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A pilot study of change in cerebral activity during personality rating by questionnaire and personal computer

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The purpose of this study was to examine cerebral blood flow in the frontal cortex area during personality self-rating tasks. Our two hypotheses were (1) cerebral blood flow varies based on personality rating condition and (2) cerebral blood flow varies based on the personality traits. This experiment measured cerebral blood flow under 3 personal computer rating conditions and 2 questionnaire conditions. Comparing the rating conditions, the results of the *t*-test indicated that cerebral blood flow was higher in the questionnaire condition than it was in the personal computer condition. With respect to the Big Five, the result of the correlation coefficient, that is, cerebral blood flow during a personality rating task, changed according to the trait for agreeableness. The results of the analysis of the 5-cluster on individual differences indicated that certain personality traits were related to the factors that increased or decreased cerebral blood flow. An analysis of variance indicated that openness to experience and Behavioural Activation System-drive was significant given that participants with high intellectual curiosity were motivated in this experiment, thus, their cerebral blood flow may have increased. The significance of this experiment was that by employing certain performance measures we could examine differences in physical changes based on personality traits.

Keywords: Personality self-rating; Cerebral blood flow; Personality trait; Individual difference; Cluster analysis.

When responding to a personality self-evaluation questionnaire, we consider one's typical behaviour as it relates to an item, assuming that the item requires a "yes" or "no" response. Considering personality rating as a type of performance of the brain, it is assumed that individual differences and some physiological responses occur in a series of processes that involve evaluating one's own personality. This study measures a series of processes involved in personality rating and examines changes in blood flow in the prefrontal cortex during personality rating.

The part of the brain that plays an important role in brain activity and regulation during performance is the prefrontal cortex, which addresses higher-order processes related to working memory and reaction restraint etc. Hemoencephalography (HEG) is a method of monitoring changes in the frontal cerebral blood flow circulation and oxygenation. HEG measurement indicates the level of neural activity of the brain based on cerebral blood flow in the prefrontal cortex, and hence, it is closely related to the cognitive function of the brain (Toomim & Carmen, 2009). When the HEG sensor irradiates with near-infrared light from the scalp, the light component diffuses into the brain tissue and reaches the cerebral cortex at the depth of approximately 20–30 mm from the scalp (Watanabe, Murota, & Nakajima, 2005). With respect to the prefrontal cortex and performance, changes in blood flow in the prefrontal cortex indicate the degree of concentration during learning and performance (Ridderinkhof, Van den Wildenberg, Segalowitz, & Carter, 2004), thus making it possible to examine the relationship between brain activity and performance. Accordingly, HEG is assumed to be an index of the activity rate of the brain during a certain activity. An additional advantage of HEG is that it is less susceptible to myoelectrical artefacts, blinking, and changes in facial expressions than electroencephalography. However, it may result in artefacts not related to brain function being mixed into the record. Therefore, by analysing using the averaging method, it is possible to remove any data mixed with artefacts. Because it is

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necessary to establish a specific task to actually record appropriate data and clarify a specific brain function, in this study, personality rating, as the task, is divided into several conditions, and the cerebral blood flow is compared. Hence, we assumed two hypotheses regarding cerebral blood flow in the prefrontal cortex during personality rating.

The first hypothesis proposes that frontal cerebral blood flow varies depending on the personality evaluation method being applied. The personality evaluation method of this experiment is under three personal computer (PC) conditions and under two questionnaire conditions. The personality rating task on the PC is divided into three sessions, namely, simple response, self-rating by term, and self-rating by sentence. In the simple response session, we measure the base amount of frontal cerebral blood flow during a simple task session for each individual, and examine individual differences in stimulation and reaction in frontal cerebral blood flow. In the self-rating by term session, considering that people may assess the personality based on the individual's personal trait terms, we measure the amount of cerebral blood flow during a self-rating task involving only personality trait terms. Trait research is based on personality trait terms (Allport & Odbert, 1936) according to the premise that we think about ourselves in terms of personality traits, some physical response may occur with favourable or unfavourable terms. In the personality self-rating by sentence session, it is by adding "Are you ..."at the beginning of each item in the by-term session and measure time to self-rating personality. This session can measure the amount of cerebral blood flow to judge own personality with sentences. In two questionnaire conditions, we measure cerebral blood flow when participants perform self-rating using paper and pen, namely, the Big Five scale, the Behavioural Inhibition System/Behavioural Activation System (BIS/BAS) and a self-control measure. These conditions were established and compare changes in cerebral blood flow under each condition during the personality rating task.

Hypothesis 2 proposes that cerebral blood flow during personality rating changes according to the personality traits. Personality traits represent tendencies to manifest patterns of cognition, emotion, motivation and behaviour in response to a variety of eliciting stimuli (Fleeson, 2001). The present experiment measures cerebral blood flow when completing inventories, allowing us to examine the relationship between personality traits of the Big Five inventory.

