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Event-related potential evidence of individual differences in the extravert-introvert personality dimension under stress*

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The aim of the present study is to elucidate the differences in neural correlates in a vigilance task performance according to stress level between extraverts and introverts. Forty-three subjects were assigned to two groups (21 extraverts; 9 males, 22 introverts; 9 males). Subjects in the two groups performed a vigilance task either under a social stress or not during the event-related potential (ERP) recording. Results showed that the response accuracies of both groups in the stress condition were higher than those in the no-stress condition. ERPs revealed that (1) N2-P2 peak-to-peak amplitudes and contingent negative variation (CNV) mean amplitudes in the introversion group were significantly greater than those in the extraversion group, (2) the N2-P2 peak-to-peak amplitudes increased significantly at Fz site in the stress condition in the extraversion group. These results suggest that introverts may sustain higher level of arousal than extraverts, regardless of stress condition, and extraverts may show augmented arousal or attention levels, specifically in performance under stress.

Key words : extravert-introvert personality dimension, social stress, arousal level, N2-P2 peak-to-peak, CNV

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Eysenck classified extraverts as easygoing, optimistic, adventurous, and sociable, whereas introverts as orderly, emotionally controlled, socially distant, and having only a few close friends (Carducci, 2009). He suggested that lower levels of cortical arousal in extraverts, in contrast to those in introverts, might be associated with the personality differences. Eysenck further hypothesized that the ascending reticular activating system (ARAS), which is known to regulate the level of cortical arousal, might be a cause of in the characteristic differences between extraverts and introverts (Eysenck, 1967, 1990). It was proposed that introverts have a lower threshold of the ARAS than extraverts, and consequently show greater responses to stimuli than extraverts (Stelmack, 1990). These are general formulations of Eysenck 's arousal hypothesis (Carducci, 2009).

Evidence for Eysenck's proposal of interaction between ARAS and the cortical arousal has been reported in spectral electroencephalogram (EEG) studies (Robinson, 1999; Schutter, Leitner, Kenemans, & van Honk, 2006). Those studies on the correlations between the extraversion-introversion dimension and the power spectrum of EEG have revealed that extraverts typically showed higher alpha band activity than introverts (Gale, Edwards, Morris, Moore, & Forrester, 2001; Matthews & Amelang, 1993; Tran, Craig, & McIsaac, 2001). Increased alpha wave has been known to be a representation of lower mental activities or relaxed states (Andreassi, 2007). In event-related potential (ERP) studies, the N1-P2 amplitude of evoked potentials was larger for introverts than for extroverts (Bruneau, Roux, Perse, & Lelord, 1984; De Pascalis & Montirosso, 1988). These studies have suggested that introverts show enhanced responsiveness concerning measures of electrocortical activities that are modulated by the ARAS and extraverts have lower levels of cortical arousal than those found in introverts.

De Pascalis (1994) attempted to evaluate that the physical stressor produced differential ERP and behavioral responses in subjects characterized by different personality traits. He showed that there was a negative correlation between extraversion and anterior P2 and N2 both in No-stress and Stress conditions. The anterior P2 and N2 were smaller in extraverts as compared with introverts. On anterior P2 and N2, there was also a significant interaction effect of stress factors (No-stress and Stress) and extraversion factors (extraverts and introverts). He suggested that the frontal cortex plays a determinant role in the differentiation between extraverts and introverts concerning the attention-discriminative ERP components (the P2 and N2 components) of the stimulus-recognition process. Evoked response studies also showed that the frontal ERP components were more

increased in introverts than extraverts (Bruneau, Roux, Perse, & Lelord, 1984; Stelmack, 1990). In the present study, visually evoked N2-P2 component was examined as index of arousal level in introverts and extraverts under social situational stress. A social situational threat was used as a stressor instead of a physical stressor, because it has been reported that most physical stressors do not elicit psychological stress responses directly, but physical stressors elicit cognitive appraisal of demand and threat in experiments (Goldberger & Breznitz, 1982; Lazarus & Launier, 1978).

