International Journal of Bio-Science and Bio-Technology
Vol.5, No.5 (2013), pp.1-12
http://dx.doi.org/10.14257/ijbsbt.2013.5.5.01

Neurophysiological and Behavior Responses in Emotion Regulation

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Abstract

Emotion regulation is the ability to modify the intensity and time course of emotional experiences and expressions to manage arousal, such as negative and positive responses. Emotion regulation is crucial for the development of adaptive social functioning. Few studies have a measurement method for identifying neural markers to examine the correlation between neural and behavior response of emotion regulation. We assessed whether neural and behavior responses to attention-emotion integration task were related to emotion regulation capacities. Before and after the negative and positive video clips were shown, EEG was recorded while participants performed attention-emotion integration task. P100, P300 amplitude, and latency were closely correlated with each other. Specially, after the negative video clip was shown, the larger the P100 amplitudes at the specific positions, the longer the P300 latencies at these same positions during attention-emotion integration task. The longer the P300 latencies at the specific positions, the longer the delay in response time. Also, there is and individual differences in ERP components and response time during attention-emotion integration task. Individuals who had larger and longer amplitude and latency of ERP components showed longer response times during attention-emotion integration task, regardless of whether video clips were presented or not. This characteristic was related to the enhanced emotion regulation.

Keywords: *Emotion regulation, Face processing, Attention-Emotion Integration, Event-Related Potentials (ERPs)*

1. Introduction

Research on emotion regulation has increased in many different fields, such as social, clinical, developmental, and cognitive psychology [1]. From a clinical perspective, the lack of emotion regulation is related to mood disruptions and behavioral problems [2]. In particular, from a developmental perspective, emotion regulation may be fundamental to develop cognitive and affective capabilities [3, 4]. More recent research suggests that the interplay between emotion and cognition is the main concept of emotion regulation [5, 6]. Despite the increase in these interests, few methodological and empirical studies have been conducted on integration of emotion-cognition and emotion regulation.

Although research on the neural bases of emotion regulation have been dominated by functional magnetic resonance imaging (fMRI) studies, event-related potentials (ERPs) are suitable to measure affective and cognitive processes related to emotion regulation because of their excellent temporal resolution [7]. Recent studies on emotion regulation use ERPs as measurement tools for identifying neural markers for emotion regulation.

ISSN: 2233-7849 IJBSBT

These studies have examined ERP components, such as P1, Nc, N2, and P3 to evaluate the ability to perform on cognitive and attentional tasks under emotional processing demands. Dennis suggests that larger P1 and Nc amplitudes were correlated with more effective emotion regulation [8]. Nc and P1 would index to predict emotion regulation capacities in response to task-irrelevant emotional faces before attention tasks. In another study, Lewis examined ERP markers for emotion regulation during completions of a Go/No-go task under emotional demands [4]. Frontal P3 and N2 amplitudes and latency were larger and longer in the No-go task compared to the Go task. Thus, they suggest that the frontal P3 and N2 components were associated with inhibitory control. These studies show that when inhibitory control is required in emotional information, enhanced ERPs related to cognitive control are associated with more adaptive emotion regulation. However, it remains unclear whether these neural responses predict measures of emotion regulation. Also, the correlation between ERP markers and behavior responses is unclear.

Emotional states can influence cognitive and behavior processes [9], and regulate the allocation of processing resources [10]. Thus, a negative mood leads to impairment in other cognitive tasks because a negative emotional state is supposed to achieve capacity dominance that would be allocated to the cognitive task at hand. Kliegel suggests that P3 is a psychophysiological indicator of cognitive resource allocation, and low P3 amplitude indicates reduced information-processing capacity, particularly after a negative video clip compared with positive and neutral stimuli [11]. This shows that ERP components related to cognition and attention tasks can be affected by an emotional stimulus. Moreover, there are individual differences in how each emotion changes over time and interacts with cognitive processes. Affective style refers to individual differences in valence features of emotional reactivity and regulation [12]. Specific parameters of affective style can be measured using dynamics of emotional responding, such as latency, peak, and decay of emotional responses [13]. The impact of affective style is linked to how these emotional characteristics influence, and are influenced by, cognitive control, attention, memory, and other cognitive processes [14]. From a perspective of emotion-cognition integration, research on affective style in emotion regulation can help detection of a neural marker of emotion regulation.