In a study of the biological theory of the Big Five, neuroticism is linked to the tendency to experience negative emotions (Clark & Watson, 2008; Costa & McCrae, 1995), and includes such traits as anxiety, self-consciousness and irritability, whereas agreeableness is linked to psychological mechanisms that allow the understanding of others' emotions, intentions and mental states, including empathy, theory of mind and other forms of social information processing (Graziano, Habashi, Sheese, & Tobin, 2007; Nettle & Liddle, 2008). Conscientiousness is linked to both academic and occupational success as well as to behaviour that promotes health and longevity (Ozer & Benet-Martinez, 2006), while openness to experience reflects the tendency to process abstract and perceptual information flexibly and effectively and includes traits such as imagination, intellectual engagement and aesthetic interest (DeYoung, Peterson, & Higgins, 2005). These tendencies are presumed to arise from regularities in the functioning of relevant brain systems (DeYoung & Gray, 2009). The theory further assumes that these five characteristics are related to the frontal blood flow in this experiment. Accordingly, we examine two attitude scales extracted from the Minnesota Multiphasic Personality Inventory and included in the Japanese version of the Big Five (Murakami & Murakami, 2008). The fictional scale is composed of strong "Yes" and "No" items to measure deviations from ordinary answer patterns. It is further assumed that the attitude scale measures public stance attitudes related to employment and recruitment examinations. These two scales may be related to cerebral blood flow as people who do not want to deviate from regular answer patterns exhibit high fictional scale scores and those who place importance on public stance have high attitude scale scores.

Additionally, since cerebral blood flow is a physical measurement, we use the BIS/BAS scale to measure facets of temperament. The BAS motive behaviour focuses on obtaining a reward by making the individual aware of the reward and giving the go-ahead signal to trigger the behaviour (Gray, 1981). In contrast, the BIS is an anxiety system that inhibits behaviours associated with potential punishment or lack of reward. BIS activity is psychologically expressed in terms of neurotic anxiety and depression (Gray, 1987). Both BAS and BIS are rooted in brain circuitry associated with the distributed limbic system, which includes the network of connections along the ventromedial PFC, anterior cingulate cortex, amygdala, hippocampus and related structures (Heimer & Van Hoesen, 2006; Morgane, Galler, & Mokler, 2005). Thus, the BIS/BAS theory and scale offer a detailed description of the neuropsychological process underlying individual differences in personality. Therefore, this experiment examines two hypotheses by cerebral blood flow during personality self-rating tasks. From this, it is possible to measure the process of cerebral blood flow at five conditions of personality self-rating, to examine the relationship between quantitative data and personality traits.

PURPOSE

The purpose of this study is to measure cerebral blood flow in the frontal cortex area during personality

TABLE 1
Stimulus terms of personality traits used in experiment

Traits		*Stimuli terms*			
Big Five	Extroversion	Active	Sociable	Passive	Restrained
	Agreeableness	Kindly	Affable	Headstrong	Tightwad
	Conscientiousness	Capable	Conscientious	Sloppy	Unreliable
	Neuroticism	Easygoing	Sedate	Irascibleness	Worrier
	Openness	Intelligent	Clever	Conservative	Naivety
Practice stimuli terms		Sincere	Amenable	Philosophical	

self-rating tasks and to examine changes in cerebral blood flow during personality self-rating tasks. Our two hypotheses are as follows.

Hypothesis 1: Cerebral blood flow varies based on personality rating condition.

Hypothesis 2: Cerebral blood flow varies based on the personality traits.

METHOD

Participants

The participants included 22 Japanese graduate students (13 males, 9 females) aged 19–22 years (one female was excluded due to incomplete data.).

Experiment period

The experimental period extended from May through December 2014.

Equipment

The equipment included a laptop computer (Dell-Vostro 3360) vital monitor ProComp TM7500 (Thought Technology Ltd., Canada) to measure the prefrontal cortex according to HEG, HR, EEG (F3, F4). For stimulus presentation during the three sessions of the self-rating task on the PC, we installed E-prime 2.0 on the same laptop computer. The degree of stress during the self-rating task was measured using a salivary amylase monitor (NIPRO; 27B1X00045000073).

Experiment stimulus

Referring to a manual of the Big Five Inventory for Japanese, we selected four terms that would be familiar to university students for each of the five personality traits (Table 1). These 20 personality trait terms were set as visual stimuli in computer image files for display on a PC screen. Auditory stimuli of these 20 traits were then recorded on a PC using a male voice (700 ms duration).

Measurement self-rating conditions of brain activity

To measure in frontal cerebral blood flow during personality rating tasks, we set under six conditions (Table 2); two questionnaire conditions and three rating conditions on the PC, and the CL condition was set as the criterion for the individual.

Personality inventory

Prior to the three sessions on the PC, participants rated the scale construction of the Big Five Inventory for Japanese (Murakami & Murakami, 2008). After three sessions on the PC, participants completed the BIS/BAS scale for Japanese (Takahashi et al., 2007) and the self-control scale (Tangney, Baumeister, & Boone, 2004).