Contingent negative variation (CNV) is a steady, relatively long-lasting, negative shift in the brain activity, which develops between the time of a warning signal (S1) and a second signal (S2: imperative stimulus) (Walter, Cooper, Aldridge, McCallum, & Winter, 1964). Previous studies came to the results that CNV indicates expectancy (Cohen & Walter, 1966), an intention to act (Low, Borda, Frost, & Kellaway, 1966), subjective motivation (Irwin, Knott, McAdam, & Rebert, 1966), or attention (McAdam & Seales, 1969; Tecce, 1972). Moreover, Tecce (1972) hypothesized that the CNV amplitude is monotonically related to attention; that is, as attention increases, CNV also increases. Low and McSherry (1968) suggested another hypothesis that the anticipation of greater energy expenditure was related to higher CNV amplitude; that is, as psychological effort increases, CNV increases as well. We hypothesized that CNV could reflect the different attention level or psychological effort under social stressors between introverts and extraverts.

The aim of this study was to find out the differences in neural activities by measuring ERP components, as well as to identify the differences in behavioral responses between extraverts and introverts under a social stress. Kaiser, Hinton, Krohne, Stewart, and Burton (1995) reported that introverts exhibited more tension than extraverts under social stress such as speech preparation in anticipation of exposure to the public (Kaiser et al., 1995). Jonassaint et al. (2009) demonstrated that higher extraversion was associated with lower cardiovascular reactivity during mental stress tasks and appeared to influence the expression and management of anger. The social stress in the present study consisted of a social situational threat, namely that the subjects w ould be asked to give a public speech when they would fail a visual monotonous task.

Methods

Subjects In this study 606 undergraduate university students (248 males, 358 females) aged between 18 and 40 years (M=22.53,

Table 1. Mean scores of Korean version of Eysenck Personality Questionnaires

	Eysenck personality dimension					
	E axis		N axis		P axis	
Group	M	SD	M	SD	M	SD
Extraverts (n=21)	11	0.830	6	1.189	2	1.884
Introverts (n=22)	4	2.128	6	1.182	1	1.006

SD=2.58) took part in an online questionnaire using the Korean version of Eysenck Personality Scales (K-EPS). Subjects who were in the top 20% or bottom 20% of this dimension were selected and screened according to scores of neuroticism and psychoticism dimension of the K-EPS (see Table 1.). Consequently, forty-three participants, consisting of twenty-one extraverts (9 males, 12 females) and twenty-two introverts (9 males, 13 females), aged between 19 and 28 years (M=21.91, SD=2.31), were selected for this study. Four participants (2 extraverts, 2 introverts) were excluded due to data acquisition malfunction or poor data quality caused by excessive eye blink or artifacts in the ERP recordings. All participants provided informed consent prior to the administration of the procedures, and these procedures were approved by the Ethics Committee.

Apparatus and Stimulus The entire experimental procedure was performed in an electrically shielded and sound insulated room with dimmed lighting. Participants were seated in front of a 19" flat CRT monitor (Samsung, Seoul, Korea; 60Hz refresh ratio) at a distance of approximately 65 cm to the screen. All tests were conducted with an Intel dual core class computer with a 256MB video card (NVIDIA Co., Santa Clara, CA), using presentation software Superlap 4.0 (Cedrus Co., San Pedro, CA). The behavioral response data were collected by using an RB-730 response pad (Cedrus Co., San Pedro, CA). A DIO-24 card (Measurement Computing, MA) was used for sending digital triggers to the electrophysiological signal recording system to mark the exact onset time and condition of stimulus.

Electrophysiological signals (Electroencephalogram; EEG, Electrooculargram; EOG) were collected from Ag/AgCl electrodes (Grass F-E5SHC; Grass-Telefactor, MASS) and amplified by Grass Model 12A5 amplifiers (Grass-Telefactor, MASS). EEG/EOG signals were digitized to 512Hz by an Intel quad core class computer equipped with National Instrument NI USB-6259 data acquisition board and Labview 2009 (National Instrument Co., Austin, TX).

