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비즈니스 문제 해결 창의성에 미치는 감정의 영향에 관한 EEG 기반 탐색연구

EEG-Based Explorative Study of the Role of Emotions on Business Problem-solving Creativity

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요 약

본 연구는 신경생리학적 분석의 관점에서 창의성의 기존 문헌에 공헌하는 것을 목표로 한다. 특히 감정이 비즈니스 문제 해결 창의성(BPSC: Business Problem-Solving Creativity)에 어느 정도의 영향을 미치는지를 뇌파(EEG) 분석을 통하여 살펴보았다. 본 연구에서 적용한 실험에서는 실험참가자로 하여금 경영정보분야에서 널리 사용되는 인지지도(cognitive map)에 기반한 비즈니스 문제를 해결하도록 하고 그 결과를 평가함으로써 비즈니스 문제해결 창의성을 측정하였다. 총 34명의 참가자를 대상으로 하였고 EEG 분석을 통해 실험자료를 분석한 결과 긍정적인 감정에서보다 부정적인 감정하에서 비즈니스 문제해결 창의성이 통계적으로 유의미하게 증가하는 것을 확인할 수 있었다. 본 연구는 경영정보분야 의사결정기법을 적용한 BPSC를 뇌파분석을 통하여 실증적으로 분석할 수 있음을 보여주었다는 면에서 기존연구에 기여한다.

키워드 : 뇌파(EEG), 인지지도, 비즈니스 문제 해결 창의성, 감정

Ⅰ. Introduction

Emotions are a key aspect of social life: emotional expressions provide information to observers, which in turn may influence others' behavior or emotions, thus having a coordinating effect on emotion regulation in social life (Van Kleef *et al.*, 2010). Emotions are seen to serve an adaptive purpose in human communication as well as motivate individuals to perform certain actions based on this emotion (Gregor *et al.*, 2014). Triggers of emotion can be seen with threats to job security, work stress, rewards, and interpersonal relationships with other colleagues, all inducing and contributing to a positive or negative emotional state (Amabile *et al.*, 1986).

Until recently, management research on emotion was considered the antithesis of rationality, deeming it unworthy for research in enhancing performance in the workplace. Furthermore, much of the ground-

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breaking research on emotion has been based on self-reports which can ultimately suffer from some unreliable measures due to their subjective nature (Dimoka *et al.*, 2011; LeDoux, 2003). Despite this, through the recent development and use of cognitive neuroscience theories and tools (Vom Brocke *et al.*, 2013), capturing and analyzing human emotion has helped to create a shift in current theoretical reasoning (Riedl and Leger, 2016).

Creativity is an important quality needed for solving problems as well as sparking innovative ideas (Amabile *et al.*, 1986). Therefore, understanding what factors trigger creativity as well as what processes help to enhance it is a key research interest (Dietrich and Kanso, 2010). In order to investigate this research problem, electroencephalography (EEG) was employed to study the neurological effects of emotion on a business problem solving creativity (BPSC) task. EEG can measure neural correlates of emotions and can be used to complement self-report measures of emotions. Therefore, this study also implements the use of the self-assessment manikin (SAM) (Bradley and Lang, 1994). To lead participants to elicit divergent thinking and support them in making creative decisions, we instructed participants to exploit the cognitive mapping technique that has been employed in information systems as a decision support tool for unstructured, complex problems (Lee and Kwon, 2006; Montazemi and Conrath, 1986; Silva *et al.*, 2019). In order to achieve our research objectives, we propose the following research questions: *(1) Is there a difference in BPSC when emotions are manipulated? (2) Are neural correlates of emotional responses related to enhanced creativity?*

This paper proceeds as follows. Section 2 provides the literature review. In Section 3 we present the method employed within this study. Section 4 presents the key findings from our analysis before section 5 provides a discussion including theoretical and practical implications of our study's findings.