Procedure

This experiment was designed to be completed in an 80–90 minutes period. After explaining the experiment to the participant, the experimenter set up the electrocardiogram, the frontal EEG (F3, F4) and the HEG. To confirm the installation of the equipment, the experimenter asked the participant to read a newspaper and confirmed that frontal cerebral blood flow could be measured using HEG. And, the experimenter began to measure self-rating conditions of brain activity.

In the Q1 condition, to measure the cerebral blood flow using HEG, participant completed the Big Five Inventory. The participant's salivary amylase was measured for 30 seconds to determine the degree of stress; and, to measure frontal cerebral blood flow during the stabilisation period of the participant, we used the CL condition.

We measured cerebral blood flow during three rating sessions on the computer. In the simple-response session, after displaying a gaze point (+) on the PC for 500 ms,

TABLE 2
Measurements conditions

Analysis conditions	*HEG measurement session*	*Contents*
Close eyes condition	CL condition	A conditions to measure the frontal blood flow at the time of stabilisation of participants, we measured eyes closed for 3 minutes as a rest time.
Questioner condition	Q1 condition	A condition to measure the activity amount of cerebral blood flow when self-rating with Big5 inventory using paper and pen, before PC sessions.
PC-condition	Simple response session	The individual differences in the cerebral blood flow to stimulation and reaction.
	Self-rating by-term session	The cerebral blood flow when doing self-rating with only personality trait term.
	Self-rating by-sentence session	The cerebral blood flow when doing self-rating with the sentence with “Are you-” in the beginning by-term session.
Questioner condition	Q2 condition	A condition to measure the activity amount of cerebral blood flow when self-rating with BIS/BAS and Self-control using paper and pen, after PC sessions.

BIS = behavioural inhibition system; BAS = behavioural activation system; PC = personal computer

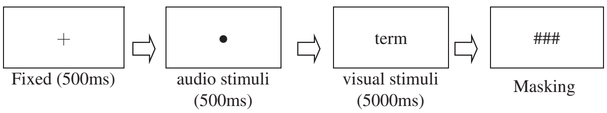

Figure 1. Experimental stimulus block diagram for self-rating by-term and by-sentence session.

we displayed a black dot (•) for 700 ms. Upon seeing the black dot, the participant heard an audio stimulus via headphones. A visual stimulus was displayed on the next screen (max = 1800 ms). If the audio and visual stimuli matched, the participant pressed “○.” If the terms did not match, the participant pressed “×.” After the participant pressed a key, that trial was finished (masking). The visual and audio stimuli were used for 20 personality terms (Table 1), and the trial was assigned randomly for each participant. In a practice session, the participant practised two or three times in the simple-response session (3 words × 5 = 15 trials) and performed 200 trials in the simple-response session (20 terms × 10 = 200 trials).

In the self-rating by term session (Figure 1), after displaying a gaze point (+) for 500 ms and a black dot (•) for 500 ms, we randomly displayed a trait term as a visual stimulus on the next screen. A black dot screen was not the audio stimulus. When participants observed a trait term that they thought applied to their own personality, they pressed ○. Conversely, when participants observed a trait term that they did not think applied to their own personality, they pressed “×.” The trial was then finished (masking). Participants performed 100 trials (20 terms × 5 = 100 trials).

In the self-rating by sentences session, we created 20 stimulations adding “Are you … ” at the beginning of the sentences used in Table 1. After silently displaying a gaze point (+) for 500 ms and a black dot (•) for 500 ms, we randomly displayed a sentence stimuli on the next screen. For example, a participant observed the sentence, “Are you kind?” and pressed “○” for a negative response and “×” for a positive response. Each participant performed 60 trials (20 terms×3 = 60 trials).

In the Q2 condition, after three sessions on the PC, the participant completed the BIS/BAS scale and the self-control scale. After another 30 seconds saliva amylase measurement for, the experimenter removed the participant’s experiment equipment.

Analysis

To examine changes in frontal cerebral blood flow during a personality self-rating task, we calculated the means and the standard deviation of the cerebral activity for each participant under each personality rating condition. The nIR-HEG was indicated by as the ratio between oxyhaemoglobin (mol/μL) and deoxidized haemoglobin (mol/μL) measured with near infrared and red visible light. The displayed measurement value was indicated by 200 times this ratio. Therefore, nIR-HEG was the value without units (Serra-Sala, Timoneda-Gallart, & Pérez-Álvarez, 2012). To examine the relationship between cerebral blood flow and personality traits, we determined the correlation coefficient between the cerebral blood flow during the personality self-rating task and each of the six conditions. To identify the change factor within the individual’s frontal cerebral blood flow, we performed cluster analysis based on casewise standardisation with Euclidean distance as the index of similarity using the Ward method and the analysis of variance (ANOVA) for the personality inventory with this cluster.

