smaller ERP differences at these components.

Materials and methods

Participants

As paid volunteers, 16 extraverted (19–25 years; mean = 21.6 years, eight males) and 16 nonextraverted (18–24 years; mean = 21.2 years, eight males) students from Southwest University in China participated in the experiment. The participants were selected from a large pool of 350 college students who filled in the NEO Five-Factor Inventory (NEO-FFI, Chinese version), a five-point (from -2 to 2) 240-item questionnaire that is widely used in personality assessment [8,10]. Extraverts and nonextraverted controls were selected in a way that the two groups scored differently on the extraversion subscale (48 items), whereas their scores were similar in the other measures of NEO-FFI. Sixteen participants whose extraversion scores (ranged from 30 to 45; mean = 36.63) were beyond centile 90 were grouped as extraverts, and another 16 participants whose extraversion scores (from -7 to 9 scores; mean = 0.50) were around centile 50 (midpoint of the distribution) were taken as nonextraverted controls. The participants of both samples were right handed, had normal or corrected-to-normal vision. Furthermore, they reported no history of affective disorder and were free of any psychiatric medication. Each participant signed an informed consent form before the experiment.

Stimuli

This study used a modified oddball task that consisted of six blocks of 100 trials, and each block included 70 standard and three conditions of 10 deviants. All deviants were pictures taken from Chinese Affective Picture System [14]. A natural scene of cup served as the frequent standard picture and 30 pictures grouped as either highly positive (HP), moderately positive (MP), or neutral served as the deviants. The sequence of standard and deviant pictures was randomized for each participant. Three groups of deviant pictures were selected in a way that they differed significantly in valence from one another [mean: HP = 7.41, MP = 6.60, neutral = 5.41; $F(2,87) = 96.16$, $P < 0.001$; max. (MP) = 6.96, min. (HP) = 7.00] but were similar in arousal [mean: HP = 5.58, MN = 5.40, neutral = 5.37; $F(2,87) = 1.29$, $P = 0.28$]. All the pictures were identical in size and resolution (15 cm × 10 cm, 100 pixels per inch), and the luminance level of the pictures was controlled across the three valence conditions.

Behavioral procedures

Participants were seated in a quiet room at approximately 150 cm from a computer screen with the horizontal and vertical visual angles below 6°. Before the experiment, all participants were told that the purpose of the study was to investigate their ability to make a fast response selection. At the end of each of the six blocks, accuracy rates for both standard and deviant stimuli were given to the participants as a feedback of their performance. Each trial was initiated by a 300-ms presentation of a small black cross on the white computer screen. Then, a blank screen whose duration varied randomly between 500 and 1000 ms was followed by the onset of picture stimulus. Each participant was instructed to press the 'F' key on the keyboard with the left index finger as accurately and quickly as possible if the standard picture appeared, and to press the 'J' key with the right index finger if the deviant picture appeared. The stimulus picture was terminated by a key pressing, or was terminated when it elapsed for 1000 ms. Each response was followed by 1000 ms of a blank screen. Ten practice trials were given before the formal experiment to familiarize participants with the procedure. All participants achieved 100% accuracy on 10 practice trials before the formal experiment.

Recording and analysis of event-related potentials

An electroencephalogram (EEG) was recorded from 64 scalp sites using tin electrodes mounted on an elastic cap (Brain Products, Munich, Germany), with the references on the left and right mastoids and a ground electrode on the medial frontal aspect. The vertical electrooculograms (EOGs) were recorded supraorbitally and infraorbitally at the left eye. The horizontal EOG was recorded from the left versus right orbital rim. The EEG and EOG were amplified using a DC $\sim$100 Hz bandpass and continuously sampled at 500 Hz/channel. Interelectrode impedance was maintained below 5 kΩ for all electrodes. Averaging of ERPs was computed off-line. Eye movement artifacts (blinks and eye movements) were rejected offline and 16 Hz low-pass filter was used. Trials with EOG artifacts (mean EOG voltage exceeding $\pm 80\,\mu V$) and those contaminated with artifacts because of amplifier clipping, peak-to-peak deflection exceeding $\pm 80\,\mu V$ were excluded from averaging.