Ⅱ. Literature Review

2.1 Emotion matters

Emotion is the psychological and behavioral reaction that people feel when confronted with an external or internal stimulus (Adolphs, 2010). It is episodic, short-term (Keltner and Gross, 1999), and phasic in nature, a distinguishing feature compared with i.e. moods (Adolphs, 2010). Work by Gregor *et al.* (2014) follows the premise that emotion serves as a function. In the functional view, emotions are viewed as the optimization of an individual's adjustment to the demands of their physical, and social environment, by prioritizing and organizing ongoing behaviors (Gregor *et al.*, 2014; Keltner and Gross, 1999; Lazarus, 1991). Functional theories of emotion not only look at the biological factors, but also at the adaptive behavior that leads to certain emotions based on specific external stimuli (Lazarus, 1991). In other words, the functional view treats emotions, behaviors, and biological components as systems of coordinated responses, ones that coherently work together to meet some end (Gregor *et al.*, 2014). Coherent with our own study, the functional viewpoint of emotion paves an appropriate viewpoint in which to explore the effect that emotion can have on BPSC (Gregor *et al.*, 2014).

2.1.1 Positive and Negative Effect on Emotional Creativity

Creativity is one of the most critical determinants of one's ability to succeed in a business environment (Kaufman, 2009). Thus, enterprises have looked to invest a significant amount of time and money into developing their employees in the hope of developing their creative skills (Moreau and Engeset, 2015). Creativity is believed to be derived from the uniform interaction between one's attitudes, cognitive processes and environment. The intrinsic interaction of these produces something deemed to be both novel and valuable within a given social context (Nori *et al.*, 2018). Many researchers have argued upon and debated the role that positive and negative emotion has on facilitating greater cognitive ability, i.e. increased creativity (Gu *et al.*, 2018).

Past research has found that positively induced subjects have shown a greater tendency to creatively complete a given task (Hutton and Sundar, 2010). Contrastingly, studies have shown that it isn't always positive emotions that help to induce creativity (Phillips *et al.*, 2002). Some individuals have been shown to excel under negative emotion in creative tasks (Ivcevic *et al.*, 2007). Research has shown that one reason for this is that people who experience a negative emotional state may facilitate the fabrication of positive or neutral ideas. Mostly as a coping strategy, this helps to avoid negative thoughts and helps to create pleasant or at least neutral ideas (Abele-Brehm, 1992). This line of reasoning was further explored by Adaman and Blaney (1995) who argued that creativity may help individuals repair some negative emotions through a mood change. Zenasni and Lubart (2008) found that participants who had negative emotions alongside a higher level of arousal had an intrinsically greater ability to generate original ideas.

H1: Participants who are primed within the negative emotional state will show higher signs of creativity than the positively primed participants.

2.2 EEG: The Link between Neural Oscillations and Creativity

The brain is a complex organ. Research suggests the prefrontal region is responsible for all cognition in the brain, while the limbic region is considered crucial in the regulation of emotions. Recent evidence suggests these systems are intertwined (Dimoka *et al.*, 2011; Pessoa, 2008) and that the belief that we have a "thinking brain", and an "emotional brain", are starting to fade (Dimoka *et al.*, 2011). In line with this belief, measuring both the cognitive and affective areas of the brain is becoming more widely seen as a necessity (Pessoa, 2008). EEG offers this functionality to study a greater number of regions in the brain and is a non-invasive measurement device.

Much research has argued for a direct link between the alpha band activity in creativity tasks (Luft *et al.*, 2018). Alpha is considered a regular pattern seen between 8 and 12Hz. Further, alpha band activity is associated with an awake but relaxed state whereby there is minimal arousal (Dietrich and Kanso, 2010) and has been found during creativity tasks, mostly within the right frontal regions of the brain (Fink *et al.*, 2009; Schwab *et al.*, 2014). Lopata *et al.* (2017) showed similar findings in that people who were immersed in an activity showed greater alpha band activity, specifically when improvisation was part of the creativity task. Additionally, alpha oscillations have been linked to the process of active inhibition whereby it acts as an energy consuming suppression process working in a top-down fashion (Klimesch *et al.*, 2007). Further evidence of this phenomenon was seen in a study whereby high cognitive load led to a failure of suppressing stronger semantic associations (Baror and Bar, 2016). Thus, based on this research we hypothesize:

H2: Higher alpha band activity will be present in the right-lateralized region of the brain during the BPSC task.

H3: Also, alpha band activity will be present within the frontal region of the brain during the BPSC task.