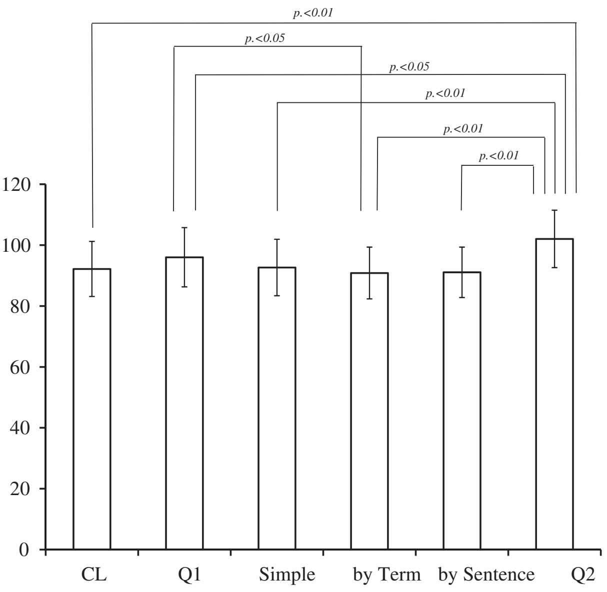

Figure 2. Means in cerebral blood flow according to rating conditions. *Note*: $N = 21$ (13 Males, 8 Females). Whisker line shows 95% critical limits of mean. The Lead lines indicate the results of paired *t*-test.

RESULTS

To examine changes in frontal cerebral blood flow during personality rating tasks, the personality rating was set to five conditions, and the CL condition (means of HEG for each participant) was set as the criterion for the individual. Thus, we analysed and examined cerebral blood flow under six conditions.

Differences in cerebral blood flow according to rating conditions

To examine differences in cerebral blood flow, we calculated the means and the standard deviation for each rating condition (Figure 2). The results of the ANOVA indicated no significant differences among the six conditions (F(5, 120) = 0.54, ns). Considering the large individual differences in cerebral blood flow, we conducted a two-way ANOVA using a random block design by participant × six conditions and identified a significant difference for participant × six conditions (F(5, 100) = 65.71, $p < .01$). Furthermore, in a paired-associated *t*-test for each condition a significant difference between the CL and Q1 condition (t(20) = 1.74, $p < .05$) was determined. However, no significance differences were found for the CL and simple-response session (t(20) = 0.28, ns), CL and self-rating by term session (t(20) = 0.78, ns), CL and self-rating by sentences session (t(20) = 0.58, ns), or the CL and Q2 condition (t (20) = 3.58, ns). In contrast, there were significant differences found for the Q1 condition and simple-response session (t(20) = 1.77, $p < .05$), the Q1 condition and self-rating by term session (t(20) = 2.15, $p < .05$), Q1 condition and the self-rating by sentences session (t(20) = 1.94, $p < .05$), and the Q1 condition and Q2 condition (t(20) = 2.54, $p < .01$). As depicted in Figure 4, cerebral blood flow in the Q1 condition (Big Five) was the highest of all conditions, and there were significant differences among all conditions.

With respect to PC conditions, a significant difference was indicated for the simple-response session and the self-rating by term session (t(20) = 2.06, $p < .05$). However, no significant difference was found for the simple-response session and the self-rating by sentence session (t(20) = 1.43, ns), the self-rating by term session or the self-rating by sentence session (t(20) = 0.36, ns). A comparison of the three PC conditions revealed no differences among the means of cerebral blood flow for the three PC conditions.

With respect to the PC conditions and the questionnaire conditions, significant differences were found for the self-rating by term session and the Q2 condition (t(20) = 5.44, $p < .01$) and the self-rating by sentence session and the Q2 condition (t(20) = 5.85, $p < .01$). A comparison of the PC condition and the Q condition indicated that cerebral blood flow increased more in the Q condition than in the PC condition.

The relationship between cerebral blood flow and personality traits

To examine the relationship between cerebral blood flow and personality, we calculated the correlation coefficient between cerebral blood flow during self-rating tasks and the six conditions (Table 3). As a Big Five scale result, the F scale was positively correlated with the five conditions of cerebral blood flow. This result indicates that cerebral blood flow increases for those with a high F score. Furthermore, agreeableness was found to be negatively correlated with the three conditions of cerebral blood flow. For participants with high degrees of agreeableness, cerebral blood flow decreased under the PC condition. No correlations with the other four traits of the Big Five were observed, and no significant correlations were found with respect to the BIS/BAS and self-control scales.

Cluster analysis and personality traits in intra-individual differences of frontal blood flow

To examine individual differences in cerebral activity during personality self-rating tasks, we calculated the mean and standard deviation and performed an ANOVA of the cerebral activity for each individual under each condition. The ANOVA results indicated a major effect on the amount of cerebral activity for each participant (F(20, 105) = 46.45, $p < .01$).