The background color of the entire stimuli set was gray. A '+' was used as the fixation point before target figures were shown on this part of the screen (size = 2.64×2.64cm, visual angle = 2.60°×2.60°). Cue was red or blue circle (size = 3×3cm, visual angle = 2.64°×2.64°) and a combination of yellow and green circles (size = 3×9cm, visual angle = 2.64°×7.92°) were used as target figures. There were 4 types of target figures: an upper green circle and lower yellow circle, an upper yellow circle and lower green circle, two green circles, and two yellow circles. The radius of each target circle was 3cm, as was the distance between the circles.

Task The monotonous vigilance task began with a fixation period of 1000ms. After the first fixation, one of the two cues was presented and lasted for 300ms on the screen. There were two cues to designate a response mapping for the vigilance task in this experiment. Cue one, a red circle, indicated that the right button should be pressed when the target figures had the same color and the left button should be pressed when the target figures consisted of different colors. Cue two, a blue circle, indicated that the left button should be pressed when the target figures were the same color and the right button should be pressed when the target figures consisted of different colors. Each cue was followed by a blank screen for 700ms and the fixation point appeared again. Following the second fixation, one of the target figures was presented for 500ms. Subjects were asked to respond as quickly as possible when the target appeared. After the target figures, a blank screen appeared as the inter-trial stimulus. Inter-trial intervals alternated and the average of intervals was 1200ms (see Figure 1).

Each experimental block contained 72 trials: 32 red cue trials, 32 blue cue trials, and 8 dummy trials. In most instances the red cue trials were followed by the blue cue trails. The dummy trials were exactly the same as the red and blue cue trials. They were inserted to prevent habituation and break the repeated order

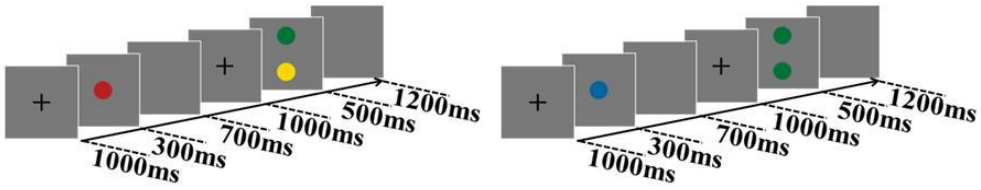

Figure 1. Details of the vigilance task. The red cue presented and the target figures consisted of different colors. Subjects should press left button (the left-hand side). The blue cue presented and the target figures consisted of same colors. Subjects should press left button (the right-hand side).

of red and blue cue trials. The two cues were counterbalanced across the subjects.

Stressor A social situational threat as social stressor was induced by using the following oral instruction: *Your performance level of correct responses was lower than that of the average performance level of the participants. I will give you one more chance to improve your performance. You are going to perform the same task. If you are unable to reach an above average performance level, you will have to explain the reason for your failure to the public.* Regardless of their performance level, each subject was given the same set of instructions by the experimenter after the first experimental session.

Procedure Prior to the experimental session, subjects completed the Korean version of State-Trait Anxiety Inventory (STAI), and performed a practice block containing 10 trials in order to familiarize them with the task. At the first experimental session, ERPs were recorded during the period in which the subjects performed the monotonous vigilance task. The result of the first session served as a baseline measurement. After the first session, the social situational threat stress was given to subjects. ERPs were recorded again while subjects performed the same task in the second experimental session. The subjects' stress level was measured again by using the STAI-State (STAI-S) after the second experimental session. Lastly, to remove stressor, subjects were informed that they had succeeded in getting high performance level and they did not have to explain the causes of their failure to public (see Figure 2).