Ⅲ. Method

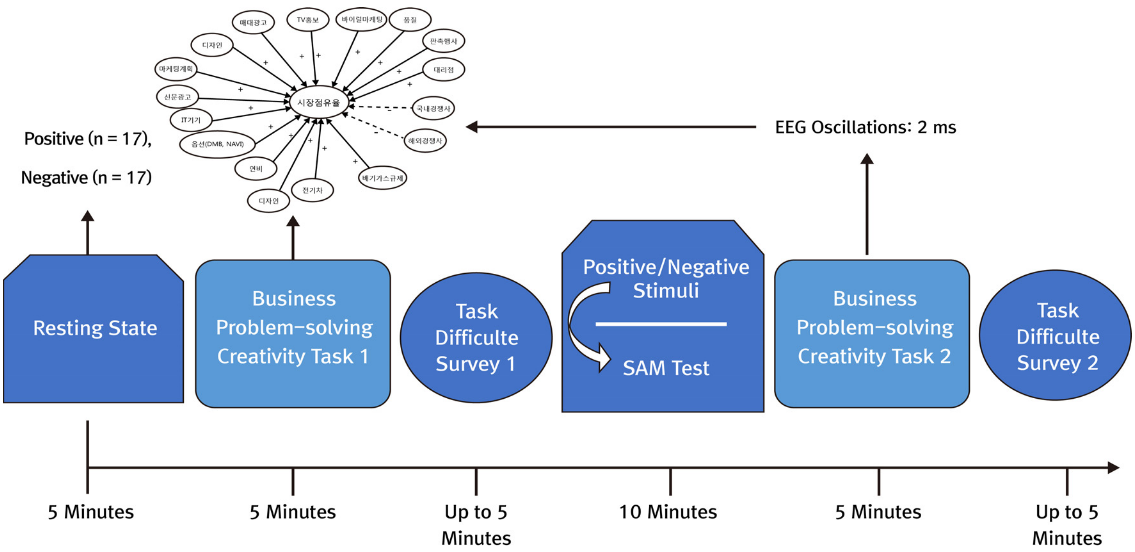
3.1 Participants

A total of thirty-nine right-handed participants undertook this study. However, due to participants reporting excessive head-motion artifacts during the EEG-recordings, these participants were removed. This left a total of thirty-four (eighteen females, sixteen males) participants who were recruited through voluntary means into this EEG experiment. Furthermore, they all reported no neurological issues before undertaking the experiment. This research was also approved by the author's university's institutional review board (IRB) before any experiment took place. All participants were provided with written informed consent before they participated and could remove their participation at any time. Lastly, they were randomly assigned to one of the two experimental conditions. Thus, seventeen of the final sample were chosen for the positive condition and seventeen were chosen for the negative condition.

3.2 Procedure and Tasks

The scheduling of the EEG study was made in advance for all participants. They were invited to the lab on an individual basis and were presented with a dimly lit and sound-attenuated laboratory. Upon arrival to the experimental lab, each participant was instructed with a presentation on a computer, as well as being provided with additional information through oral communication. Participants were then provided with a layout of the study as well as detailed written instructions of each task, including what a cognitive map (CM) is and the best way in which to approach formulating one. The last preparation involved applying the EEG device (Emotiv EPOC+) to the scalp of each participant and seating them into a comfortable chair.

The procedure of this study was performed with the software E-Prime 2.0 (Psychology Software Tools,

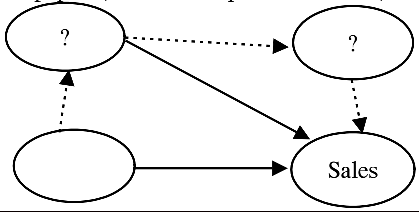


〈Figure 1〉 Flowchart of the Research Methodology Presented In Time Sequential Order

Pittsburgh, PA) and followed a sequenced procedure (See <Figure 1> for a graphical representation). The first BPSC task was presented in order to test creativity before any manipulation stimulus was presented. A brief description of the business problem was presented, and participants were asked to articulate upon potential nodes as a sign of idea creation to solving the problem (See <Table 1> for a full description). Once this first task was finished participants were asked to rate the difficulty of the task on a Likert scale ranging from one to seven.

Participants were then presented with one of two types of emotional stimuli. This was through music which was previously classified as either negative or positive (Zentner *et al.*, 2008). Music is considered an effective mediator to evoke certain emotions (Bhatti

〈Table 1〉 The Scenarios of Business Problem-Solving Creativity (BPSC) Task. Two Scenarios Were Created for the Participants to Undertake and Were Undertaken Either Side of the Participants Receiving the Conditioned Emotion.