TABLE 3
Correlations between each conditions and Big Five questioner scales

	Big Five scale before PC sessions						
	F	*Att*	*Extraversion*	*Agreeableness*	*Conscientiousness*	*Neuroticism*	*Openness*
CL condition	.458*	.080	.003	−.382	−.160	.073	.033
Q1 condition	.425	.030	−.006	−.423	−.090	.039	−.046
Simple response session	.515*	−.042	−.027	−.442*	−.129	.047	−.121
Self-rating by Term session	.534*	−.037	−.018	−.438*	−.135	.052	−.126
Self-rating by Sentence session	.508*	.001	.043	−.435*	−.089	.059	−.123
Q2 condition	.457*	−.109	−.010	−.416	.038	−.001	−.239

Note: $N = 21$ (13 Males, 8 Females)
*$p < .05$

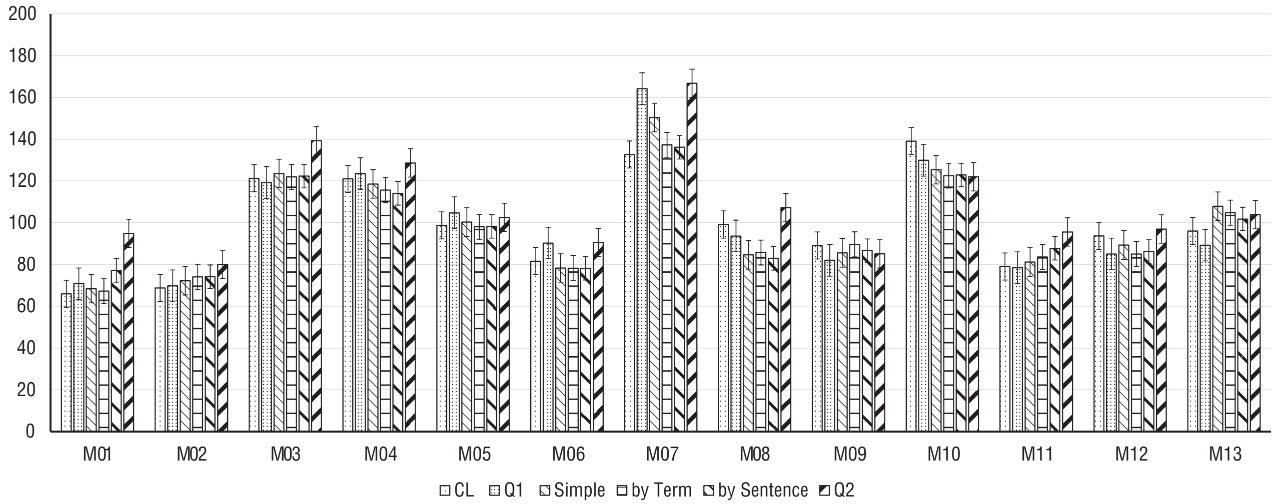

Figure 3. The means of individual differences in cerebral blood flow of male participants.

As a tendency of the individual differences with respect to frontal blood flow, for some participants, the cerebral blood flow means were close to 80, whereas those for others were close to 140. Furthermore, the cerebral blood flow of some participants exceeded 100 in the CL condition. One male participant's blood flow increased by more than 20 during some performances, a result that suggests individual variations in the cerebral blood flow of each individual. More specifically, men exhibited a wider range of variation than did their female counterparts (Figure 3) as the means of female participants were less than those of the male participants and stabilised at 80 (Figure 4). It is also noted that the fluctuation range of cerebral blood flow was small during some performances. In the rating condition, a significant difference by gender was noted, with the means of cerebral blood flow being higher for men than women in all conditions. The results were as follows: CL ($t(19) = 2.11$, $p < .05$), simple ($t(19) = 1.98$, $p < .05$), by term ($t(19) = 2.16$, $p < .05$), by sentence ($t(19) = 2.22$, $p < .05$), Q2 ($t(19) = 2.05$, $p < .05$).

To examine individual differences and personality traits with respect to cerebral blood flow, we performed a cluster analysis for the six conditions and presented the findings in a dendrogram (Figure 5). The results indicated that the changes in cerebral activity were divided into five clusters as factors of intra-individual variability rather than by differences among subjects due to gender or club activities. The first cluster (Male = 4, Female = 2) remained almost stable with fluctuations of 10–20 in cerebral blood flow in the PC conditions, but the cerebral blood flow tended to gradually increase in the Q2 condition. While the Big Five (Q1) did not increase significantly, the cerebral blood flow gradually increased in the last BIS/BAS (Q2), with an increase of more than 20 in the means of individuals. Participants in this cluster tended to take more time for work and for activities in their daily lives, for example, studying or job hunting. The second cluster's cerebral blood flow (Male = 3, Female = 1) gradually increased even when not performing, that is, when listening to instructions or undergoing amylase measurement, and cerebral blood flow tended to stabilise during PC rating. Cerebral blood flow then further increased in the Q condition. Such a tendency may indicate that the participant was either concentrating on the rating performance or was nervous. This cluster