ERP recording and Analysis The EEG was recorded from 14 channels with Ag/AgCl

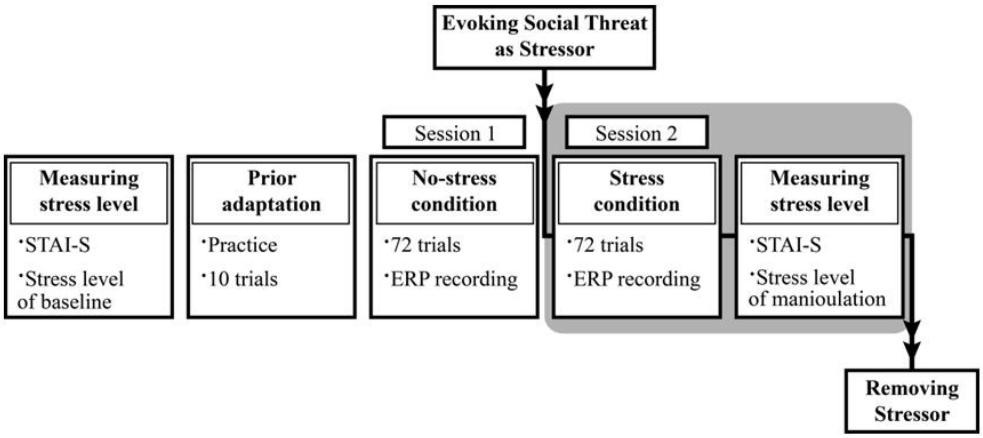

Figure 2. Details of experimental procedure

electrodes (Fz, F3, F4, Cz, C3, C4, Pz, P3, P4, Oz, O1, O2, T5, and T6) as defined by the international 10/20 system (Jasper, 1958). The right earlobe (A2) was used as reference during recording data. A ground electrode was placed on the center of the forehead. The EOG generated from eye blinks or eye movements was recorded using Ag/AgCl electrodes placed approximately 1 cm above and below the participant's right outer canthus. All EEG electrode impedances were below 5kΩ and the EOG electrode impedances were below 10kΩ. Electrophysiological signals were amplified and filtered (amplification = 20,000. Band-pass filter = 0.1 ~ 100 Hz). EEG/EOG signals were digitized at 512Hz.

The offline data analysis was conducted with EEGLAB (version 9.0.4.5 stable) running under Matlab 2009a (The Mathwork, Inc.) (Delorme & Makeig, 2004). All EEG activities were re-referenced to the mean of the right and left earlobe voltages. Additionally, the raw EEG data were re-sampled to 256 Hz and filtered using band-pass filter of 0.1 and 30Hz. Every single-trial epoch was extracted for 200ms before the stimuli onset. The mean of these voltage values was used as a baseline of each epoch. Trials with artifacts were defined as abnormal voltages of over ±50 μV. The artifact trials were rejected and individual EOG artifacts were additionally removed using the results of independent component analysis (ICA).

N2-P2 peak-to-peak amplitude. In order to analyze N2-P2 peak-to-peak amplitude, epochs were extracted using a time window which started 200ms before, and ended 1000ms after, the first fixation onset. To find peak voltage and latency of N2, a measurement window of 100-200ms was used and the time point of minimum voltage value within the measurement window was defined as N2 peak latency of grand mean at Fz site. In a similar manner, in order to find the peak voltage and latency of P2, a measurement window of 200-300ms was used and the time point of maximum voltage value within the measurement window was defined as P2 peak latency of grand mean at Fz site. These fixed N2 and P2 peak latencies were used to determine the voltage of individual N2 and P2 peaks. After finding individual N2 and P2 peaks, N2-P2 peak-to-peak amplitude was calculated by subtracting the N2 peak from P2 peak (see Figure 4).

CNV mean amplitude. For analyzing CNV mean amplitude, epochs were extracted using a time window that began 200ms before and 2200ms after the second fixation onset. CNV mean amplitude was quantified by using the measurement window of 400-1300ms at the Cz site (see Figure 6).

Statistical procedure. All statistical procedures were conducted under SPSS (version 12.0.1). Data, except STAI-S scores, were analyzed with a two-way mixed analysis of variance (ANOVA), including the within factors stress (No-stress and stress condition) and between factors personality (extraverts and introverts group). In order to compare mean differences on each personality factor and stress factor, two-tailed paired t-tests were used respectively.

