



Brain Activation in Response to Literature-Related Activities

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Objective A humanities-based approach to understanding the brain can yield valuable insights, advancing neuroscience and enhancing mental, emotional, and social well-being. This study was aimed at exploring how engagement in literature-related activities stimulates brain activity in the prefrontal cortex.

Methods We recruited 24 healthy male participants aged 20 to 29 years. They completed clinical scales assessing depression, anxiety, attention, and humanistic knowledge. They also performed six tasks comprising various literature-related cognitive challenges while hemodynamic changes in their frontal cortices were measured using functional near-infrared spectroscopy.

Results Task 1 (word memory and recognition) increased activation in the ventrolateral prefrontal cortex (VLPFC), as did Task 2 (emotional words classification), which also elevated activity in the left orbitofrontal cortex (OFC). Task 3 (understanding context) increased activation in the dorsolateral PFC (DLPFC). Tasks 4 (interpersonal relationship) and 5 (listening, memory, understanding, and expression) drove similar increases in the frontopolar and DLPFC regions. Task 6 (creative activities using characters and items) significantly activated multiple regions, including the right and left VLPFC and OFC. Humanistic knowledge scores were positively correlated with left and right DLPFC activation in Tasks 3 and 5, respectively. Conversely, Task 6 showed negative correlations between attention-deficit/hyperactivity disorder scores and both right DLPFC and right OFC activation.

Conclusion This study identified key brain regions involved in literature activities. Complex activities (semantic processing, understanding and creative expression, decision-making and emotional regulation, etc.) stimulated various regions of prefrontal cortices, including the VLPFC, DLPFC, and OFC.

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Keywords Humanities; Literature; Cognition; Prefrontal cortex; Functional near-infrared spectroscopy.

INTRODUCTION

Humanities and brain science

Medical humanities can be a valuable avenue in which to enrich our understanding of the human brain and psychology.¹ The fusion of humanities and brain research has emerged as a critical topic in modern academia. A humanities-based approach to comprehending the brain's function and structure can offer new insights that contribute to the advancement of neuroscience.^{2,3} This assertion is supported by Iacoboni et al.,⁴ who suggested that artistic and humanities-based interventions positively affect psychological well-being. Interventions across various arts and humanities fields have also been linked

to improvements in emotional and social well-being as well as self-awareness. Such studies have emphasized that the arts and humanities can play a vital role in human mental health and flourishing, going beyond the mere implementation of cultural activities.⁵

Moreover, literature and films that explore brain-related topics can be used as educational tools that transcend disciplinary boundaries. For instance, an undergraduate seminar jointly led by neuroscientists and literature scholars demonstrated how literature and films can provide valuable methods for exploring the relationship between the brain and the mind.⁶ The fusion of medical humanities and critical neuroscience can contribute to understanding the deep entanglements between subjectivity, scientific practice, and economic formations. This implies that the integration of humanities and brain research extends beyond simple academic curiosity, playing a crucial role in enhancing mental, emotional, and social well-being.⁷

Literature activities and brain activation

Of various humanities activities related to the human brain, writing training affects the brain's functional networks, thus

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receiving significant scholarly attention. In particular, studies have provided meaningful findings on how writing influences the brain's reading network during the learning of complex writing systems, such as Chinese.⁸ For example, a study comparing character and pinyin writing in the process of learning Chinese characters demonstrated that character writing is instrumental in the formation of high-quality representations of visual-spatial structures and emotional expressions.⁸ In addition, research aimed at illuminating the mechanisms by which various cognitive and motor skill training induce functional changes in the brain provides an important background for understanding the brain activation changes resulting from writing training.⁹

The impact of writing training on brain language and cognitive functions has also been reported.¹⁰ For instance, a study analyzing the writing experiences of individuals with traumatic brain injury discussed the effects of writing difficulties on daily activities and proposed support strategies for overcoming these challenges.¹⁰ Another study suggested that writing training induces similar activation patterns in specific brain areas and emphasized that writing training can be a powerful tool for stimulating functional changes in the brain.¹¹

Using functional near-infrared spectroscopy to measure brain activity in response to literature tasks

Functional near-infrared spectroscopy (fNIRS) is an effective non-invasive technique for assessing changes in cerebral oxygenation and hemodynamics through the analysis of how near-infrared light is absorbed as it passes through brain tissue.^{12,13} This method involves projecting two different wavelengths of near-infrared light onto the forehead, which penetrate the brain, interact with oxygenated and deoxygenated hemoglobin, and are then detected by an optical probe on the skin.¹⁴ fNIRS illuminates brain activity without the limitations associated with traditional imaging techniques, such as positron emission tomography, single-photon emission computed tomography, and functional magnetic resonance imaging. These approaches are constrained by the need for subjects to remain still and the use of bulky equipment. Conversely, fNIRS allows for greater mobility and flexibility in experimental settings.¹⁴

Previous studies using fNIRS have demonstrated its effectiveness in evaluating activities related to literature.^{15,16} A case in point is Artemenko et al.,¹⁵ who reported that both number and letter copying is associated with brain activation within the bilateral middle and left inferior frontal gyri. Zhang et al.¹⁶ found that emotional autobiographical tasks improve depressed mood and increase brain activity within the dorso-lateral prefrontal cortex, as measured by fNIRS.

Hypothesis

We hypothesized that literature-related tasks stimulate brain activity within the prefrontal cortex. More specifically, complex activities, including reading, understanding, and emotional control, can activate various regions of prefrontal cortices.

METHODS

Participants

A total of 24 participants were recruited via flyer advertisements at Chung-Ang University. The inclusion criteria were as follows: 1) aged 20 to 29 years, 2) no history of psychiatric or medical conditions, and 3) right-handedness. The exclusion criteria were 1) a history of head trauma and 2) a history of substance use, except for social drinking and smoking. The sample comprised 24 healthy male adults with a mean age of 25.0 years (standard deviation [SD]=2.2) and an average of 14.9 years of education (SD=1.5). Written informed consent was obtained from all the participants, after which they were asked to refrain from consuming food, caffeine, or alcohol for at least three hours prior to the study. The protocol of the present study was approved by the Institutional Review Board of Chung-Ang University (1041078-20240514-HR-120).