Previous studies have predicted emotion regulation capacity by attention performance during attention tasks and ERP markers as neural responses to task-irrelevant emotional faces as distracter before an attention task. However, there is still ambiguity about whether these ERP markers reflect the emotion regulation capacity. Thus, the following questions arise: 1) What ERP markers can be used in relation to neural response in our attention-emotion task? 2) How are these ERP markers affected after an emotional stimulus, such as video clip? 3) What will emotional after-effect do to the correlation between neural response and behavior response? 4) Are there individual differences in the variance of ERP markers after an emotional stimulus?

Emotional after-effects and individual differences in neurophysiological measures of emotion regulation have not before been examined. Thus, the aim of the present study was to examine whether neurophysiological markers can effectively reflect emotion regulation capacity of individuals in a paradigm similar to that described in Bush and Shin [15], whereby emotion regulation capacity could be evaluated. This was tested by examining the characteristics of ERP components when an attention-emotion task was performed before and after an emotional video clip. We hypothesized that although strong enough in emotion induction, if the affective style of ERP markers are not changed during an attention-emotion task after an emotional stimulus, the ERP markers would reflect emotion regulation capacity.

Here we show that first, there is correlation between the P100 component related to emotional face processing and the P300 component related to selective attention. Second, a negative emotional stimulus reduces the amplitude of P100 and P300 and increases the latency of P100 and P300 by after effect. Third, there is a correlation between the ERP response (P100 and P300) and behavioral response (response time), and the correlation remains even after the emotional stimulus. Finally, there are individual differences in the affective style of ERP markers during the attention-emotion task before the emotional stimulus. The affective style is maintained after the emotional stimulus. Thus, ERP markers could be associated with emotion regulation capacity.

2. Methods

2.1. Participants

Nineteen right-handed graduates from the Yonsei University (ten male, nine female; mean age: 30 years) participated. Participants were free from psychiatric and neurological disorders. Written informed consent was obtained and volunteers were paid for participation. The study was approved by the Severance hospital review board.

2.2. Materials and Procedure

Pictures for emotional face processing were selected from the FACES 3.3.1 database at the Max Planck Institute for Human Development [15]. Pictures included a set of images of naturalistic faces of 144 younger men, displaying six facial expressions: neutrality, sadness, disgust, fear, anger, and happiness. Three digits, two matching and one different, were presented around the nose of the emotional face. The single different digit was the target number. For example, given 232, the digit 3 would be target number. Video clips to evoke 2 negative and 1 positive emotion were selected from Korea Human Documentary-LOVE (sadness) made by Munhwa Broadcasting System, and America's Funniest Home Video (joy) made by ABC.com, respectively.

2.3. Procedures

Participants participated in three sessions (2 sessions: sadness; 1 session: joy) that were conducted at the same time of day. After taking a 10-minute break with their eyes open, the attention-emotion task was presented to familiarize participants with the protocol prior to the experiment.

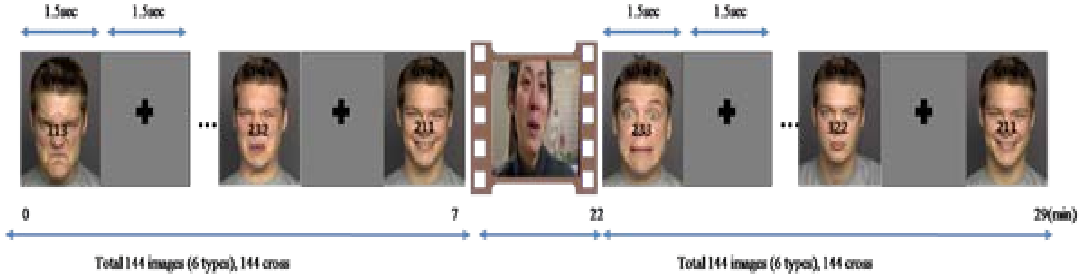

Figure 1. Diagram of Experimental Design

During the experiment, 144 pictures with six facial types and 144 fixation cross pictures were presented 24 times for 1.5 seconds. The three numbers (*e.g.*, 1, 2, 3) on an emotional face were presented at random. Participants were asked to press target button (indicating the digit that is different from the other two) using a number keypad, which was made in laboratory. Response time was recorded at this moment. After the attention-emotion task, a negative or positive video clip was shown for 15 minutes and the attention-emotion task was performed again to examine emotional after-effect.