Results

Behavioral data

Measurement of STAI-S. The result of the one tailed t-test on the STAI-S score showed a stress manipulation effect on both the extravert and introvert groups. The STAI-S score for extraverts in the Stress condition (M = 44.84, SE = 2.736) increased significantly in comparison to the No-stress condition (M = 40.11, SE = 2.285), $t(18) = -2.048$, $p < .05$. Also, the STAI-S score for introverts in the Stress condition (M = 45.55, SE = 1.860) significantly increased compared to the No-stress condition (M = 38.85, SE = 1.873), $t(18) = -2.048$, $p < .05$. These results indicate that the level of anxiety in both groups increased as a result of social situational threat stress (see Figure 3.).

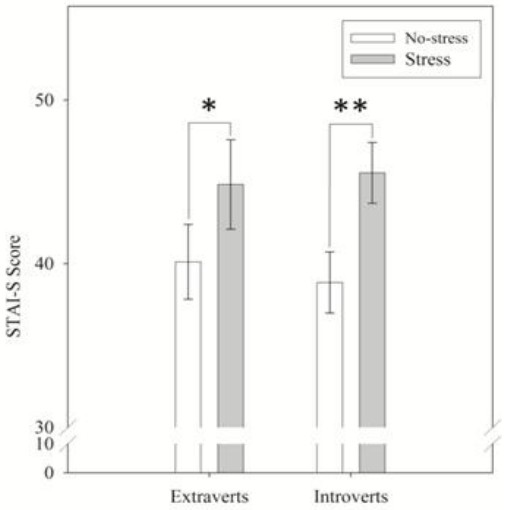

Figure 3. Mean STAI-S score. The STAI-S scores of both extraverts and introverts group were increased after evoking social situational threat. Therefore, this result guaranteed that both groups were stressed by the stressor.

Response accuracy. A two-way mixed analysis of variance (ANOVA) on the response accuracy, with within-factors of stress (No-stress and Stress condition) and between-factors of personality (extraverts and introverts group), showed the significant main effects of stress, $F(1, 37) = 11.499$, $p < .01$. However, there was no-significant interaction effect between stress and personality.

A two tailed t-test showed that the response accuracy of extraverts in the Stress condition (M = 96.05, SE = 0.897) was higher than the response accuracy in the No-stress condition (M = 92.599, SE = 1.543), $t(18) = -2.539$, $p <$

.05. In addition, for introverts, the response accuracy in the Stress condition (M = 96.80, SE = .646) was also significantly higher than the response accuracy in the No-stress condition (M = 94.531, SE = 0.985), t(19) = -2.228, p < .05. There was no significant difference in response time.

Response time. A two-way mixed analysis of variance (ANOVA) on the response time, with within-factors of stress (No-stress and Stress condition) and between-factors of personality (extraverts and introverts group), showed no significant main effects of stress, F(1, 37) = .245, p > .05, no-significant interaction effect between stress and personality, F(1, 37) = .072, p > .05, and no-significant between-subject effect of personality, F(1, 37) = 2.001, p > .05.

ERP data

N2-P2 peak-to-peak amplitude at Fz. A two-way mixed analysis of variance (ANOVA) on N2-P2 peak-to-peak amplitude at Fz, with within-factors of stress (No-stress and Stress condition), and between-factors of personality (extraverts and introverts group), shows a significant interaction effect between stress and personality, F(1, 37) = 9.677, p < .01 and a significant between-subject effect of personality, F(1, 37) = 6.142, p < .05. A two tailed t-test showed that the N2-P2 peak-to-peak amplitude of extraverts (M = 3.251, SE = .721) was larger in the Stress condition than the N2-P2 peak-to-peak amplitude of extraverts in the No-Stress condition (M = .982, SE = .817), t(18) = -2.393, p < .05. However, there was no significant difference in the N2-P2 peak-to-peak amplitude of the introvert group between the No-stress and the Stress conditions.

A two tailed t-test showed that the N2-P2 peak-to-peak amplitude of extraverts (M = 3.251, SE = .721) was larger in the Stress condition than the N2-P2 peak-to-peak amplitude of extraverts in the No-Stress condition (M = .982, SE = .817), t(18) = -2.393, p < .05. However, there was no significant difference in the N2-P2 peak-to-peak amplitude of the introverts group between the No-stress (M = 5.092, SE = .847) and the Stress condition (M = 3.81, SE = .718), t(19) = 1.961, p > .05.