Study procedure

Assessment scales

The depressed mood and anxiety experienced by the participants were assessed using Beck's Depressive Inventory (BDI)^{17,18} and Beck's Anxiety Inventory (BAI),^{19,20} respectively. BDI-II is a widely used self-report measure of the severity of depression in both research and clinical settings. It has exhibited high internal consistency, with Cronbach's alpha values typically falling around 0.9, indicating excellent reliability.^{17,18} Its test-retest reliability ranges from 0.73 to 0.96, further supporting its stability over time.¹⁷

Similarly, BAI is an extensively employed self-report instrument designed to measure the severity of anxiety symptoms. The scale consists of 21 items, each rated on a four-point Likert scale, intended to assess various physiological and cognitive symptoms associated with anxiety. BAI also exhibits high internal consistency, with Cronbach's alpha values typically ranging from 0.88 to 0.93 across various studies.²¹⁻²³ Its test-retest reliability likewise shows strong stability over time, with coefficients ranging from 0.75 to 0.84.^{21,23}

The attention of the participants was assessed using the Korean adult attention deficit hyperactivity disorder scale (K-AARS),²⁴ which focuses on eight factors (inattention, hyperactivity, impulsivity, antisocial personality disorder/conduct disorder/oppositional defiant disorder, impairment, driving,

emotional dysregulation, and disorganization). The K-AARS is considerably reliable in terms of internal consistency (Cronbach's $\alpha=0.77-0.95$) and correlation between factors ($0.57-0.86$).

Humanistic knowledge was assessed using the humanistic knowledge scale,²⁵ which consists of four sections: literary reading skills, historical knowledge, literary and philosophical knowledge, and artistic knowledge. Each section encompasses 13 items, to which participants respond using a five-point scale ranging from 1 (not at all) to 5 (very much). The structure and reliability of this test range from 0.823 to 0.891 (Cronbach's α).

Task composition

The study, which lasted for 71 minutes, involved six task segments interspersed with five rest periods (1 minute $\times$ 5=5 minutes). Each segment consisted of a two-minute fNIRS scan before a given task, a seven-minute task, and another two-minute fNIRS scan afterward. The tasks covered different themes: word memory and recognition (Task 1); classification of emotional words (Task 2); understanding context (Task 3); interpersonal relationship (Task 4); listening, memory, understanding, and expression (Task 5); and creative activities using characters and items (Task 6).

For Task 1, the participants were asked to memorize words that appear in 10 poems for 3 minutes. After 2 minutes, they were instructed to write down the words that they could remember within a 2-minute period. For Task 2, they were directed to divide emotion word cards, given in sets of 30, into 4 similar emotions. For Task 3, the participants were asked to read a written problematic situation and craft a solution to be read afterward. For Task 4, they were instructed to describe in writing who the people are that form relationships around

them and what kind of relationships they have with these individuals. For Task 5, they were asked to listen to an audiobook for 3 minutes, remember the content, solve 5 questions about the audiobook for 2 minutes, and then create a title and headline that match the content of the audiobook in 2 minutes. For Task 6, the participants were directed to create two characters that represent their positive and negative emotions and thoughts. They were further requested to write down 5 items that strengthen the positive character and 5 items that improve the negative character. They were then asked to use the positive and negative characters, along with the 10 items, to formulate a short scenario (Table 1).

Hemodynamic changes within the frontal cortex

fNIRS is a non-invasive technique that uses near-infrared light to monitor changes in brain concentration and hemodynamics without causing discomfort. The NIRSIT[®] device (OBELAB), a compact headband, was placed on each participant's forehead to track brain activity in the frontal lobe region. This device measures the concentrations of deoxyhemoglobin and oxyhemoglobin in the brain's cortex, which reflects oxygen levels in the blood. Oxygen-rich blood appears bright red, allowing practitioners to evaluate brain activity by observing its distribution. The NIRSIT[®] device delivers real-time data on brain activity to a tablet. By placing a small helmet on the forehead, practitioners can assess brain activation and cell oxygenation. The NIRSIT[®] device is less prone to external interference than other measurement methods and rapidly provides results (Figure 1).

Data analysis

The normality of the accHbO₂ data was evaluated using the Shapiro–Wilk test, with all eight brain regions showing nor-

Table 1. Brian stimulation via literature activities

Tasks	Descriptions	Activities
Task 1	Word memory and recognition	Memorize words that appear in 10 poems for 3 minutes. After 2 minutes, write down the words that you can remember within 3 minutes.
Task 2	Classification of emotional words	Divide the emotion word cards, given in sets of 30, into 4 similar emotions for 7 minutes.
Task 3	Understanding context	Read a written problematic situation (3 minutes). Write down a solution and read it (4 minutes).
Task 4	Interpersonal relationship	Describe in writing the people who form relationships around you (3 minutes) and what kinds of relationships they have with you (4 minutes).
Task 5	Listening, memory, understanding, and expression	Listen to an audiobook for 3 minutes, remember the content, solve questions about the audiobook for 2 minutes, and then create a title and headline that match the content of the audiobook in 2 minutes.
Task 6	Creative activities using characters and items	Create two characters that represent your positive and negative emotions and thoughts (1 minute). Write down 5 items that strengthen the positive characters and 5 items that improve the negative characters (3 minutes). Using the positive and negative characters, along with the 10 items, create a short scenario (3 minutes).