2.4. Neurophysiological Recording and Data Analysis

Electroencephalography (EEG) was continuously recorded during the task. EEG was recorded with electrodes positioned according to the international 10-20 method of electrode placement, including the earlobes. The ground electrode was placed at the back of the neck (Iz), whereas the reference electrode was placed on the right and left ear, (A1+A2) reference. Eye movement artifacts were corrected using ICA algorithm. All electrode impedances were under 5kΩ. EEG was amplified using a Biopac MP150 TM system, band-pass filtered (0.1-100Hz), and digitized at a sampling rate of 1000 Hz. The high-pass filter of the EEG signal was set to 0.5 Hz, and the low-pass filter was 100 Hz. The 60 Hz notch filter was on at all times. ERP waveforms were obtained by stimulus-locked averaging from 0 ms to 1000 ms after baseline correction. P100 (100-200 ms) and P300 (250-450 ms) components elicited by faces and numbers vs. fixation cross were compared by analyzing mean amplitudes and peak latencies at F3, F4, Cz, and Pz positions after stimulus onset. EEG data of three participants were excluded from analyses in the sadness session due to poor quality EEG recording.

3. Results

3.1. Manipulation Check

The subjective and external mood ratings are reported. As summarized in Table 1, the participants' self-ratings confirm that the positive video clip did indeed induce a positive valence, while the negative video clip induced a negative valence.

Table 1. Participants' Valence self-rating

Video condition	Rating M (S.D.)
Negative	3.192982 (0.74255)
Positive	2.590909 (0.85407)

Note: The 4-point scale ranged from 1 (almost never) to 4 (almost always).

3.2. Electrophysiological Response

ERP waveforms during the attention-emotion task with emotional face as a distracter are represented in Figure 2. An early-emerging P100 peak appeared to be related to the presentation of the emotional face, and a later-emerging P300 peak was associated with selective attention. These ERP waveforms showed the same pattern after an emotional stimulus, regardless of the type of stimulus. Figure 2 shows that the amplitudes of P100 and P300 slightly decreased, and the latencies of P100 and P300 slightly increased, after an emotional stimulus.

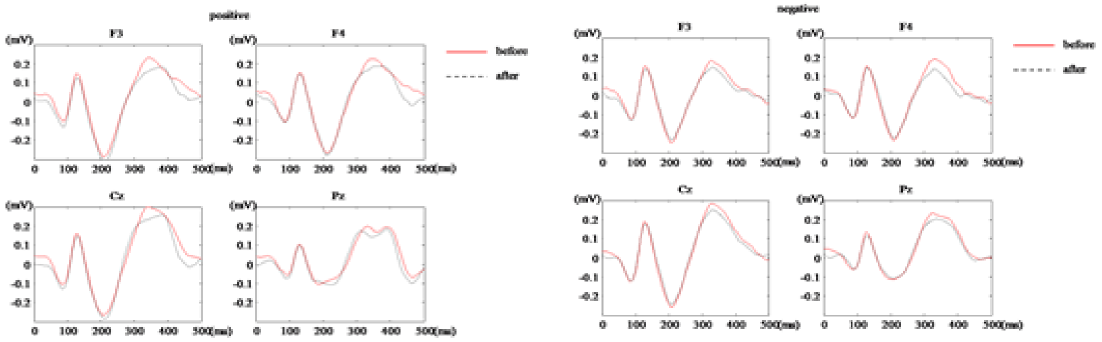

Figure 2. P100 and P300 ERP Results. Average ERP for Attention-emotion Task Before and After Negative and Positive Stimulus at F3, F4, Cz, and Pz

3.3. Correlations between P100 and P300 Components

To detect a relation between P100 and P300 during the attention-emotion task, we tested whether a correlation between P100 and P300 components exists. A significant positive correlation was found between P100 amplitude at F3, F4, and Cz, and P300 latencies at the same positions. P100 latencies at F3 and F4 had a significant positive correlation with P300 latencies at all positions. Also, P100 amplitude at F4 had a positive correlation with P300 amplitude at all positions. P300 amplitude at Cz had a positive correlation with P100 amplitude at the F3, F4, and Cz positions. In addition, P300 amplitude at Pz had a negative correlation with P100 latencies at the F3 and F4 positions. Table 2 shows that the larger the P100 amplitude, the longer the P300 latency at the F3, F4, and Cz positions. Table 3 represents the correlation of ERP components after an emotional stimulus. Correlations between P100 amplitude and P300 amplitude were enhanced. However, P100 latencies had no correlation with P300 amplitudes and latencies. Thus, these results show that a positive correlation between P100 and P300 components still exists after an emotional stimulus.