The N2-P2 peak-to-peak amplitude of introverts (M = 5.092, SE = .847) was significantly larger in the No-stress condition than the N2-P2 peak-to-peak amplitude of extraverts in the same condition (M = .982, SE = .817), t(37) = -3.486, p < .01. In the Stress condition, there was no significant N2-P2 peak-to-peak amplitude difference between extraverts and introverts. These results indicate that in the No-stress condition the N2-P2

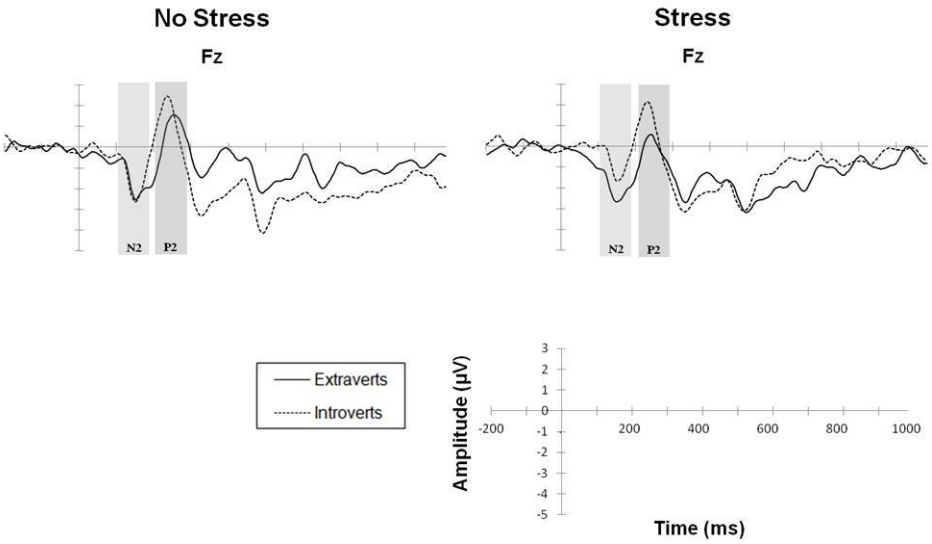

Figure 4. Grand mean of ERP waveform at Fz. To find the N2 peak, a measurement window of 100-200ms was used and to find P2 peak, the measurement window of 200-300ms was used.

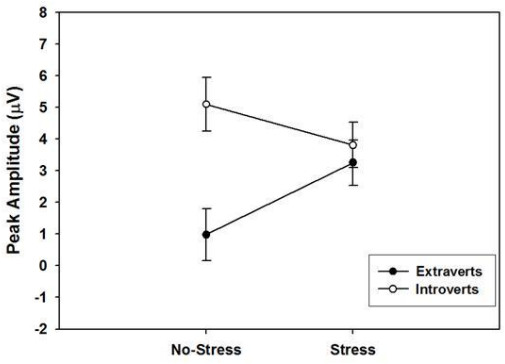

Figure 5. N2-P2 peak-to-peak amplitude at Fz

peak-to-peak amplitude of extraverts is smaller than the N2-P2 peak-to-peak amplitude of introverts, whereas there is virtually no difference in amplitude between both personality groups in the Stress condition. Consequently, only extraverts showed increased N2-P2 peak-to-peak amplitude after being stressed (see Figure 4 and 5).

Mean amplitude of CNV at Cz. A two-way mixed analysis of variance (ANOVA) for the mean amplitude of CNV at Cz, with within-factors of stress (No-stress and Stress condition) and between-factors of personality (extraverts and introverts group), showed significant main effects of stress, $F(1, 37) = 5.782$, $p < .05$ and significant between-subject effect of personality, $F(1, 37) = 4.199$, $p < .05$. However, there was no-significant interaction effect between stress and personality.

A two tailed t-test showed no significant difference in the mean amplitude of CNV for

the extraverts group between the No-stress (M = -4.445, SE = .710) and the Stress condition (M = -5.612, SE = .7351), t(18) = 2.010, p > .05 and for introverts group, there was no significant difference in the mean amplitude of CNV between the No-stress (M = -6.658, SE = .691) and the Stress condition (M = -7.240, SE = .708), t(19) = 1.306, p > .05.