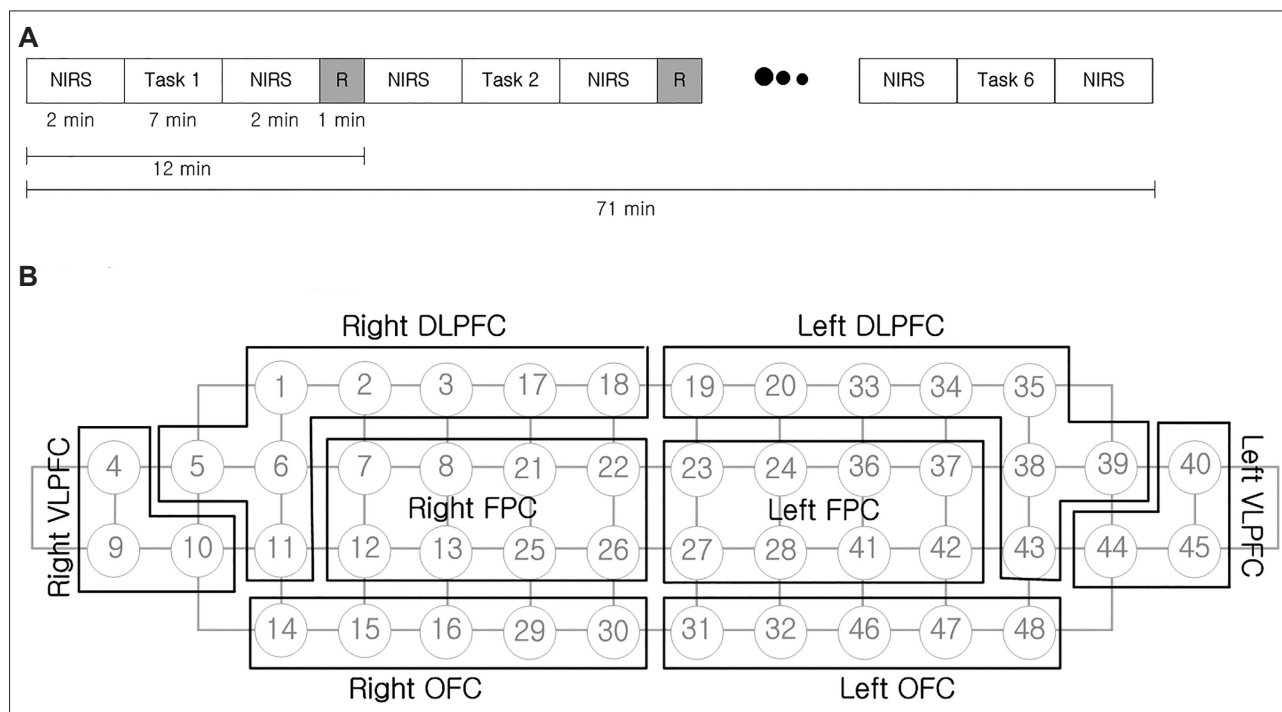


Figure 1. Design of study procedure and regions of interest in near-infrared scope. A: Procedure and design of near-infrared scope. B: Eight regions of interest: (1) right DLPFC: 1, 2, 3, 5, 6, 11, 17, and 18 channels; (2) left DLPFC: 19, 20, 33, 34, 35, 38, 39, and 43 channels; (3) right FPC: 7, 8, 12, 13, 21, 22, 25, and 26 channels; (4) left FPC: 23, 24, 27, 28, 36, 37, 41, and 42 channels; (5) right VLPFC: 4, 9, and 10 channels; (6) left VLPFC: 40, 44, and 45 channels; (7) right OFC: 14, 15, 16, 29, and 30 channels; and (8) left OFC: 31, 32, 46, 47, and 48 channels. DLPFC, dorsolateral prefrontal cortex; FPC, frontopolar cortex; VLPFC, ventrolateral prefrontal cortex; OFC, orbitofrontal cortex; NIRS, near-infrared spectroscopy.

mal distribution (p ranging from 0.178 to 0.894). The change in accHbO_2 (ΔaccHbO_2) was calculated by subtracting the resting NIRS measurement from the result obtained during the kinesthetic (or sensory) task. Within-group differences in ΔaccHbO_2 for each brain region were analyzed using paired t -tests. All statistical analyses were conducted using SPSS version 24 (IBM Corp.). A $p < 0.05$ was regarded as indicative of statistical significance. For within-brain region comparisons, significance was adjusted for multiple comparisons and set at $p < 0.006$ (0.05/8).

RESULTS

ΔaccHbO_2 changes in response to each of the six tasks

All the accHbO_2 data on the eight brain regions showed normal distribution (p ranging from 0.178 to 0.894). In response to Task 1 (word memory and recognition), the ΔaccHbO_2 within the right ($t = -3.02$, $p = 0.004$) and left ($t = -3.36$, $p = 0.002$) ventrolateral prefrontal cortex (VLPFC) increased. In response to Task 2 (emotional words classification), the ΔaccHbO_2 within the right ($t = -3.12$, $p = 0.003$) and left ($t = -2.95$, $p = 0.005$) VLPFC as well as the left orbitofrontal cortex (OFC) ($t = -3.35$, $p = 0.002$) increased. In response to Task 3 (understanding the context), the ΔaccHbO_2 within the right ($t = -3.34$, $p = 0.002$)

and left dorsolateral prefrontal cortex (DLPFC) ($t = -3.29$, $p = 0.002$) increased (Figure 2).

In response to Task 4 (interpersonal relationship), the ΔaccHbO_2 within the right ($t = -2.98$, $p = 0.004$) and left ($t = -2.96$, $p = 0.005$) frontopolar cortex (FPC) was elevated. In response to Task 5 (listening, memory, understanding, and expression), the ΔaccHbO_2 within the right DLPFC ($t = -3.35$, $p = 0.002$) as well as the right ($t = -3.33$, $p = 0.002$) and left ($t = -3.01$, $p = 0.004$) VLPFC increased. In response to Task 6 (creative activities using characters and items), the ΔaccHbO_2 within the right DLPFC ($t = -2.96$, $p = 0.005$), the right ($t = -4.15$, $p = 0.001$) and left ($t = -3.42$, $p = 0.001$) VLPFC, and the right ($t = -2.97$, $p = 0.005$) and left ($t = -2.91$, $p = 0.006$) OFC increased (Figure 3).