Table 2. Correlation Scores between P100 and P300 Component before an Emotional Stimulus

		P100 latency				
	Position	F3	F4	Cz	F3	F4
P300 amplitude	F3	-	0.298*	-	-	-
	F4	-	0.344*	-	-0.279*	-
	Cz	0.244*	0.344*	0.240*	-	-
	Pz	-	0.289*	-	-0.351**	-0.277*
P300 latency	F3	0.587**	0.601**	0.561**	0.307*	0.338*
	F4	0.598**	0.591**	0.540**	0.395**	0.383**
	Cz	0. 606**	0.602**	0.557**	0.319*	0.346*
	Pz	0.626**	0.613**	0.613**	0.311*	0.288*

Table 3. Correlation Scores between P100 and P300 Component after an Emotional Stimulus

		Negative (sadness : N=35)			Positive (joy : N=19)		
		P100 amplitude			P100 amplitude		
	Position	F3	F4	Cz	F3	F4	Cz
P300 amplitude	F3	-	0.361*	-	0.648**	0.638**	0.491*
	F4	0.410*	0.451**	-	0.705**	0.681**	0.520*
	Cz	0.407*	0.465**	0.415*	0.559*	0.556*	0.562*
	Pz	-	0.356*	-	-	-	-
P300 latency	F3	0.721**	0.673**	0.607**	0.665**	0.692**	0.724**
	F4	0.671**	0.601**	0.572**	0.577**	0.713**	0.644**
	Cz	0.706**	0.654**	0.583**	0.688**	0.735**	0.762**
	Pz	0.698**	0.675**	0.598**	0.731**	0.720**	0.665**

** p<.01, * p<.05

Note: Analyses were based on 19 participants for 3 sessions (negative: 2 sessions and positive: 1 session). Available sample size is 54 except for 3 samples for poor quality EEG recording.

3.4. Correlations between ERPs and Response Time

Pearson correlation analysis was conducted to test whether a correlation between ERP responses and behavior responses exists. A significant positive correlation was found between response time and ERP P300 latency at all positions (F3: r = 0.358, p = .008; F4: r = 0.357, p = .008; Cz: r = 0.310, p = .023; Pz: r = 0.295, p = .030). There was also a positive correlation for ERP P300 amplitudes and response time (Cz: r = 0.369, p = .006; Pz: r = 0.299, p = .028). However, there was no correlation for the ERP P100 component and response time. These results indicated that response time was closely related to the P300 component. These correlations between the P300 component and response time were weakened by an emotional stimulus. When the attention-emotion task was performed after a negative stimulus, there was only a positive correlation between P300 latency and response time at the F3 position (r = 0.338, p = .047). After a positive stimulus, there was a positive correlation between P300 latency and response time at the F3 and F4 positions (F3: r = 0.490, p = .033; F4: r = 0.551, p = .015). These results suggest that ERP patterns of P300 (larger amplitude, longer latency) are associated with longer response time, and that the P300 component related to selective attention is directly associated with response time.

3.5. Variance of ERPs and Behavior Response by Emotional Stimulus

It was hypothesized that participants would show a lower amplitude and longer latency of ERPs particularly after a negative stimulus. To identify emotional after-effects by an emotional stimulus, a paired t test analysis was conducted on ERP P100 and P300 components and response time during the attention-emotion task. Table 4 shows the significant variance of ERPs and behavior response by emotional stimuli. After a positive video clip, only P100 latency (Pz) and P300 latency (Cz) indicated a significant average difference. After a negative video clip, P100 latencies (F3, F4, and Cz) and P300 latencies (F3) appeared longer, and P300 amplitude (Cz and Pz) appeared lower, compared to a positive video clip. Also, response time was quicker compared with before the emotional stimuli. These results suggest that a negative stimulus induced longer latency, lower amplitude of ERP components, and quicker response time. P100 latencies related to emotional face processing were especially influenced by an emotional stimulus compared to other ERP components.