Scenario (1) Description	• This management strategy task assumes that you are the CEO of a company and therefore please think about how you would deal with and oversee a strategy for the following case. • Myung-Ryun Motors is attempting to launch into the domestic market its new car called the “RM7”. For the RM7 model to successfully launch within the domestic market, certain conditions must be met. • Thus, as CEO of Myung-Ryun Motors, build a sales strategy to help to maximize RM7’s potential domestic market share.
Scenario (1) Concept Node Generation	• Please consider all factors in order to maximize the domestic market share. • Based on concept nodes and their causal relationship, from the perspective of Myung-Ryun Motors, draw a Cognitive Map (CM) to establish a strategy for achieving domestic market share.
Scenario (2) Description	• This management strategy task assumes that you are the CEO of a company and therefore please think about how you would deal with and oversee a strategy for the following case. • Myung-Ryun Corporation purchases various kinds of garments at a reasonable price from a supplier company and sells them to the market. • In order to purchase high quality clothing at a reasonable price, Myung-Ryun Co., Ltd. must negotiate with Kaap-Eul Trading Co. If the terms of the negotiations are met (i.e. price, delivery date), the intention to order will increase from the Myung-Ryun Co. • If the intention of the order rises to a certain level, an order is made for the clothing.
Scenario (2) Concept Node Generation	• As the lead negotiator, please suggest the various factors that you should consider in order to successfully strike a purchasing deal with Kaap-Eul Trading Co. • Based on the factors mentioned above and the potential causal relationships, please draw a Cognitive Map (CM) for ordering from Kaap-Eul Trading Co. which also has favorable terms for Myung-Ryun Co.
Business Problem-solving Creativity Task (BPSC)	• Considering all the factors in the scenario, please draw a Cognitive Map using a pencil on the paper (You have up to 5 minutes). An example is presented below: 

Positive Relationship

Negative Relationship

et al., 2016; Eskine *et al.*, 2018) as well as modulate underlying neurophysiological processes (Lin *et al.*, 2014). Much attention has centered on the Arousal-and-Mood hypothesis (Husain *et al.*, 2002) in explaining a link between musically induced emotion and increases in human cognitive abilities (Eskine *et al.*, 2018). This theory postulates the importance of two emotional reaction factors, namely activation and valence (He *et al.*, 2017). It has been shown that these can play a key role in affecting the cognitive performance within a given task, with activation being defined as the arousal level, and valence defined as how positive this arousal is (Eskine *et al.*, 2018; He *et al.*, 2017; Husain *et al.*, 2002). For these reasons the music stimulus was given for a time period of five minutes before participants were asked to rate their emotional state (valence) and arousal state based on the SAM measurement (Bradley and Lang, 1994). Next, the second BPSC task was presented in order to test creativity after the manipulation stimulus was presented to the participants via music. This task's purpose was once again to help promote divergent thinking based on node creation and the effects these nodes would have on the negotiations between the two companies (based on a positive/negative outcome). Once this second task was finished participants were asked to rate the difficulty of the task on a Likert scale ranging from one to seven. After participants completed the creativity tasks, the EEG device was removed from their head. Lastly, participants were debriefed and were paid according to the agreed amount of compensation for participation.

3.2.1 Evaluation Methods and Manipulation Checks

The first manipulation check was based on the task difficulty. In order to check that the task difficulty was evenly spread for pre and post manipulation, a t-test was performed in order to make sure there was no significant difference between task one and two's difficulty. The second manipulation was based on the creativity evaluation using the cognitive mapping tool. The marking criteria was based on four factors: complexity, focus, clustering, and mechanisms. To further check this score, ten business administration graduate students who had taken a course based on CM theory were asked to rate the CM scores given for each participant. Their assessment helped to verify whether these CM scores were a reliable representation and measure of BPSC.

3.3 EEG Recording and Analysis

The Emotiv EPOC 14-channel EEG wireless recording headset (Emotiv Systems, Inc., San Francisco, CA) was used for the EEG recordings of the cortical scalp. CMS and DRL were referenced to the average of left (P3) and right (P4) mastoids. Each electrode was placed according to the 10-20 international system: AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, and O2. All EEG data was sampled at a frequency of 128 Hz.