Correlations between the ΔaccHbO_2 changes and clinical scale scores

In Task 3, the humanistic knowledge scores of the respondents were positively correlated with the changes in ΔaccHbO_2 within the left DLPFC ($r = 0.65$, $p = 0.001$). In Task 5, such scores were positively correlated with the changes in ΔaccHbO_2 within the right DLPFC ($r = 0.64$, $p = 0.001$) (Figure 4). In Task 6, the ADHD scores were negatively correlated with the changes in ΔaccHbO_2 within the right DLPFC ($r = 0.51$, $p =$

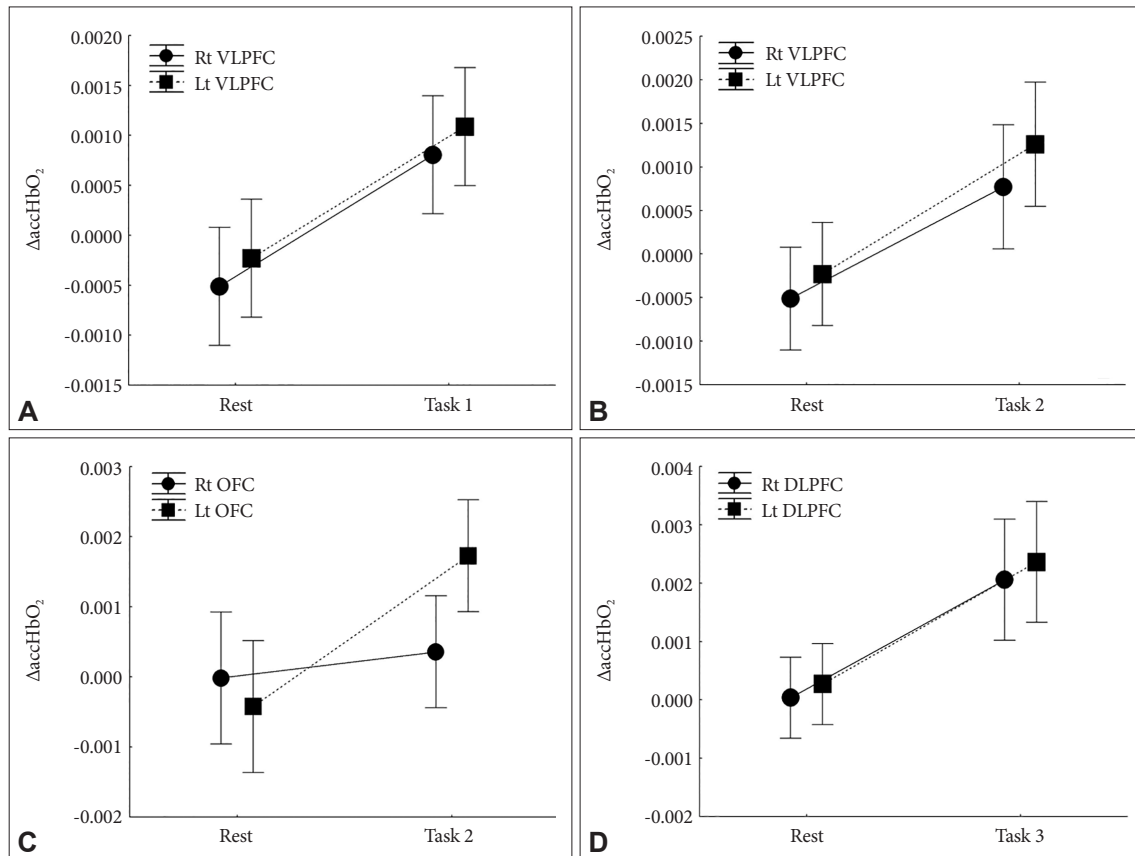


Figure 2. ΔaccHbO_2 changes in response to each of the six tasks (T1–T3). A: Changes in the ΔaccHbO_2 within the both VLPFC in response to Task 1 (right: $t=-3.02$, $p=0.004$; left: $t=-3.36$, $p=0.002$). B: Changes in the ΔaccHbO_2 within the both VLPFC in response to Task 2 (right: $t=-0.64$, $p=0.526$; left: $t=-3.35$, $p=0.002$). C: Changes in the ΔaccHbO_2 within the both OFC in response to Task 2 (right: $t=-0.64$, $p=0.526$; left: $t=-2.95$, $p=0.005$). D: Changes in the ΔaccHbO_2 within the both DLPFC in response to Task 3 (right: $t=-3.34$, $p=0.002$; left: $t=-3.29$, $p=0.002$). VLPFC, ventrolateral prefrontal cortex; OFC, orbitofrontal cortex; DLPFC, dorsolateral prefrontal cortex.

0.012). In Task 6, these scores were negatively correlated with the changes in ΔaccHbO_2 within the right OFC ($r=0.63$, $p=0.001$) (Figure 4).

DISCUSSION

ΔaccHbO_2 changes in response to each of the six tasks

Task 1 (word memory and recognition) was associated with brain activation within the VLPFC, which is associated with word memory and recognition.^{26–29} The VLPFC seems to be involved in sustaining information in working memory and handling semantic processing, such as identifying lexical meaning and linking words to others within a semantic network.²⁹ Han et al.²⁷ demonstrated that the left VLPFC plays a causal role in the use of selective encoding and the recognition of strategies based on value, likely by enhancing the deep semantic processing of high-value words. Galli et al.²⁶ reported that verbal episodic memory is associated with the late processing stage of encoding and recognizing functions within the VLPFC. Park et al.²⁸ suggested that the VLPFC enhances memory

formation regardless of the presence of a distractor during verbal encoding.

Task 2 (emotional words classification) was associated with brain activation within the VLPFC and OFC. These cortices are well-known brain regions implicated in emotional perception.^{30–32} The VLPFC is regarded as a mediator of the regulation of interpersonal emotions, including empathy, cognitive control, and affective generation.³² Michel et al.³⁰ suggested that VLPFC and OFC engagement during emotion regulation is a potential predictor of treatment response in borderline personality disorder. In a meta-analysis of face and natural scene processing, Sabatinelli et al.³¹ implied that the OFC serves a crucial function in the differentiation of emotional expression in the face and scenes.