Table 4. Mean Difference of Neural and Behavior Response by before-after Emotional Stimulus

Stimulus		Position	M	S.D.	t	p
Negative	P100 latency	F3	-7.000	14.685	-2.820	.008
		F4	-7.286	11.801	-3.652	.001
		Cz	-6.571	13.345	-2.913	.006
	P300 latency	F3	-9.971	27.237	-2.166	.037
	P300 amplitude	Cz	0.013	0.278	2.827	.008
		Pz	0.011	0.202	3.238	.003
	Response time		20.167	37.488	3.183	.003
Positive	P100 latency	Pz	-4.526	7.648	-2.580	.019
	P300 latency	Cz	11.158	16.863	2.884	.010
	Response time		16.096	26.623	2.635	.017

3.6. Individual Difference in Affective Style of ERP Response

The next hypothesis was that there was an individual difference in affective style and neurophysiological responses related to emotion regulation, and that the affective style would be unaffected by changed affective state after an emotional stimulus. We conducted a statistical analysis on ERP factors that exhibited a significant correlation between the P100 and P300 components during the attention-emotion task. The participants were divided into three groups using k-means cluster analysis based on the ERP factors. There was a significant mean difference among the three groups (see Table 4). We repeated k-means cluster analysis varying k from 2 to 10 by 100 times to determine the proper initial cluster k. We selected an initial k, which has greater F value, lower significance probability, and proper case. In Table 5, the differences between the F-ratios make it possible to draw general conclusions about the role of the different mean variables in the forming of the clusters. They show that P100 and P300 components have the influence in the forming of the clusters. The group 1 had larger P100 and P300 amplitudes and longer P100 and P300 latencies, whereas group 2 had lower P100 and P300 amplitudes and reduced P100 and P300 latencies.

Table 5. Group Classification based on ERP Components

	Position	Final cluster center (N=54)			ANOVA	
		Group1 (N=15)	Group2 (N=22)	Group3 (N=17)	F	p
P100 latency	F3	178.7	160.8	167.2	7.698	.001
	F4	177.9	161.1	168.7	7.359	.002
P300 latency	F3	410.6	313.1	363.8	208.298	.000
	F4	408.1	316.1	358.1	145.256	.000
	Cz	419.8	320.6	374.1	117.141	.000
P100 amplitude	F4	0.149427	0.065469	0.091780	14.513	.000
	Cz	0.158822	0.079060	0.120563	11.847	.000
P300 amplitude	Cz	0.064974	0.001927	0.050895	5.146	.009

Table 6 and 7 shows group differences in the ERP components after an emotional stimulus. Although P100 latencies showed significant mean difference in paired t-tests before and after a negative stimulus, P100 latencies (F3 and F4) were no longer significant group difference after emotional stimuli (positive and negative). As with before the stimulus, group 1 showed the highest amplitude and the longest latencies of P100 and P300, whereas group 2 showed the lowest amplitude and the shortest latencies of P100 and P300. However, there was no significant group difference in P300 amplitudes after a positive stimulus.

Table 6. Mean Difference of Neural Response by Group after a Negative Stimulus

	Position	Total (N=35)			ANOVA	
		Group1(N=7) M(S.D.)	Group2(N=16) M(S.D.)	Group3(N=12) M(S.D.)	F(2,32)	p
P300 latency	F3	414.000(18.502)	324.000(36.940)	377.417(26.821)	23.544	.000
	F4	410.857(16.385)	310.250(25.096)	373.500(24.975)	51.508	.000
	Cz	421.857(20.440)	319.000(34.783)	378.750(32.993)	32.039	.000
P100 amplitude	F4	0.156(0.244)	0.064(0.049)	0.092(0.432)	10.994	.000
	Cz	0.152(0.033)	0.078(0.053)	0.134(0.030)	9.860	.000
P300 amplitude	Cz	0.084(0.044)	0.005(0.078)	0.023(0.048)	3.787	.033