EEG data was extracted from the Emotiv EPOC TestBench suite and all pre-processing of the EEG signals was performed using the CURRY suite (version 7.0.9, Compumedics Neuroscan, Inc., Charlotte, NC, USA). A band pass filter was applied between 0.1 Hz and 30Hz in order to remove any low and high frequency artifacts from the EEG signals. Furthermore, due to ocular movements, additional artifact reduction was applied using independent component analysis (ICA). From the 14 channels, electrical voltage was recorded over a time sequence at different wave frequencies.

Next, the EEG data was submitted to a Fast Fourier transformation (FFT), using a Hanning-window. During the five-minute time window that participants were asked to draw the CM, EEG power spectra was analyzed after the FFT was applied. This was then averaged, resulting in spectral data for all participants individually. In this study the bands selected for spectral analysis were the theta-band (3 to 8 Hz), the alpha-band (8 to 12 Hz), and the beta-band (12 to 30 Hz). Lastly, averaged segments for each frequency band were exported to IBM SPSS for statistical analysis.

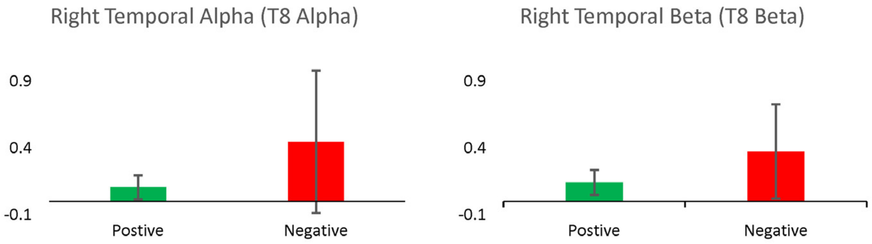
3.4 Statistical Analyses

Firstly, one-way analysis of variance (ANOVA) was used to check the condition manipulation on SAM. Second, one-way ANCOVA was also employed to test the differences of the manipulated condition (i.e. positive vs. negative) on the CM score (i.e. the main dependent variable) with gender and age as covariates. The power spectral values of each frequency band were then averaged across each participant. One-way ANCOVA (condition: positive vs. negative) was employed on each frequency band at frontal, ordinal and temporal sites with gender and age used as covariates.