Task 3 (understanding context) was related to brain activation within the DLPFC. Executive functions within this brain region, including planning and working memory, are associated with word comprehension linked to phonological dissociations and semantic control mechanisms.^{33,34} In phonological dissociations, inner speech cueing is viewed as a strategy for

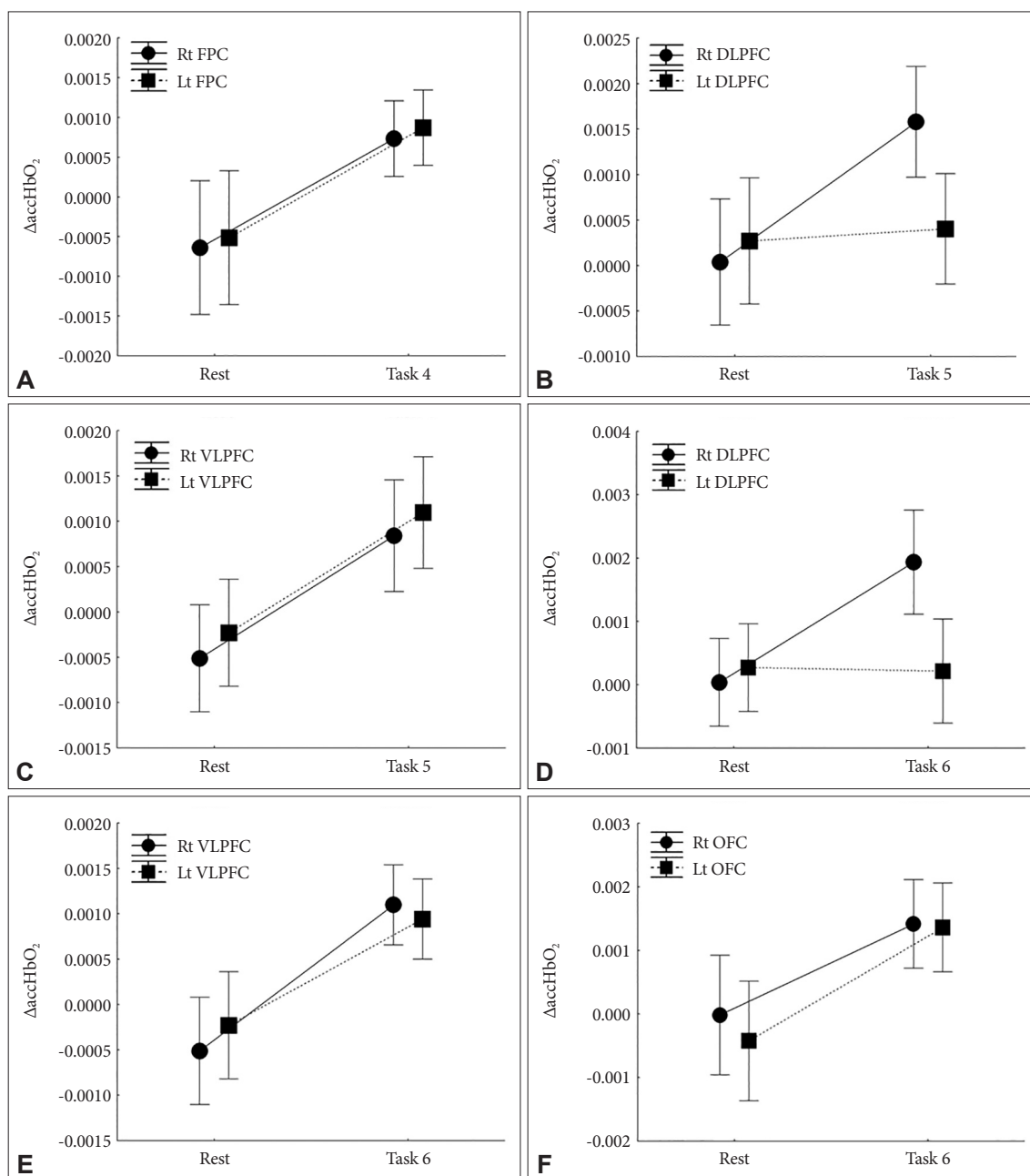


Figure 3. ΔaccHbO_2 changes in response to each of the six tasks (T4–T6). A: Changes in the ΔaccHbO_2 within the both FPC in response to Task 4 (right: $t = -2.98, p = 0.004$; left: $t = -2.96, p = 0.005$). B: Changes in the ΔaccHbO_2 within the both DLPFC in response to Task 5 (right: $t = -3.35, p = 0.002$; left: $t = -0.29, p = 0.772$). C: Changes in the ΔaccHbO_2 within the both VLPFC in response to Task 5 (right: $t = -3.33, p = 0.002$; left: $t = -3.01, p = 0.004$). D: Changes in the ΔaccHbO_2 within the both DLPFC in response to Task 6 (right: $t = -2.96, p = 0.005$; left: $t = 0.141, p = 0.888$). E: Changes in the ΔaccHbO_2 within the both VLPFC in response to Task 6 (right: $t = -4.15, p = 0.001$; left: $t = -3.42, p = 0.001$). F: Changes in the ΔaccHbO_2 within the both OFC in response to Task 6 (right: $t = -2.97, p = 0.005$; left: $t = -2.91, p = 0.006$). FPC, frontopolar cortex; DLPFC, dorsolateral prefrontal cortex; VLPFC, ventrolateral prefrontal cortex; OFC, orbitofrontal cortex.

enhancing performance, wherein a phonological cue is maintained in working memory to aid in the processing of an upcoming target word.³⁵

Task 4 (interpersonal relationship) was linked to brain activation within the FPC, which is associated with metacognition.^{36,37} Metacognition is defined as the cognitive process involved in thinking about thinking. The components of

metacognition are related to complex personal and narrated accounts of life events.³⁸ Nordahl et al.³⁹ suggested that metacognition is a crucial factor for treating interpersonal problems in individuals with anxiety disorder.