In the No-stress condition, the mean amplitude of CNV of introverts (M = -6.658, SE = .691) was significantly greater than the mean amplitude of CNV of extraverts (M = -4.445, SE = .710), t(37) = 2.234, p < .05. There was also no significant difference of mean amplitude of CNV in the Stress condition between extraverts and introverts. These results mean that the mean amplitude of CNV was increased after both groups were stressed and introverts showed greater the mean amplitude of CNV than extraverts. There was an increasing tendency of the mean amplitude of CNV in extraverts after they were stressed, t(18) = 2.010, p= .06. (see Figure 6 and 7).

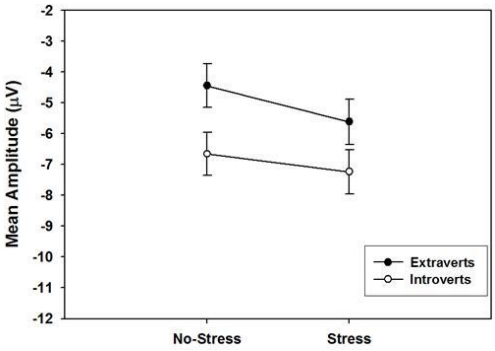

Figure 7. CNV mean amplitude at Cz

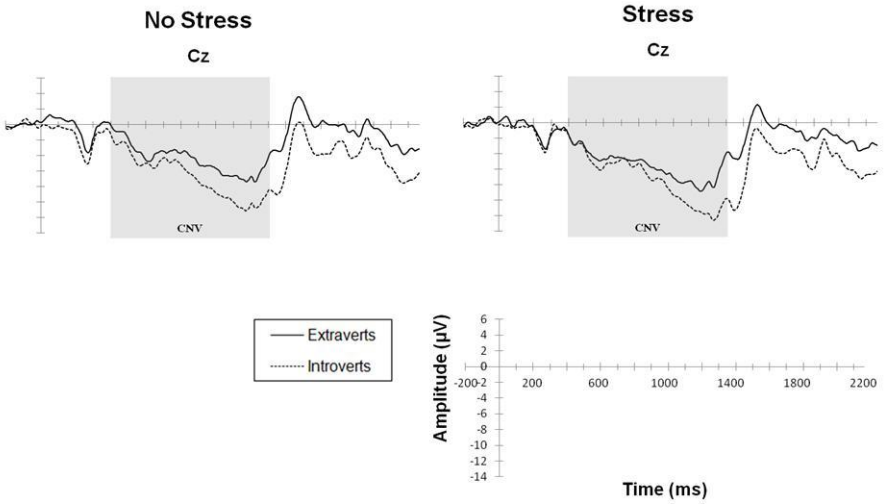

Figure 6. Grand mean of ERP waveform at Cz. CNV mean amplitude was quantified by using the measurement window of 400-1300ms

Discussion

The purpose of the present study was to investigate the differences in behavioral responses and ERPs to a social stress according to individual differences in the Extraversion dimension of personality. The STAI-S scores of both extraverts and introverts group increased after an anxiety-producing potential event was introduced to provoke social stress. According to the arousal hypothesis, introverts' arousal level is higher than extraverts' because introverts have a lower threshold of ARAS than extraverts (Eysenck, 1967, 1990). In the No-stress condition, the N2-P2 peak-to-peak amplitude at Fz was greater for introverts compared to that for extraverts. In other words, introverts showed a higher level of cortical arousal than extraverts in the No-stress condition. This result is consistent with findings from De Pascalis (1994) that anterior P2 and N2 were greater for introverts as compared to extraverts in the No-stress condition. He suggested that the frontal cortex has a role in differentiating introverts from extraverts as regards attention-discriminative ERP components. This finding is also consistent with other findings showing that P2 peak amplitude was greater for introverts as compared to extraverts (De Pascalis & Montirosso, 1988; Stelmack, Achorn, & Michaud, 1977).