The EEG for correct response during each valence condition was averaged separately. The ERP waveforms were time locked to the onset of stimuli and the averaged epoch for ERPs was 700 ms including a 100 ms prestimulus baseline. As shown by Figs 1 and 2, conspicuous P2 and P3 components were elicited by each valence condition across the two participant groups. The P2 activity, irrespective of extraversion, was distributed mainly at central and frontal areas, whereas P3 amplitudes, which were broadly distributed across the scalp, were largest at posterior-parietal sites. Thus, the following 13 electrode sites were selected for statistical analysis: Fz, F3, F4, FC3, FC4, FCz, Cz, C3, C4 (nine frontal and central sites), CP3, CPz, CP4, and Pz (four parietal sites). The amplitudes (baseline to peak) and peak latencies of P2 (approximately 140–200 ms) and P3 (approximately 350–450 ms) were measured and analyzed. Repeated-measures analysis of variance (ANOVA) on the amplitudes and latencies of P2 and P3 components was conducted with valence (three levels: HP, MP, neutral) and electrode (13 sites) as repeated factors, and extraversion as a between-subjects factor. In addition, the amplitudes and peak latencies of frontal N1 (approximately 60–120 ms, see Figs 1 and 2) were analyzed at central and frontal sites, to see whether there are extraversion-related differences in early visual processing [11]. The degrees of freedom of the F-ratio were corrected according to the Greenhouse–Geisser method.

Results

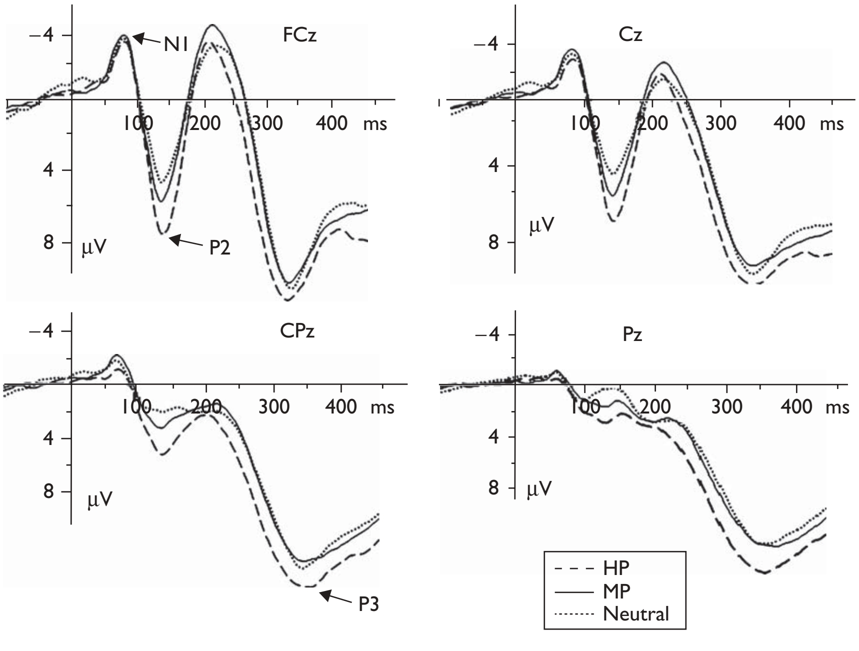
Behavioral data

False alarms were rare, as nearly all participants achieved 100% accuracy rates for both standard and deviant stimuli. The repeated-measures ANOVA on the reaction time (RT) data, which includes valence conditions as repeated factor and extraversion as between-subjects factor, showed no significant valence [$F(2,60) = 3.40$, $P > 0.05$] or extraversion [$F(1,30) = 3.69$, $P > 0.05$] main effect. However, there was a significant interaction effect between extraversion and valence [$F(2,60) = 3.97$, $P < 0.05$]. Further analyses of the interaction effect showed a significant valence effect in extraverts [$F(2,30) = 14.09$, $P < 0.001$]. RTs were shorter during HP condition (473 ms) than during MP [485 ms, $F(1,15) = 16.91$, $P < 0.01$] and neutral [483 ms, $F(1,15) = 14.38$, $P < 0.01$] conditions. In contrast, no significant valence effect was observed in controls [$F(2,30) = 1.43$, $P > 0.1$].