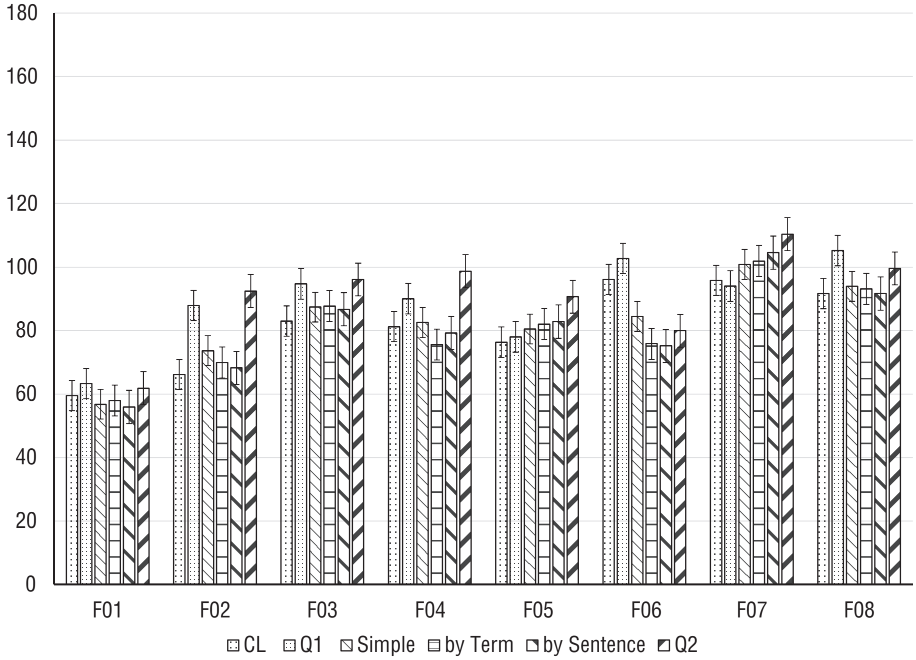

Figure 4. The means of individual differences in cerebral blood flow of female participants.

included participants who were chosen as leaders in clubs and who experienced tension that may have reflected during their performance in this experiment. In the third cluster (Male = 3, Female = 4), almost no change in cerebral blood flow was observed in the means of individual participants. In the PC and Q conditions, cerebral blood flow increased and decreased only by 10, and it remained stable even when the participants were not performing. People in this cluster were also calm and emotionally stable in their studies and club activities. The fourth cluster's cerebral blood flow (Male = 2) gradually increased at the beginning of the rating performance; however, it also tended to increase and decrease repeatedly in the CL, PC, and Q conditions and to decline during instruction temporarily. In this cluster, motivation was occasionally diminished by lectures and club activities, but would rise again when someone encouraged them. It was suggested that they could not motivate themselves to perform. The experiment the fifth cluster (Male = 1, Female = 1) had a wide variety of cerebral blood flow because of sneezing and sleepiness. The participant's cerebral blood flow varied finely overall, whereas not much change in cerebral blood flow was observed between performing and non-performing conditions. During the experiment, participants commented, "I made a mistake," or they fell asleep while performing. The results of each cluster clarified that the cerebral blood flow fluctuation is influenced by intra-individual factors during performance.

Since this result suggests that personality traits are individual factors, we performed an ANOVA using the personality inventory with this cluster. For the Big Five (Table 4), a significant difference was indicated in the amount of cerebral activity for openness to experience ($F(4, 16) = 6.03$, $p < .01$), although no significance was found for extraversion ($F(4, 16) = 1.94$, ns), agreeableness ($F(4, 16) = 0.69$, ns), conscientiousness ($F(4, 16) = 0.27$, ns), or neuroticism ($F(4, 16) = 1.35$, ns). Additionally, no significance was found for the self-control scale ($F(4, 16) = 0.59$, ns). With respect to the BIS/BAS (Table 5), however, the ANOVA confirmed a major effect on the amount of cerebral activity based on the total BAS score ($F(4, 16) = 4.47$, $p < .01$) and the BAS-Drive ($F(4, 16) = 4.10$, $p < .05$). The results of the ANOVA indicated cerebral activity during personality rating tasks changes due to the following personality traits: approach tendency regarding reward as a BAS, sustainable pursuit of goals as a BAS-Drive and intellectual curiosity as openness. A cluster analysis indicated that intra-individual change factors of cerebral blood flow, such as sleepiness, tension, and intellectual curiosity, during personality self-rating tasks served as a motivation to perform.

DISCUSSION

The aim of this experiment was to measure and examine cerebral blood flow in the frontal cortex area during personality self-rating tasks.