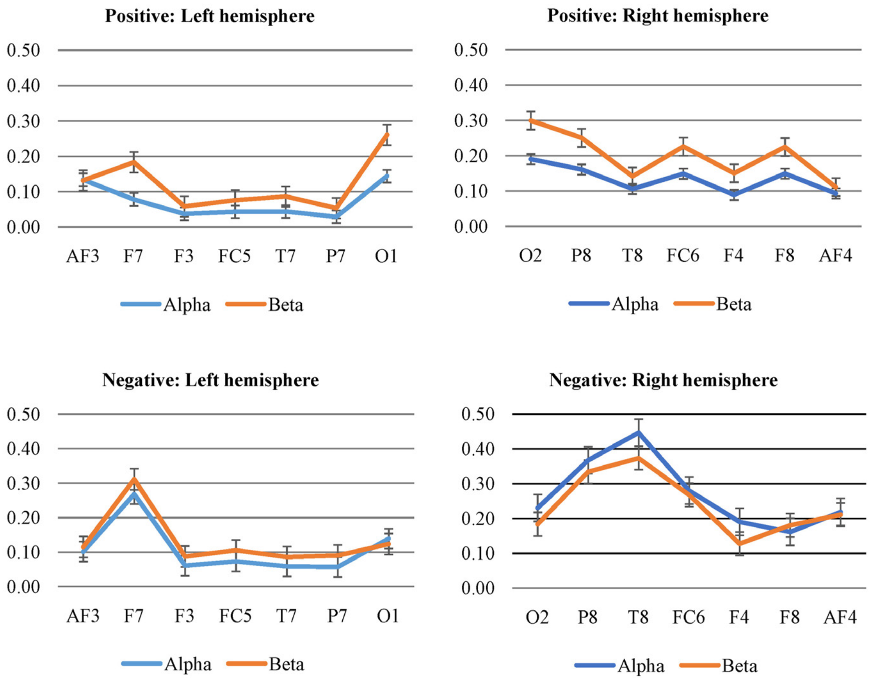
Ⅳ. Results

The first analysis made was to check for any differences between the task difficulty before and after the manipulation was given to the participants. Based on a one-sample t-test, we can see that the statistical means are very similar for task one (M = 5.12, SD = .95) and task two (M = 4.82, SD = 1.14, t = 1.157, p = 0.251). With this, we have confidence that both scenarios had a similar level of task difficulty. The next manipulation check was to see how the participants perceived their emotion based on the SAM test. Firstly, for arousal, participants that were primed with the emotionally positive music showed a higher level of arousal (M = 6.12) compared with the participants primed with the emotionally negative music (M = 4.29, F (1, df) = 13.44, p = .001). Additionally, for the valence test positively primed participants once again had a higher valence (M = 5.65) compared with participants that were conditioned with negatively primed music (M = 4.65, F (1, df) = 3.50, p = 0.71). However, the differences in valence were not seen to be significantly different despite a higher average valence in positively primed participants. Therefore, the manipulation was partially successful in priming the wanted emotion, however, at a lower arousal than anticipated. In terms of behavioral results, participants who were primed with the positive condition showed a significantly poorer result on the CM score of the BPSC task (M = 8.00) compared with the negatively primed participants who showed greater creativity in their answers (M = 11.82, F (1, 30) = 9.234, p = .005), whilst controlling for age and gender (p > .01).

Next, an investigation into participants' brain wave oscillations was performed with ANCOVA analysis. We found significant differences between positively and negatively primed participants within the right temporal-alpha and right temporal-beta band activity (see <Figure 2>). For right temporal-alpha, participants primed in the negative condition showed stronger activity (M = .4468) compared with those primed in the positive condition (M = .1059, F (1, 30) = 5.727, p = .023, η^2 = 0.160), whilst controlling for age and gender (p > .01). To a greater effect, the same result was found within right temporal-beta band activity. Those primed in a positive condition produced lower beta oscillations (M = .1414) compared to those participants that were primed in a negative condition, which evoked higher temporal beta band activity (M = 0.3737, F (1, 30) = 6.863, p = .013, η^2 = 0.177), whilst controlling for age and gender (p > .01). Outside of these findings, no significant differences were found within two priming conditions on any of the other wave band activities



〈Figure 2〉 Mean Values of Right Temporal Beta- and Alpha-Power Activity for Each Priming Condition. Error Bars Indicate Standard Deviations.



〈Figure 3〉 Task-Related Changes in Power Spectral in Both Alpha and Beta Band during the Business Problem-Solving Creativity (BPSC) Task after Receiving the Conditioned Stimuli.

(p > .01). All band wave oscillations can be viewed in <Figure 3>.

Ⅴ. Discussion

This study looked to explore the role that positive or negative emotions can have on a business problem-solving creativity (BPSC) task by implementing the use of a cognitive map. We measured brain activity by means of EEG while the participants underwent the experimental procedure as previously stated. First in answering hypothesis one, it was clear that participants who were primed into the negative emotion state were more creative in the BPSC task. This result agrees with prior research that suggests negative emotion can help to promote greater creativity (Ivcevic *et al.*, 2007; Zenasni and Lubart, 2008). For the second hypothesis, we can accept it. This is because our results also showed an increase in alpha band activity in the right-lateralized region of the brain during the BPSC task. Our results aligned with prior research that has hypothesized a link between right-lateralized alpha and increased creativity (Luft *et al.*, 2018; Schwab *et al.*, 2014). Lastly, we have to reject hypothesis three. Although we found increased alpha band activity in the right-lateralized region of the brain, it was not in the frontal region. Specifically, in this paper we have found evidence for the role in which right temporal alpha oscillations may play in BPSC after participants were induced in the negative condition. Although greater alpha oscillations have appeared more frequently in prior research within the prefrontal right regions of the brain, our results support more recent literature that is starting to find the link in which the right temporal region plays in inhibiting the most common and near associations upon creative cognition (Luft *et al.*, 2018). Increased alpha oscillations have been known now to represent a period of increased attention that allows for the inhibiting of internal and external stimuli (Bonnefond and Jensen, 2013; Klimesch *et al.*, 2007), and has been suggested as a key region for the processing of semantically close material.