Although we could not counterbalance sequences of the stress and no stress conditions due to the different duration of recovery from social situational stress responses between the subjects, after the social situational stress was presented to both groups, extraverts showed significantly increased N2-P2 peak-to-peak amplitude, whereas introverts did not show significant changes in N2-P2 peak-to-peak amplitude. Thus, the interplay between personality and stress could be found. This result is again consistent with findings from De Pascalis (1994). In his experiment, extraverts had an increased anterior P2 and N2 in the Stress condition, which is associated with a greater level of arousal. In contrast, introverts did not show a significant difference in anterior P2 and N2 between the No-stress and Stress conditions. This result might be due to a high level of baseline arousal from the beginning of the experiment, i.e. introverts ' arousal level might have been almost maximal from the outset of No-stress condition. Therefore, an additional increase of arousal level might be harder to achieve.

Previous studies did not show significant differences in arousal levels between introverts and extraverts in the baseline phase in electrodermal activity or EEGs. In the present study, however, both groups showed different arousal levels in the baseline phase in the

No-stress condition. Although introverts were not presented with the stress-provoking potential situation in the No-stress condition in the present study, they could regard the experimental situation as a stressful event. For this reason, introverts could not show a significant difference of N2-P2 peak-to-peak amplitude between the No-stress and the Stress conditions in the present study.

CNV in the present study was significantly increased in both groups in the Stress condition. In particular, introverts showed greater mean amplitude of CNV than extraverts. Tecce (1972) hypothesized and found a supporting piece of evidence that CNV amplitude is monotonically related to attention; that is, as attention increases, CNV increases. Low and Mcsherry (1968) suggested that the anticipation of greater energy expenditure was related to higher CNV amplitude. Consequently, introverts might show higher attention levels and a higher degree of psychological effort than extraverts. Although in CNV mean amplitude there was no-significant interaction effect between stress and personality, there was an increased tendency of the mean amplitude of CNV in extraverts after they were stressed.

The results of the present study suggest that introverts and extraverts differ in using their resources when they perform cognitive tasks. Introverts might show a higher level of cortical arousal than extraverts to solve a problem in real situations supporting the arousal hypothesis (Eysenck, 1967, 1981). In conclusion, dimensions of extraversion-introversion can predict different behavioral response patterns and arousal levels in extraverts and introverts in usual conditions as well as under social stresses.

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스트레스 상황에서 외향적-내향적 성격 차원에 따른 사건관련전위의 개인차 연구

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본 연구에서는 사건관련전위(event-related potentials: ERPs)를 사용하여 외향적인 사람들과 내향적인 사람들이 경계과제를 수행할 때 스트레스 유무에 따라 발생하는 뇌신경 활동의 차이를 밝히고자 하였다. 마흔 세 명(외향성 21, 내향성 22)의 피험자들을 각각 외향성 집단과 내향성 집단으로 나누어서 사회적 스트레스 요인이 없는 상황과 사회적 스트레스 요인이 있는 상황에서 경계과제를 수행하는 동안 사건관련전위를 측정하였다. 행동반응에서는 두 집단 모두 사회적 스트레스 요인이 있는 경우에 정확도가 증가하였다. 사건관련전위에서는 첫 번째, 내향성 집단의 경우에 사회적 스트레스 요인 유무에 관계없이 N2-P2 최고점간 진폭과 CNV(contingent negative variation) 평균진폭이 외향성 집단 보다 유의미하게 크게 나타났다. 두 번째, 외향성 집단의 경우에 사회적 스트레스 요인이 있는 경우에만 전두엽 부위(Fz)에서 N2-P2 최고점간 진폭이 유의미하게 증가하였다. 이러한 결과는 동일한 사회적 스트레스 요인이 외향적-내향적 성격에 따라 상이한 뇌신경활동에 의해서 매개될 수 있다는 것을 보여주며, 내향성 집단이 외향성 집단 보다 더 높은 각성 수준과 주의 수준을 유지하고 있음을 시사한다.

주제어 : 외향적-내향적 성격 차원, 사회적 스트레스, 각성 수준, N2-P2 최고점간 진폭, CNV