The first hypothesis proposed that cerebral blood flow varied with personality rating conditions. However, while the results indicated no significant differences in a one-way ANOVA with only the rating condition, the

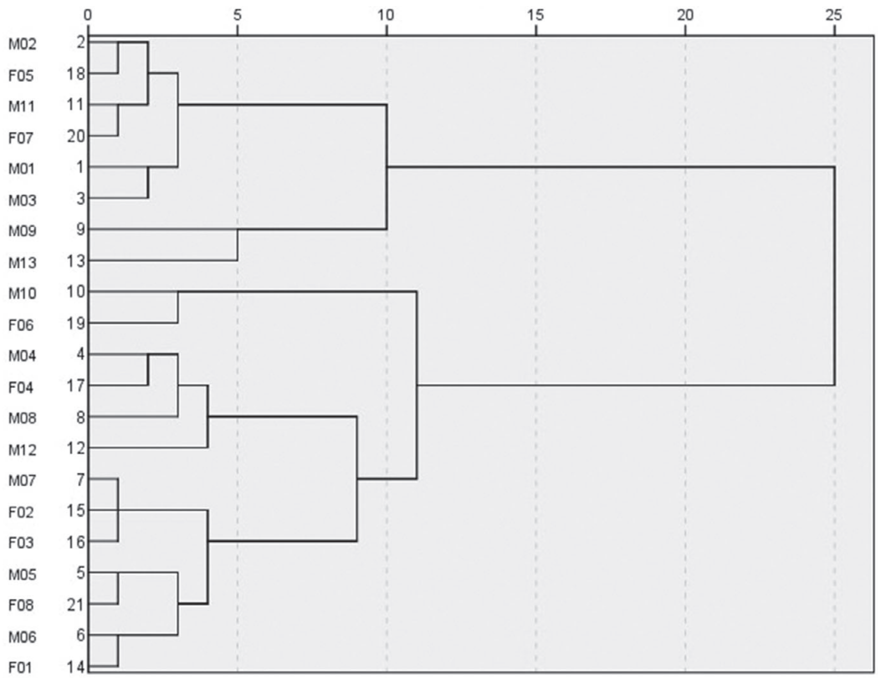

Figure 5. Dendrogram of the cluster analysis in cerebral activity during personality rating. *Note*: $N = 21$ (13 Males, 8 Females). The vertical axis shows gender (M of F) and case number, the horizontal axis shows an index of similarity with Euclidean distance.

TABLE 4
One-way ANOVA and multiple comparisons of Big Five questioner scales by cluster

		Fictional		*Supposedly attitude*		*Extraversion*		*Agreeableness*		*Conscientiousness*		*Neuroticism*		*Openness to experience*	
Cluster	*n*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
1	6	1.67	1.75	2.83	2.56	7.50	2.88	8.33	2.58	5.67	3.67	4.50	2.35	3.00	1.67
2	4	2.00	1.16	2.75	1.89	4.00	3.56	8.50	2.38	4.00	3.46	3.25	2.22	1.00	1.16
3	7	2.29	1.60	2.43	2.23	4.38	1.65	7.14	1.77	5.14	3.24	3.86	2.27	2.43	2.51
4	2	1.50	2.12	2.50	0.71	3.50	0.71	9.50	2.12	4.50	0.71	6.00	1.41	3.50	2.12
5	2	1.00	1.41	6.50	0.71	10.00	0.00	9.00	0.00	3.50	0.71	7.00	1.41	9.00	0.00
Total	21	1.86	1.49	3.00	2.26	5.57	3.80	8.14	2.08	4.86	2.99	4.43	2.27	3.05	2.75
ANOVA		$F(4, 16) = 0.32$ ns		$F(4, 16) = 1.49$ ns		$F(4, 16) = 1.94$ ns		$F(4, 16) = 0.70$ ns		$F(4, 16) = 0.27$ ns		$F(4, 16) = 1.35$ ns		$F(4, 16) = 6.03$ $p < .01$	
Multiple comparison		ns		3 vs. 5		ns		ns		ns		ns		1 vs. 5, 2 vs. 5, 3 vs. 5, 4 vs. 5	

Note. In the multiple comparison column shows the combinations where a significant difference was found at $p < .05$.
ANOVA = analysis of variance; ns = not significant.

results of a two-way ANOVA indicated a difference in cerebral blood flow by participant × condition, thus suggesting that individual differences in cerebral blood flow were large and varied. In other words, the results indicated a difference due to the rating evaluation condition. In addition, the results of a *t*-test that compared the Q condition and the PC condition indicated that cerebral blood flow was higher in the Q condition than in the PC condition and that no significant differences in the means of cerebral blood flow were observed among the three PC sessions. The CL condition was accepted as the means when not performing in this experiment, and the results indicated a significant difference in cerebral blood flow in the CL and the Big Five conditions. This suggests that cerebral blood flow during the PC rating was the same as it was during the CL condition, thereby indicating that cognitive and decision-making performances in the prefrontal cortex may not function during the PC the rating condition.

