Degree project

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Exploring the Relationship Between Frontal Alpha Asymmetry and the Big Five Personality Traits

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Abstract

Frontal Alpha Asymmetry (FAA) has been associated with individual differences such as various aspects of personality. However, the nature of the relationship between FAA and personality traits is not yet fully understood. The present study further investigated this relationship by exploring the correlation between resting-state FAA and the Big Five personality traits: openness, agreeableness, conscientiousness, extraversion, and neuroticism. 15 healthy participants completed resting-state EEG recordings three times and the Big Five Personality Inventory (BFI) twice. The results showed only one statistically significant correlation among the 20 correlations examined, between the F4-F3 resting-state FAA and openness scores. Besides, the direction of the relationship was the opposite of what would be expected. The small sample size of this study may have contributed to results, indicating the need for future research with larger samples. Nonetheless, the current findings add to the existing literature and suggest that the relationship between resting-state FAA and personality traits may be more complex than previously thought.

Keywords: Frontal Alpha Asymmetry, EEG, resting-state, personality traits, Big Five

Exploring the Relationship Between Frontal Alpha Asymmetry and the Big Five Personality Traits

"Personality is an individual's unique variation on the general evolutionary design for human nature, expressed as a developing pattern of dispositional traits, characteristic adaptations, and integrative life stories, complexly and differentially situated in culture" (McAdams & Pals, 2006, p. 212). According to this definition, personality can be evaluated in three different ways: traits, characteristic adaptations, and life stories. Most of the focus in personality neuroscience has been placed on traits, which are consistent patterns of behavior, motivation, emotion, and cognition that are independent of a person's environment or culture (Zillig et al., 2002), i.e., not that traits manifest identically across cultures, but rather that they persist over time and across various contexts (DeYoung, 2010). Individuals with high scores of a particular trait will experience the states connected to that trait more frequently and intensely than people who have low scores of that trait (Fleeson, 2001; Fleeson & Gallagher, 2009). For instance, a person with a high extraversion score will be chatty and outgoing more frequently than a person with a low extraversion score, but even the latter may occasionally have those characteristics (DeYoung, 2010).

The patterns of behavior, motivation, emotions, and cognition seem to be lateralized, meaning they are more strongly associated with certain processes or functions in one hemisphere of the brain than the other (Smith et al., 2017). For example, the left hemisphere has been strongly associated with positive emotions, whereas the right hemisphere has been strongly associated with negative emotions (e.g., Davidson et al., 1979; Gainotti, 1972; Galin, 1974; Machado & Cantilino, 2017; Sackeim et al., 1982; Tucker, 1981). The goal of personality neuroscience is to comprehend both the neurological systems underlying the states connected to the traits and the factors that make these neurological systems behave differently across individuals (DeYoung, 2010). Typically, traits are measured through questionnaires, self-reports, and/or ratings from peers. The personality questionnaires draw on raters' experiences over a much longer period than is possible in the lab (DeYoung, 2010). Another legitimate strategy is to study traits in a biological measure, such as asymmetry in the activity level between the left and right cortical hemispheres, and try to identify the psychological traits that are associated with this biological characteristic (DeYoung, 2010).

Frontal Alpha Asymmetry

"Frontal Alpha Asymmetry" (FAA) refers to the difference in alpha activity (8-13 Hz) between the left and right frontal regions of the brain's cortex (Allen et al., 2004a). Frontal alpha activity is inversely connected to cortical activity; higher frontal alpha activity implies decreased cortical activity while lower frontal alpha activity implies increased cortical activity (Buchbalm et al., 1984). Furthermore, the relative increased alpha power over one hemisphere indicates relative increased cortical activity in the opposite hemisphere (Allen et al., 2004a). This is due to the semi-independent nature of the hemispheres' parallel processing systems (Chiarello & Maxfield, 1996); the hemispheres are partially independent but have a connection via the white matter fiber tract corpus callosum (Chiarello & Maxfield, 1996; Cook, 1984; Hoptman & Davidson, 1994; Nowicka & Tacikowski, 2011; van der Knaap & van der Ham, 2011). The corpus callosum's inhibitory pathways (interhemispheric suppression, interhemispheric isolation, and interhemispheric interference) regulate interhemispheric communication and make it more efficient by selectively inhibiting or suppressing certain types of information transfer (Chiarello & Maxfield, 1996). FAA has been introduced as a measure of the relative activation levels of the left and right frontal regions of the brain (Allen et al., 2004a).