Task 5 (listening, memory, understanding, and expression) was associated with brain activation within the DLPFC and VLPFC. The DLPFC is well known for its critical role in high-

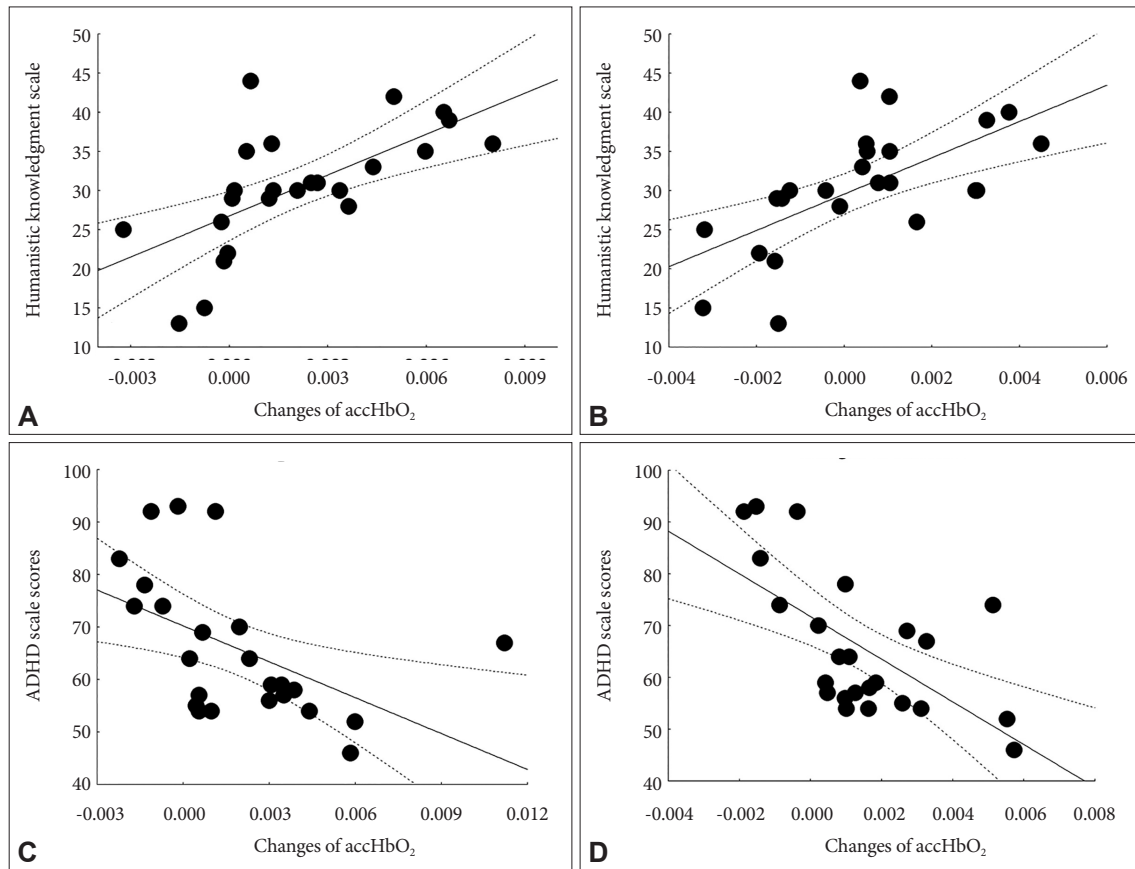


Figure 4. Correlation between the humanistic knowledge scores and the changes in ΔaccHbO_2 within the left DLPFC. A: Correlation between the humanistic knowledge scores and the changes in ΔaccHbO_2 within the left DLPFC in response to Task 3 ($r=0.65$, $p=0.001$). B: Correlation between the humanistic knowledge scores and the changes in ΔaccHbO_2 within the right DLPFC in response to Task 5 ($r=0.64$, $p=0.001$). C: Correlation between the scores on the ADHD scale and the changes in ΔaccHbO_2 within the right DLPFC in response to Task 6 ($r=0.51$, $p=0.012$). D: Correlation between the ADHD scores and the changes in ΔaccHbO_2 within the right OFC in response to Task 6 ($r=0.63$, $p=0.001$). DLPFC, dorsolateral prefrontal cortex; ADHD, attention-deficit/hyperactivity disorder; OFC, orbitofrontal cortex.

er-order cognitive processes, such as working memory, planning, and decision-making, all of which are central to tasks that require memory retention and the interpretation of complex information.⁴⁰ Previous studies have shown that the DLPFC is also instrumental in tasks that involve manipulating and recalling information, particularly when participants are asked to engage with auditory stimuli and then respond to questions that test their memory and comprehension.⁴¹ The VLPFC serves a significant function in language processing and emotional regulation, especially in tasks that involve creating verbal outputs or expressions based on auditory inputs.⁴² This process likely requires cognitive reappraisal, verbal expression, and creativity in summarizing and creating titles. The VLPFC is particularly active during tasks involving verbal processing, including generating verbal responses after engaging with complex auditory material.⁴³

Task 6 (creative activities using characters and items) was related to brain activation in the OFC, which is essential in processing complex emotional and creative information, sig-

nificantly influencing decision-making, impulse control, and emotional regulation.⁴⁴ Its role in balancing emotional and non-emotional stimuli facilitates cognitive control during tasks that require individuals to create characters representing emotions and generate narratives, likely activating the OFC throughout the creative decision-making process.⁴⁵

Correlations between the changes in ΔaccHbO_2 and clinical scale scores

For Task 3, the item “reading a problematic situation and providing a solution” indicated a positive correlation between the left DLPFC and the humanistic knowledge scores of the respondents. This task requires reasoning, problem solving, and decision-making. The left DLPFC, essential for logical thinking and problem solving,^{46,47} is considerably activated in individuals with high humanistic knowledge scores, underscoring its role in facilitating the generation of well-reasoned solutions to complex tasks. In Task 5, listening, memory, understanding, and expression reflected a positive correlation

between the right DLPFC and the humanistic knowledge scores. This task requires auditory working memory, comprehension, and creative summarization. The right DLPFC is associated with creative thinking and the flexible processing of information.⁴⁸ Individuals with high humanistic knowledge scores showed increased activation in the right DLPFC, indicating that this region supports the ability to retain, understand, and creatively summarize auditory information.

In Task 6, creating characters and writing a scenario based on emotions showed negative correlations between the ADHD scores and right DLPFC and right OFC. Task 6 involves emotional processing and creativity, requiring individuals to create characters that represent emotions and develop a scenario. The right DLPFC is involved in memory and planning, while the right OFC regulates emotional processing and impulse control.^{40,49} The negative correlation with ADHD scores suggests that individuals with considerable ADHD tendencies exhibit reduced activation in the aforementioned brain regions, leading to difficulties in impulse control, emotional regulation, and creative decision-making during the task.