The second hypothesis proposed that cerebral blood flow varied with personality traits, and as a result, the correlation coefficient between each rating condition and

TABLE 5
One Way ANOVA and Multiple Comparisons of Behavioural Activation System Scale by Cluster

Cluster	n	Drive		Reward responsiveness		Fun seeking	
		Mean	SD	Mean	SD	Mean	SD
1	6	13.67	2.16	17.33	2.81	12.50	1.87
2	4	12.50	1.29	17.25	2.06	11.75	1.89
3	7	11.14	1.68	13.86	2.27	10.57	1.72
4	2	8.50	0.71	16.50	2.12	10.00	1.41
5	2	11.00	1.41	17.00	1.41	11.00	2.83
Total	21	11.86	2.20	16.05	2.66	11.33	1.91
ANOVA		$F(4, 16) = 4.10$ $p < .05$		$F(4, 16) = 2.30$ ns		$F(4, 16) = 1.19$ ns	
Multiple Comparison		1 vs. 3, 1vs. 4, 2 vs. 4		1 vs. 3, 2 vs. 3		ns	

Note. In the multiple comparison column shows the combinations where a significant difference was found at $p < .05$.
ANOVA = analysis of variance; ns = not significant.

the Big Five revealed that agreeableness was negatively correlated with the PC sessions. Cerebral blood flow decreased in participants with high agreeableness in the PC rating condition, suggesting that those with high degrees of agreeableness do not consider cooperation an important trait according to the PC rating. More specifically, the positive pole of agreeableness describes prosocial traits such as cooperation, compassion and politeness, whereas its negative pole describes antisocial traits, such as callousness and aggression (Sampaio & Soares, 2013). In the experiment, since there was a negative correlation in the PC rating, it was suggested that personality rating tasks using they PC lacked a degree of politeness, thereby causing aggression to appear. Furthermore, the frequency scale positively correlated with five conditions of cerebral blood flow suggesting that people who did not want to depart from an ordinary response pattern exhibited a higher *F* scale score, thus suggesting that cerebral blood flow increases for those with higher *F* scores.

Thus, the result of the correlation coefficient was clarified only for the relationship between agreeableness and the frequency scale regarding the Big Five. More directly, there was no relation with the temperament aspect inventory such as BIS/BAS. In addition, we examined individual differences and personality traits. The hypothesis was that the rating condition suggested that individual differences in cerebral blood flow were large and varied. With respect to the relationship between the physiological index and the personality traits, this study determined that physiological individual differences affected the results of the experiment (Eysenck, 1967; Perez-Alvarez, Serra-Sala, & Timoneda-Gallart, 2016). Furthermore, this experiment also concluded that the variation in cerebral blood flow, as presented in Figures 3 and 4, revealed individual differences in frontal blood flow. This individual difference was concluded that there is a baseline cerebral blood flow for each individual and that the rating condition is a variation from that baseline. This result suggests that individual differences in cerebral blood flow are variations from baseline within the individual rather than variations due to rating conditions and gender difference.

Furthermore, to examine the relationships among personality and cerebral blood flow, cerebral blood flow was divided into five clusters of characteristic personality traits by cluster analysis. The results of these five clusters indicated that some personality traits were related to factors that increase or decrease cerebral blood flow during the personality rating tasks. An ANOVA conducted after the cluster analysis indicated that openness to experience was significant. Given that individual brain regions can serve multiple functions, openness/intellect may reflect complementary, albeit potentially conflicting, functions of lateral PFC by ensuring the stable execution of plans and manipulating abstract information to explore alternative possibilities (DeYoung & Gray, 2009). The openness/intellect trait is likely to involve the PFC and functionally related regions, particularly those involved in working memory, abstract reasoning and the control of attention. Hence, this trait is the only one of the Big Five traits to be consistently and positively associated with intelligence (DeYoung et al., 2005). Because it is unusual to complete personality rating tasks using laboratory equipment, participants with high intellectual curiosity were likely more motivated in this experiment than those with less intellectual curiosity, and thus, their cerebral blood flow may have increased. The BIS/BAS scale indicated that cerebral blood flow changes were due to remuneration (BAS) and the sustainable pursuit of the target BAS Drive. The BAS system is thought to be related to dopaminergic pathways in the cortical−striatal−thalamic−cortical loop system associated with the orbitofrontal cortex (Depue & Collins, 1999). Thus, it is suggested that the association between BAS/Drive and remuneration and goal may have caused both the increase and decrease of cerebral blood flow if the person considers the PC rating to be a game. Hence, cerebral blood flow during personality self-rating was associated with personality characteristics of motivation and openness. The findings suggest that a change in motivation and curiosity increases cerebral blood flow, whereas social desirability may decrease cerebral blood flow. Because the participants were limited age adolescents and the group was rather small. Hence, additional data are necessary to generalise the findings to a broad range of individuals of diverse demographics.

However, in this experiment, it was possible to clarify the difference in cerebral blood flow according to rating condition and personality traits. This result suggests that the quantitative data obtained using certain performance measurements could provide personality information that differs from that obtained using a questionnaire method.

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