FAA can be measured using electroencephalography (EEG) during the resting-state (baseline) when the participants are awake, relaxed, and alternating between having their eyes closed and opened while looking at a fixation cross (Coan & Allen, 2003; Coan et al., 2006). To quantify the relative alpha activity at the corresponding right and left electrode channels, a difference score is calculated. This FAA score is measured by subtracting the alpha power in the left frontal region from the alpha power in the right frontal region. The alpha power is usually natural-logarithm transformed: ln(Right)-ln(Left) alpha power. Positive FAA scores indicate greater relative left cortical activity (i.e., greater relative right alpha activity) while negative FAA scores indicate greater relative right cortical activity (i.e., greater relative left alpha activity); (Allen et al., 2004a).

The founder of FAA, Richard Davidson, presented a paper in 1978 proposing that the experiences of positive and negative affect were linked to distinct patterns of asymmetrical frontal brain electrical activity (Allen & Kline, 2004). This frontal asymmetry of emotion model is one of the most popular cortical-centered theories in affective and social neuroscience. Hundreds of investigations since then have explored FAA as a potential marker of motivation, emotion, and psychopathology (Allen et al., 2018; Hofman, 2008). For instance, several studies are based on the motivational direction model which posits that left and right frontal cortical activity is indicative of approach and withdrawal motivation, respectively (Davidson, 1992; Harmon-Jones & Gable, 2018; Harmon-Jones et al., 2010).

The approach/withdrawal theory of FAA proposes that individual differences in the frontal brain activity patterns reflect individuals' motivational tendencies to approach or withdraw to unknown stimuli (Smith et al., 2017). Those with higher relative left frontal cortical activity tend to have approach-related emotions and behaviors such as optimism (De Pascalis et al., 2013), self-control (Schmeichel et al., 2016), jealousy (Harmon-Jones et al., 2009), and anger (Harmon-Jones & Sigelman, 2001). Whereas those with higher relative right frontal cortical activity (or less left frontal cortical activity) tend to have withdrawal-related emotions and behaviors, such as sadness and fear (Coan et al., 2001), depression (Thibodeau et al., 2006), anxiety (Mathersul et al., 2008), and empathy (Tullett et al., 2012). The approach/withdrawal theory of FAA emphasizes that the frontal brain activity patterns can reflect situational or environmental factors (states) and stable individual variability (traits); (Coan & Allen, 2004).

The Big Five Personality Traits

The Big Five personality traits are openness, agreeableness, conscientiousness, extraversion, and neuroticism (John & Srivastava, 1999). A high score on openness indicates imagination, a complex and rich emotional life, sensitivity to art and aesthetics, intellectual curiosity, flexible behavior, and non-dogmatic attitudes and ideals (Costa & McCrae, 1992). Individuals with a high score on agreeableness are sympathetic, trustworthy, and cooperative (Costa & McCrae, 1992). A high score on conscientiousness implies that the individual is scrupulous, well-organized, and active but relaxed (Costa & McCrae, 1992). Extraversion underlies a range of characteristics, such as impulsiveness (Eaves & Eysenck, 1975) sociability, activity, and the propensity to feel the emotions of joy and pleasure (Costa & McCrae, 1992). Neuroticism scores, on the other hand, show a person's propensity to feel psychological distress such as anxiety or sadness (Costa & McCrae, 1992).

The Big Five traits are scales ranging from one extreme to another: openness vs. closedness to experience, agreeableness vs. antagonism, conscientiousness vs. lack of direction, extraversion vs. introversion, and neuroticism vs. emotional stability (John & Srivastava, 1999). By evaluating traits from each of the five components, a therapist can get a complete picture of a client's personality (Costa & McCrae, 1992). Openness (e.g., DeYoung et al., 2007), agreeableness (e.g., Buss & Craik, 1983), conscientiousness (e.g., Roberts & DelVecchio, 2000), and extraversion (e.g., Lucas et al., 2000) are related to approach tendencies and approach-related emotions, while neuroticism is related to withdrawal tendencies and withdrawal-related emotions (e.g., Watson et al., 1988). This suggests that the Big Five personality traits may also be related to either greater relative left frontal cortical activity or greater relative right frontal cortical activity depending on their approach- or withdrawal association (Davidson, 1992; Harmon-Jones et al., 2010).