Event-related potential results

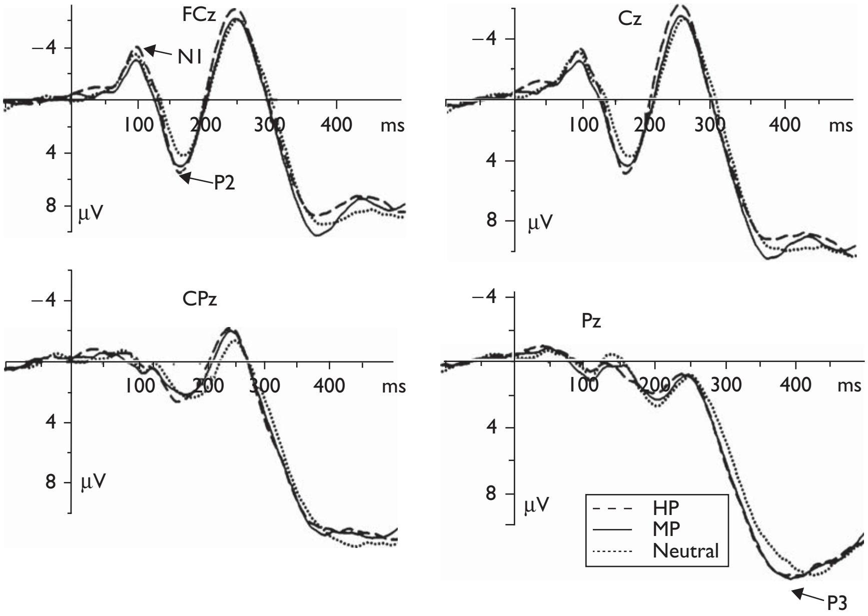
The repeated-measures ANOVA on N1 amplitudes showed no significant main or interaction effects, nor did the analysis on N1 latencies. The ANOVA on P2 amplitudes showed significant main effects at valence [$F(2,60) = 12.85$, $P < 0.001$] and electrode [$F(12,360) = 7.20$, $P < 0.01$], as well as a significant interaction effect between valence and extraversion [$F(2,60) = 5.45$, $P < 0.01$]. Moreover, the extraversion main effect was significant [$F(1,30) = 4.13$, $P < 0.05$], with greater positivity recorded in extraverts than in nonextraverts. The P2 amplitudes were larger at central and frontal sites than at posterior sites, irrespective of valence condition. The extraversion by valence interaction effect was broken down by examining valence effect in extraverts and nonextraverts separately.

Fig. 1



Grand-averaged event-related potentials during highly positive (HP), moderately positive (MP), and neutral conditions at FCz, Cz, CPz, and Pz electrode sites in extraverts.

Fig. 2



Grand-averaged event-related potentials during highly positive (HP), moderately positive (MP), and neutral conditions at FCz, Cz, CPz, and Pz electrode sites in nonextraverted controls.

The valence effect was significant in extraverts [F(2,30) = 12.01, $P < 0.01$], with larger amplitudes elicited during HP condition than during MP condition [F(1,15) = 5.95, $P < 0.05$]. The MP condition, in turn, elicited larger amplitudes than neutral condition [F(1,15) = 8.41, $P < 0.05$]. In contrast, the valence effect was not significant in nonextraverts [F(2,30) = 2.41, $P > 0.05$]. No other main or interaction effects were significant for P2 amplitudes, and there were no significant effects for P2 latencies, either.

Moreover, the repeated-measures ANOVA showed a significant main effect of electrode sites [F(12,360) = 28.01, $P < 0.001$] as well as a significant extraversion by valence interaction effect [F(2,60) = 5.83, $P < 0.01$] for P3 amplitudes. Although P3 amplitudes were distributed broadly across the scalp, the largest amplitudes of P3 were recorded at posterior parietal sites. The simple-effects analyses for the extraversion and valence interaction effect showed a significant valence effect in extraverts [F(2,30) = 6.47, $P < 0.01$]. HP condition elicited larger amplitudes than MP [F(1,15) = 13.37, $P < 0.01$] and neutral [F(1,15) = 7.51, $P < 0.05$] conditions. However, the amplitude differences during MP and neutral conditions were not significant [F(1,15) = 1.41, $P > 0.1$]. In contrast, there was no significant valence effect in nonextraverts [F(2,30) = 0.82, $P > 0.1$]. Analyses on P3 latency showed no other main or interaction effects except for a main effect of electrode sites [F(12,360) = 6.73, $P < 0.01$]. P3 latencies were longer at central parietal and parietal sites than at anterior sites.