Additionally, we found increased right temporal beta oscillations in our findings which was not hypothesized. However, although not commonly found, this finding has been previously seen whereby the link between emotion and cognition was harmonized with an increase in beta oscillations (Ray and Cole, 1985). However, the findings in this study support the idea that negatively induced participants showed a greater level of beta band oscillations upon performing the BPSC task, not supporting prior research that has seen greater increases in the beta power band activity within a positive state of emotion (Ray and Cole, 1985).

5.1 Implications of this Research

This study looked to explore the role that positive or negative emotions can have on a business problem-solving creativity (BPSC) task which involved the use of a cognitive map for exploring creative ideas while EEG recordings were made. Specifically, in this paper we have found evidence for the role in which right temporal alpha oscillations may play in BPSC after participants were induced in the negative condition. Increased alpha oscillations have been known now to represent a period of increased attention that allows for the inhibiting of internal and external stimuli (Bonnefond and Jensen, 2013; Klimesch *et al.*, 2007), and has been suggested as a key region for the processing of semantically close material. Thus, within our BPSC task, the higher levels of alpha oscillations seen could be an example of participants exploring creative ideas for the given tasks. Additionally, we found increased right temporal beta oscillations which coincided with the temporal alpha oscillations when participants were under the negatively induced control group.

These findings agree with prior research that hypothesized a link between right-lateralized alpha and increased creativity (Luft *et al.*, 2018; Schwab *et al.*, 2014). Although greater alpha oscillations have appeared more frequently in prior research within the prefrontal right regions of the brain, our results support more recent literature that is starting to find the link in which the right temporal region plays in inhibiting the most common and near associations upon creative cognition (Luft *et al.*, 2018).

5.2 Limitations and Future Research

Firstly, the convenience sample used within this study might have a bias. As all participants were natives to South Korea, generalizing the findings to non-Korean citizens could have limitations. Furthermore, the scenario presented was based on small facets of a business problem and therefore all the dynamics that are at play in real-world environments may not have been reflected in our study. Lastly, there is a limitation on the number of nodes used within this study. Although, we were able to study the fundamental areas of the brain, an increased node count might have yielded varied results and given a broader picture in which to analyze.

For future recommendations we suggest research should look to implement a longitudinal study whereby the same participant can be tested on different dates and problems. This would eliminate the potential for one-off success and help to generalize the study greater. Furthermore, inclusion of a personality trait test (i.e. Yoo and Gretzel, 2011) and a creativity test (i.e. the alternate uses task (Guilford, 1967) could act as co-variates on the creativity scores in order to tease out individual differences. Lastly, following previous literature that found findings much alike this paper (i.e. Luft *et al.*, 2018), the use of emotional stimuli and its interplay on creativity should firstly be studied through functional near-infrared spectroscopy (fNIRS) or Functional magnetic resonance imaging (fMRI) in order to investigate other potential regions of the brain.

Ⅵ. Conclusion

The current paper examined the relationship between the manipulated emotional states and BPSC by using EEG. Positive and negative emotions manipulated by music was found to influence creativity as assessed by CM scores. Specifically, negative emotions were found to be an effective way to enhance creativity, eliciting right temporal alpha and beta power activities. Consonant with prior studies on creativity, we showed the importance of increased temporal-alpha oscillations during the BPSC task. Despite conflicting views on which emotional states improve creativity, our work illustrates that the use of negative emotions in an organizational environment can contribute to greater creativity.

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EEG-Based Explorative Study of the Role of Emotions on Business Problem-solving Creativity

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Abstract

This study aims to contribute to the existing literature in creativity from the viewpoint of neuro-physiological analysis. Further, we looked at emotional influences on creativity within a business problem-solving context that implemented the use of a cognitive map in exploring creativity. For this purpose, we measured brain cortical activity as people solved a business strategy problem to explore the neural mechanisms of "insight problems" that are influenced by distinct emotions. Through an Electroencephalography (EEG) analysis of 34 qualified participants, we investigated the relationship between emotions and business problem-solving creativity (BPSC). Insightful results were derived such that participants primed in a negative condition evoked higher temporal alpha band activity compared to those primed in the positive condition. Meanwhile, there were no significant differences between two priming conditions on the other band activities. Therefore, this study sheds a very positive light on the scholarly value of conducting rigorous studies about the relationship between emotional states and BPSC status.

Keywords: EEG, Business Problem-Solving Creativity, Cognitive Map, Emotion

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