Table 7. Mean Difference of Neural Response by Group after a Positive Stimulus

			Total (N=19)		ANOVA	
	Position	Group1(N=8) M(S.D.)	Group2(N=6) M(S.D.)	Group3(N=5) M(S.D.)	F(2,16)	p
P300 latency	F3	409.875(22.427)	303.500(18.251)	354.200(48.277)	21.598	.000
	F4	399.625(29.549)	303.333(13.064)	357.000(20.893)	29.201	.000
	Cz	405.500(30.458)	307.833(10.496)	358.000(29.072)	25.162	.000
P100 amplitude	F4	0.139(0.042)	0.045(0.046)	0.102(0.044)	8.064	.004
	Cz	0.146(0.037)	0.061(0.046)	0.132(0.053)	6.661	.008

3.7. Individual Difference in Response Time

An analysis of variance (ANOVA) was conducted to test the hypothesis that there would be individual differences between ERP components and response time. It showed the means of response time to differ significantly by group (F(2,51) = 9.460, p = .000). We compared means of response time by Tukey HSD post hoc test. The mean difference between group 1 (M = 700.221, S.D. = 46.026) and group 2 (M = 637.178, S.D. = 79.914) was significant (p = .022), and the mean difference between group 2 and group 3 (M = 737.818, S.D. = 83.965) was significant (p = .000). Group 2 ERP patterns (lowest amplitude and shortest latency) showed the quickest response time. After a negative stimulus, the mean difference in response time by groups was significant (F(2,32) = 4.354, p = .021). The mean of response time by groups is as follows: group 1 (M = 679.493, S.D. = 74.598), group 2 (M = 629.876, S.D. = 73.602), and group 3 (M = 716.092, S.D. = 83.106). As was the case before the stimulus, the response time of group 2 was the quickest. However, after a positive stimulus, there was no significant group difference in response time.

4. Discussion

The present study shows that ERPs in response to simultaneous emotional face (distracter) and selective attention can be neurophysiological markers related to emotion regulation capacity. The ERP markers exhibited were closely correlated with behavior responses, such as response time. Also, these ERP markers were affected by emotional state, and latencies and amplitudes of ERP markers were longer and lower after a negative emotional stimulus compared with after a positive emotional stimulus, indicating reduced information-processing capacity. Although emotional state has an effect on the response of these ERP markers, individual differences in affective style in the ERP markers during the attention-emotion task were still unchanged after inducement of an emotional state. These results suggest that the ERP markers reflect emotion regulation capacity, and that there are individual differences in emotion regulation capacity based on the affective style of ERP markers.

Previous studies on emotion regulation have suggested that if enhanced attention related to neural activity in emotional contexts supports regulation control [4] then enhanced attentional ERPs may be associated with more effective emotion regulation. Dennis suggests that larger P1 and Nc amplitudes in response to fearful and sad faces were correlated with more effective emotion regulation during an attention task following an emotional face as distracter [8]. In our study, emotional face and selective attention were presented concurrently to discover the relation between attentional ERPs and emotion regulation. Emotional face in our task was induced earlier than attention and was an effective distracter. Ebner suggests that task-irrelevant faces distract from the face-unrelated number task [16]. In another study, P100 was linked to face processing in adults and children [17]. Research on selective attention has insisted that target compared with non-target stimulus processing is associated with an enhanced P300 [18]. We hypothesized that if ERP amplitude to selective attention is increased in spite of enhanced ERP to an emotional face, then it could be interpreted as more effective emotion regulation. Consistent with previous studies, there was a positive correlation between P100 amplitude to an emotional face and P300 amplitude to selective attention in our task. The larger the P100 amplitude at the F4 and Cz positions, the larger the P300 amplitude at the Cz position. Thus, P100 and P300 ERPs in our task are positively correlated, from an integration of emotion-attention point of view, and can be associated with emotion regulation.

When inhibitory control is required in emotional contexts, enhanced ERPs related to cognitive control are associated with more adaptive emotion regulation [19]. Lewis suggests that ERP markers showed larger amplitude and longer latency in a No-go task compared to a Go task during Go/No-go tasks under emotional demands in developing children [4]. Usually, larger amplitude components are also quicker to appear. However, Eimer [20] reported a longer P300 latency on a No-go task related to inhibitory control. Larger amplitude and longer latency of ERP markers seems consistent with Falkenstein’s suggestion [21]. In our task, our results showed larger amplitude and longer latency of the P100 and P300 components. Longer latency of ERP markers could be associated with inhibitory control of each other in our task, which presented emotional faces and selective attention concurrently. Inhibitory control is essential to emotion regulation capacity.