Discussion

The analysis of N1 showed no significant main or interaction effects, which suggests that extraverts and controls are similar in early visual processing. Therefore, emotional processing and its interaction with extraversion may occur at later stages [11]. At about 170 ms after the onset of stimulus, a frontal P2 component was elicited in all three valence conditions. We found a significant valence and extraversion interaction effect on P2 amplitudes. Previous studies indicated that frontal P2 activity within 200 ms is related to a rapid process of feature detection that attends to salient emotional content [11]. With important adaptive values, emotionally salient stimuli elicit greater attentional resources than other stimuli in a short time, which leads to larger P2 amplitudes under emotional versus neutral conditions [15]. This study observed that positive stimuli, irrespective of valence intensity, elicited larger P2 amplitudes than did neutral stimuli in extraverts. This suggests that the emotional positivity of MP and HP images was detected by extraverts during the attentional stage. Furthermore, HP stimuli elicited increased P2 amplitudes compared with MP stimuli, suggesting that extraverts are sensitive to valence changes in positive stimuli such that HP stimuli, whose positivity was more pronounced, elicited increased attentional resources than MP stimuli.

As 170 ms is an early time point, the attentional bias of extraverts for positive stimuli, as well as their differential attentional allocation for positive stimuli of varying valence conditions, probably occurred automatically at this stage [16]. Therefore, apart from the well-known negative bias humans shared in emotional processing [17], there is an attentional bias of highly extraverted individuals for positive stimuli such that they are not only able to detect the emotional positivity rapidly but are also able to detect valence changes in positive stimuli automatically [16]. Conversely, nonextraverts showed no significant amplitude differences between valence conditions. This coincides with previous studies that reported similar brain reactions to positive images of diverse saliency [11], or to happy facial expressions of increasing intensities [12]. This suggests that nonextraverted individuals are less sensitive to the emotionality of positive stimuli, and insensitive to valence changes in positive stimuli. Being engaged in a distracting task, they processed positive and neutral stimuli similarly during attention stage. Moreover, they did not perceive the valence intensity differences between HP and MP stimuli in terms of early attentional allocation.

Moreover, the P3 peaked at about 400 ms poststimulus onset, and its largest peak amplitudes were recorded at parietal sites (Figs 1 and 2). On the basis of these attributes, the P3 observed in this study is a P3b component that has been accepted as an index for a controlled process that involves cognitive evaluation of stimulus meaning [11]. Information is represented and analyzed more fully, with more factors considered and more experiences referenced at this stage [11,13]. This study observed an extraversion by valence interaction effect on P3 amplitudes. HP condition elicited increased P3 amplitudes than did MP and neutral conditions. This suggests that highly extraverted individuals evaluated HP stimuli as more emotionally positive; consequently, they differentially processed these stimuli relative to MP and neutral stimuli. This was consistent with the behavioral data that RTs of extraverts were faster during HP than during MP and neutral conditions. Probably, the evaluation bias of extraverts for HP stimuli contributed to the largest amplitudes during the HP condition. Therefore, HP stimuli elicited enhanced cognitive resources, leading to faster motor preparation and execution. In contrast, the P3 activity induced by the three conditions remains similar in controls. Therefore, less-extraverted individuals are insensitive to valence differences in positive stimuli, such that they react similarly to positive stimuli of diverse valence conditions at both early attentional and later evaluation-related stages.

The biological basis underlying this individual difference, however, remains unclear and requires further attention. Studies that used neuroimaging and genetic measures have shown that the presence of A1 allele on the dopamine D2 receptor gene is a predictor for the reward sensitivity of orbitofrontal cortex and amygdala [18], whose reactions to positive stimuli were shown to correlate positively with the degree of extraversion [18]. Moreover, there was direct evidence showing higher scores of reward dependence, which characterizes the trait of extraversion [19], in individuals whose D2 dopamine receptor gene carries less-frequent alleles (for example, TaqI B1) [20]. Thus, the increased sensitivity of extraverts to positive stimuli may be underlain by certain genetic bases, which may influence the transmission of dopamine to cortical and subcortical areas associated with reward sensitivity (e.g. orbitofrontal cortex, amygdala). Possibly, the absence of A1 allele [18], or the presence of other less-frequent alleles on the dopamine D2 receptors [20] led to a better transmission of dopamine to the reward system and contributed, at least in part, to higher extraversion. Consequently, the reward system of extraverted individuals is more reactive to positive stimuli and differently susceptible to positive stimuli of diverse valence conditions. These assumptions, obviously, require examination in future studies using combined measures of neuroscience and genetics.