The relationship between the humanities-based intervention and brain activation revealed in this study could provide scientific evidence for developing cognitive behavioral therapy that incorporates humanities elements. In particular, it appears to be a valuable component for CBT, which progresses with specific goals for each session.

Limitations

This study has several limitations that should be considered. First, the sample size of 24 may limit the generalizability of the findings. A more diverse sample that includes individuals with varying ages and genders can enable a more comprehensive grasp of the cognitive processes studied. Second, the reliance on self-report measures to assess the participants' psychological states may have introduced bias, as these scales can be influenced by individual perceptions and social desirability. Using objective assessments alongside self-report instruments can yield more accurate evaluations of cognitive and emotional states. Finally, in current study, the absence of a control group or control conditions made it difficult to determine the precise mechanism of the intervention. Future studies should include these conditions to provide clearer insights.

Conclusion

This study revealed how specific brain regions contribute to cognitive task completion, especially for those related to literature. The VLPFC's activation during word memory tasks highlights its role in semantic processing, which is essential for literary comprehension. The DLPFC's involvement in understanding and creative expression underscores its impor-

tance in decision-making and emotional regulation, which are vital for literary analysis and creative writing. Additionally, the OFC's engagement during creative activities punctuates its function in balancing emotional and cognitive demands, which is crucial for narrative creation. These findings enhance our understanding of the neural mechanisms underlying literary and humanities-related activities.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Doug Hyun Han. Data Curation: Seungpil Jeong. Formal analysis: Doug Hyun Han. Funding acquisition: Doug Hyun Han. Investigation: Seungpil Jeong. Methodology: Ji Sun Hong. Project administration: Doug Hyun Han. Resources: Seungpil Jeong. Software: Doug Hyun Han. Supervision: Ji Sun Hong. Validation: Ji Sun Hong. Visualization: Seungpil Jeong. Writing—original draft: Doug Hyun Han. Writing—review & editing: Seungpil Jeong.

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REFERENCES

- Slaby J. Critical neuroscience meets medical humanities. *Med Humanit* 2015;41:16-22.
- Frégnac Y, Laurent G. Neuroscience: where is the brain in the Human Brain Project? *Nature* 2014;513:27-29.
- De Vos J, Pluth E. *Neuroscience and Critique: Exploring the Limits of the Neurological Turn*. New York: Routledge; 2015.
- Iacoboni M, Jenson D, Uchitel J, White LE. Editorial: representation in neuroscience and humanities. *Front Integr Neurosci* 2022;16:1035367.
- Reilly C. Neuromimesis: picturing the humanities picturing the brain. *Front Integr Neurosci* 2022;16:760785.
- Bolton G. Boundaries of humanities: writing medical humanities. *Arts Hum High Educ* 2008;7:131-148.
- Gallese V. Embodied simulation. Its bearing on aesthetic experience and the dialogue between neuroscience and the humanities. *Gestalt Theory* 2019;41:113-127.
- Patel R, Spreng RN, Turner GR. Functional brain changes following cognitive and motor skills training: a quantitative meta-analysis. *Neurorehabil Neural Repair* 2013;27:187-199.
- Dinnes C, Hux K, Holmen M, Martens A, Smith M. Writing changes and perceptions after traumatic brain injury: "Oh, by the way, I can't