Research on relations between neural and behavior responses can provide important information on the effect of emotion regulation on emotional behavior. Ruchsow suggested that impulsiveness was linked to fast guesses and premature responses in reaction time in a Go/No-go task [22]. The amplitudes of No-go P3 in the high impulsiveness group were reduced compared with that of the low impulsiveness group. In several studies, P3 of ERP has been found to be related to response inhibition in No-go tasks [23-25]. In our task, participants were required to concentrate on selective attention by suppressing interference effects from emotional faces. If participants had poor inhibition control, then the amplitude of P300 and response time should show lower and faster premature responses. As expected, our results showed that there was a significant correlation among response time, amplitudes of P300 (Cz and Pz), and latencies of P300 at all positions. In particular, the lower the amplitude of P300, the shorter delay in response time.

There may be individual differences in emotional reactivity and regulation. Especially, difficulties inhibiting an emotional response and excessive attention towards negative emotional information have been associated with mood and anxiety problems [26-28]. Thus, an individual difference in emotional response could reflect emotion regulation capacity. In our study, we classified 3 groups according to ERP responses during the attention-emotion task to detect individual difference. We found that the group with larger amplitude and longer latency of P100 and P300 showed a longer response time, whereas the group with lower amplitude and shorter latency of P100 and P300 showed a quicker response time.

Also, affective states can influence subsequent experiences, such as cognition and behavior. Numerous studies suggest that the emotional valence of the context or preceding stimulus impacts cognitive functions, including expectancies and attention

[10, 29, 30, 31]. As mentioned in the hypothesis, if affective styles of ERP markers related to emotion regulation before the emotional stimulus are maintained after the emotional stimulus, then the ERP markers would be neural indices of emotion regulation. Research by Kliegel, Horn, and Zimmer [11] on emotional after-effects suggests that the amplitude of P3 is reduced after a negative stimulus, representing reduced information processing capacity. During the attention-emotion task after an emotional stimulus in our study, the amplitude of P300 (Cz and Pz) related to selective attention was reduced after a negative stimulus compared with after a positive stimulus. Also, the latencies of P100 (F3, F4, and Cz) and P300 (F3) were longer and response time was quicker. In addition, considering the relation between response time and lower amplitude of P300 after a negative stimulus, quicker response time could be interpreted as a premature response due to reduced attention capacity.

The variance of neural and behavior responses by emotional after-effects may have an effect on individual differences in affective style. However, our results show that individual difference of affective style in neural and behavior responses during the attention-emotion task before the emotional stimulus was maintained after the emotional stimulus. The group with higher P100 amplitudes and longer P300 latencies (F3, F4, and Cz) showed the same affective style regardless of the type of stimulus, whereas the group with lower P100 amplitudes and shorter latencies (F3, F4, and Cz) showed the same affective style. This latter group showed the quickest response time after a negative stimulus. These results could be interpreted as suggesting that higher P100 amplitudes and longer P300 latencies (F3, F4, and Cz) are related to more effective emotion regulation capacity, whereas lower P100 amplitudes and shorter latencies (F3, F4, and Cz) are associated with a lack of emotion regulation capacity. Thus, the amplitudes of P100 and the latencies of P300 (F3, F4, and Cz) may be neural markers reflecting emotion regulation capacity.

Our results suggest that there is an association between ERPs and behavior response related to the emotion regulation. Our results show that the P100 and P300 components could be used as ERP markers of emotion regulation. These ERP markers are closely associated with response time as a behavioral response. The ERP markers and response time showed lower amplitudes, longer latencies, and longer response times after a negative stimulus compared with a positive stimulus. Moreover, the pattern of these factors for each individual is maintained, regardless of the type of stimulus. Individuals who had a pattern of lower amplitudes and shorter latencies of P100 and P300, and a quicker response time, during the emotion-attention task before an emotional stimulus, had a similar pattern after an emotional stimulus. These patterns can be related to a lack of emotion regulation capacity. Thus, these results provide insights into ERP markers and affective style in emotion regulation.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2010-0026833).

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