Conclusion

This study observed that, in contrast to the insensitivity of nonextraverted people to valence changes in positive stimuli, extraverts are differently susceptible to positive stimuli of diverse valences. Thus, the established conclusion that the human brain is insensitive to valence changes in positive stimuli is suitable only for less-extraverted individuals.

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References

1 Eysenck HJ. Biological dimensions of personality. In: Pervin LA, editor. *Handbook of personality: theory and research*. New York: Guilford Press; 1990. pp. 244–276.
2 Costa PT, McCrae RR. *NEO Five-Factor Inventory (NEO-FFI) professional manual*. Odessa: FL Psychological Assessment Resources; 1991.
3 Ashton MC, Lee K, Paunonen SV. What is the central feature of extraversion? Social attention versus reward sensitivity. *J Pers Soc Psychol* 2002; **83**:245–252.
4 Rusting CL, Larsen RJ. Extraversion, neuroticism and susceptibility to positive and negative affect: a test of two theoretical models. *Pers Individual Differences* 1997; **22**:607–612.
5 Gray JA. The neuropsychology of temperament. In: Strelau J, Angleitner A, editors. *Explorations in temperament: International perspectives on theory and measurement*. New York: Plenum Press; 1991. pp. 105–128.
6 Pascalis VD, Speranza O. Personality effects on attentional shifts to emotional charged cues: ERP, behavioural and HR data. *Pers Individual Differences* 2000; **29**:217–238.

7 Derryberry D, Reed MA. Temperament and attention: orienting towards and away from positive and negative signals. *J Pers Soc Psychol* 1994; **66**:1128–1139.

8 Canli T, Zhao Z, Desmond EJ, Kang E, Gross J, Gabrieli JDE. An fMRI study of personality influences on brain reactivity to emotional stimuli. *Behav Neurosci* 2001; **115**:33–42.

9 Canli T, Sivers H, Whiteld SL, Gotlib IH, Gabrieli JDE. Amygdala response to happy faces as a function of extraversion. *Science* 2002; **296**:2191.

10 Amin Z, Constable RT, Canli TH. Attentional bias for valenced stimuli as a function of personality in the dot-probe task. *J Res Pers* 2004; **38**:15–23.

11 Yuan JJ, Zhang QL, Chen AT, Li H, Wang Q, Zhuang ZCX, Jia SW. Are we sensitive to valence differences in emotionally negative stimuli? Electrophysiological evidence from an ERP study. *Neuropsychologia* 2007; **45**:2764–2771.

12 Leppanen JM, Kauppinen P, Peltola MJ, Hietanen JK. Differential electrocortical responses to increasing intensities of fearful and happy emotional expressions. *Brain Res* 2007; **1166**:103–109.

13 Ito TA, Larsen JT, Smith NK, Cacioppo JT. Negative information weighs more heavily on the brain: the negativity bias in evaluative categorizations. *J Pers Soc Psychol* 1998; **75**:887–900.

14 Bai L, Ma H, Huang Y, Luo YJ. The development of native Chinese affective picture system – a pretest in 46 college students. *Chin Mental Health J* 2005; **19**:719–722.

15 Carretié L, Mercado F, Tapia M. Emotion, attention, and the negativity bias, studied through event-related potentials. *Int J Psychophysiol* 2001; **41**:75–85.

16 Del Cul A, Baillet S, Dehaene S. Brain dynamics underlying the nonlinear threshold for access to consciousness. *PLoS Biol* 2007; **5**:0001–0016.

17 Bartussek D, Becker G, Diedrich O, Naumann E, Maier S. Extraversion, neuroticism, and event-related brain potentials response to emotional stimuli. *Person Individ Diff* 1996; **20**:301–312.

18 Cohen MX, Young J, Baek JM, Kessler C, Ranganath C. Individual differences in extraversion and dopamine genetics predict neural reward responses. *Cognitive Brain Res* 2005; **25**:851–861.

19 Depue RA, Collins PF. Neurobiology of the structure of personality: dopamine facilitation of incentive motivation and extraversion. *Behav Brain Sci* 1999; **22**:491–569.

20 Lee HJ, Kim Y-K, Kim L, Lee MS, Jung IK, Suh KY, Kim S. D2 and D4 dopamine receptor gene polymorphisms and personality traits in a young Korean population. *Am J Med Genet* 2003; **121B**:44–49.