- write." *Am J Speech Lang Pathol* 2018;27:1523-1538.
10. Lin CY, Xiao ZW, Shen L, Zhang JX, Weng XC. Similar brain activation patterns for writing logographic and phonetic symbols in Chinese. *Neuroreport* 2007;18:1621-1625.
 11. Enzinger C, Dawes H, Johansen-Berg H, Wade D, Bogdanovic M, Collett J, et al. Brain activity changes associated with treadmill training after stroke. *Stroke* 2009;40:2460-2467.
 12. Ferrari M, Quaresima V. A brief review on the history of human functional near-infrared spectroscopy (fNIRS) development and fields of application. *Neuroimage* 2012;63:921-935.
 13. Scholkmann F, Metz AJ, Wolf M. Measuring tissue hemodynamics and oxygenation by continuous-wave functional near-infrared spectroscopy-how robust are the different calculation methods against movement artifacts? *Physiol Meas* 2014;35:717-734.
 14. Tsujii T, Yamamoto E, Ohira T, Saito N, Watanabe S. Effects of sedative and non-sedative H antagonists on cognitive tasks: behavioral and near-infrared spectroscopy (NIRS) examinations. *Psychopharmacology (Berl)* 2007;194:83-91.
 15. Artemenko C, Coldea A, Soltanlou M, Dresler T, Nuerk HC, Ehlis AC. The neural circuits of number and letter copying: an fNIRS study. *Exp Brain Res* 2018;236:1129-1138.
 16. Zhang Y, Li XQ, Guo Y, Zhang Z, Xu F, Xiang N, et al. Dorsolateral prefrontal activation in emotional autobiographical task in depressed and anxious college students: an fNIRS study. *Int J Environ Res Public Health* 2022;19:14335.
 17. Dozois DJA, Dobson KS, Ahnberg JL. A psychometric evaluation of the Beck Depression Inventory-II. *Psychol Assess* 1998;10:83-89.
 18. Lee EH, Lee SJ, Hwang ST, Hong SH, Kim JH. Reliability and validity of the Beck Depression Inventory-II among Korean adolescents. *Psychiatry Investig* 2017;14:30-36.
 19. Beck AT, Epstein N, Brown G, Steer RA. An inventory for measuring clinical anxiety: psychometric properties. *J Consult Clin Psychol* 1988; 56:893-897.
 20. Lee HK, Lee EH, Hwang ST, Hong SH, Kim JH. Psychometric properties of the Beck Anxiety Inventory in the community-dwelling sample of Korean adults. *Korean J Clin Psychol* 2016;35:822-830.
 21. Julian LJ. Measures of anxiety: State-Trait Anxiety Inventory (STAI), Beck Anxiety Inventory (BAI), and Hospital Anxiety and Depression Scale-Anxiety (HADS-A). *Arthritis Care Res* 2011;63 Suppl 11:S467-S472.
 22. Osman A, Hoffman J, Barrios FX, Kopper BA, Breitenstein JL, Hahn SK. Factor structure, reliability, and validity of the Beck Anxiety Inventory in adolescent psychiatric inpatients. *J Clin Psychol* 2002;58:443-456.
 23. de Lima Osório F, Crippa JA, Loureiro SR. Further psychometric study of the Beck Anxiety Inventory including factorial analysis and social anxiety disorder screening. *Int J Psychiatry Clinical Pract* 2011;15:255-262.
 24. Kang T, Kam J, Bahn GH, Song SH, Kim J, Kim J, et al. Development of Korean Adult ADHD Rating Scale. *Korean Acad Child Adolesc Psychiatry* 2015;26:295-310.
 25. Hong S. Influence of humanistic knowledge and resilience on communication skills in nursing students. *Korean J Health Commun* 2017;12: 189-200.
 26. Galli G, Feurra M, Pavone EF, Sirota M, Rossi S. Dynamic changes in prefrontal cortex involvement during verbal episodic memory formation. *Biol Psychol* 2017;125:36-44.
 27. Han LT, Cohen MS, He LK, Green LM, Knowlton BJ, Castel AD, et al. Establishing a causal role for left ventrolateral prefrontal cortex in value-directed memory encoding with high-definition transcranial direct current stimulation. *Neuropsychologia* 2023;181:108489.
 28. Park H, Leal F, Abellanoza C, Schaeffer JD. The formation of source memory under distraction. *Behav Brain Funct* 2014;10:40.
 29. Raposo A, Han S, Dobbins IG. Ventrolateral prefrontal cortex and self-initiated semantic elaboration during memory retrieval. *Neuropsychologia* 2009;47:2261-2271.
 30. Michel CA, Schneck N, Mann JJ, Ochsner KN, Brodsky BS, Stanley B. Prefrontal cortex engagement during an fMRI task of emotion regulation as a potential predictor of treatment response in borderline personality disorder. *J Affect Disord* 2024;364:240-248.
 31. Sabatinelli D, Fortune EE, Li Q, Siddiqui A, Krafft C, Oliver WT, et al. Emotional perception: meta-analyses of face and natural scene processing. *Neuroimage* 2011;54:2524-2533.
 32. Wang J, Yang Z, Klugah-Brown B, Zhang T, Yang J, Yuan J, et al. The critical mediating roles of the middle temporal gyrus and ventrolateral prefrontal cortex in the dynamic processing of interpersonal emotion regulation. *Neuroimage* 2024;300:120789.
 33. Brunoni AR, Vanderhasselt MA. Working memory improvement with non-invasive brain stimulation of the dorsolateral prefrontal cortex: a systematic review and meta-analysis. *Brain Cogn* 2014;86:1-9.
 34. McCall J, van der Stelt CM, DeMarco A, Dickens JV, Dvorak E, Lacey E, et al. Distinguishing semantic control and phonological control and their role in aphasic deficits: a task switching investigation. *Neuropsychologia* 2022;173:108302.
 35. Miyake A, Emerson MJ, Padilla F, Ahn JC. Inner speech as a retrieval aid for task goals: The effects of cue type and articulatory suppression in the random task cuing paradigm. *Acta Psychol (Amst)* 2004;115:123-142.
 36. Paolini M, Palladini M, Mazza MG, Colombo F, Vai B, Rovere-Querini P, et al. Brain correlates of subjective cognitive complaints in COVID-19 survivors: a multimodal magnetic resonance imaging study. *Eur Neuropsychopharmacol* 2023;68:1-10.
 37. Prasannakumar A, Korann V, Jacob A, Bharath RD, Kumar V, Varambally S, et al. Relation between frontal pole volumes and cognitive insight in Schizophrenia. *Asian J Psychiatr* 2022;76:103204.
 38. Lysaker PH, Tsai J, Maulucci AM, Stanghellini G. Narrative accounts of illness in schizophrenia: association of different forms of awareness with neurocognition and social function over time. *Conscious Cogn* 2008; 17:1143-1151.
 39. Nordahl H, Strand ER, Hjemdal O, Nordahl HM. Is meta-worry relevant to interpersonal problems? Testing the metacognitive model of generalized anxiety disorder in an analogue- and a clinical sample of GAD. *Cogn Behav Ther* 2024;53:455-466.
 40. Petrides M. Lateral prefrontal cortex: architectonic and functional organization. *Philos Trans R Soc B* 2005;360:781-795.
 41. Barbey AK, Koenigs M, Grafman J. Dorsolateral prefrontal contributions to human working memory. *Cortex* 2013;49:1195-1205.
 42. Cheng S, Qiu X, Li S, Mo L, Xu F, Zhang D. Different roles of the left and right ventrolateral prefrontal cortex in cognitive reappraisal: an online transcranial magnetic stimulation study. *Front Hum Neurosci* 2022;16:928077.
 43. Badre D, Wagner AD. Left ventrolateral prefrontal cortex and the cognitive control of memory. *Neuropsychologia* 2007;45:2883-2901.
 44. Horr NK, Braun C, Volz KG. Feeling before knowing why: the role of the orbitofrontal cortex in intuitive judgments--an MEG study. *Cogn Affect Behav Neurosci* 2014;14:1271-1285.
 45. Khalil R, Godde B, Karim AA. The link between creativity, cognition, and creative drives and underlying neural mechanisms. *Front Neural Circuits* 2019;13:18.
 46. Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. *Annu Rev Neurosci* 2001;24:167-202.
 47. Wagner AD, Maril A, Bjork RA, Schacter DL. Prefrontal contributions to executive control: fMRI evidence for functional distinctions within lateral prefrontal cortex. *Neuroimage* 2001;14:1337-1347.
 48. Beaty RE, Benedek M, Kaufman SB, Silvia PJ. Default and executive network coupling supports creative idea production. *Sci Rep* 2015;5: 10964.
 49. Bechara A, Damasio H, Damasio AR. Emotion, decision making and the orbitofrontal cortex. *Cereb Cortex* 2000;10:295-307.