The Relationship Between Frontal Alpha Asymmetry and The Big Five Personality Traits

For decades, researchers have used resting-state EEG recordings to investigate the association between FAA and trait-like individual differences (Coan & Allen, 2004; Coan et al., 2006; Davidson, 1998; Nilsson, 2021). Numerous psychological factors are associated with resting-state FAA such as affective disorders (Mikolajczak et al., 2010), emotional intelligence, and personality traits (Hagemann et al., 1999; Mikolajczak et al., 2010; Reznik & Allen, 2018). Specifically, extraversion and neuroticism have been investigated frequently in resting-state FAA research. Less research has been conducted on openness, agreeableness, and conscientiousness and resting-state FAA (Monni et al., 2022). According to the motivational direction model, there is a *positive* correlation between extraversion and greater relative left frontal cortical activity and a *negative* correlation between the personality trait neuroticism and greater relative left frontal cortical activity (Davidson, 1992; Harmon-Jones et al., 2010).

In support of this model are studies that have investigated several personality traits from the extraversion dimension (e.g., Schmidt, 1999) and neuroticism (e.g., Huang et al., 2014; Minnix & Kline, 2004). Schmidt (1999) investigated the pattern of resting-state FAA in 271 right-handed undergraduates with varying levels of shyness and sociability, in which the latter is a characteristic of extraversion (Costa & McCrae, 1992). The revised 13-item Cheek and Buss Shyness Scale (Cheek, 1983; Cheek & Buss, 1981) measured shyness whereas the 5-item Cheek and Buss Sociability Scale (Cheek & Buss, 1981) evaluated sociability. The results showed that sociability was related to greater relative left frontal cortical activity whereas shyness was related to greater relative right cortical frontal activity.

A study using the Eysenck Personality Questionnaire (EPQ) and EEG found that neuroticism correlates with increased FAA variability over time in 140 right-handed college students. The results showed that higher neuroticism scores were associated with greater mid-frontal asymmetry (Minnix & Kline, 2004). Another study measured FAA in 37 right-handed healthy females with high and low scores on neuroticism throughout the menstrual cycle (the menstrual stage, the late follicular stage, and the mid-luteal stage) using Eysenck personality questionnaire short scale (EPQ-RSC) and EEG. The high-neuroticism females during the mid-late luteal phase showed greater relative right prefrontal cortical activity than low-neuroticism females (Huang et al., 2014).

Inconsistent Results

However, studies correlating resting-state FAA with personality traits have shown contradicting results. Many of the correlations between resting-state FAA and extraversion and neuroticism have only been found in a few studies using small sample sizes (Kuper et al., 2019). Studies with larger sample sizes have failed to replicate these associations (e.g., Kuper et al., 2019; Nilsson, 2021; Vecchio & De Pascalis, 2020). Psychology has recently experienced a replication crisis, with many findings failing to replicate previous investigations (Open Science Collaboration, 2015). The absence of a correlation between resting-state FAA and extraversion and neuroticism reflects low replication in this research area, which is consistent with the situation in many other areas of psychology (Kuper et al., 2019). Thus, additional research of better quality is required to determine if resting-state FAA correlates with the Big Five personality traits or if the inconsistent results suggest non-existent correlations (Hagemann et al., 1999; Kuper et al., 2019; Monni et al., 2022).

The Present Study

In this study, I investigated the potential relationship between resting-state FAA and the Big Five personality traits: openness, agreeableness, conscientiousness, extraversion, and neuroticism by using resting-state EEG recordings three times and the BFI twice. Since this study is part of a larger project, test-retest reliability was conducted to minimize potential state-dependent factors (e.g., Davidson, 1998) such as the mental state which can affect the resting-state FAA scores (Vecchio & De Pascalis, 2020). The test-retest reliability enabled me to explore the consistency in the resting-state FAA scores across the

EEG sessions and then to average the resting-state FAA scores to further perform correlations.

Following the recommendations by Kuper et al. (2019) of using more valid self-report measures, I utilized the Big Five Personality Inventory (BFI); (John et al., 1991, 2008). The BFI is well-researched (Paulhus & Vazire, 2009, p. 232), brief and simple to complete, has strong reliability and validity (Goldberg, 1992), and is one of the most widely used personality questionnaires (Zhao et al., 2018) since it is frequently used in personality research investigations (e.g., Jensen-Campbell et al., 2007; Tullett et al., 2015; Zhao et al., 2018). To obtain a more stable estimate of the individual's personality traits and also minimize effects of state-dependent factors (Vecchio & De Pascalis, 2020), the BFI was administered during two of the three EEG sessions. This allowed me to also observe the consistency in the BFI scores across sessions and then to average the BFI scores to perform the correlations. I hypothesized that there is a *positive* correlation between the personality trait extraversion and greater relative left frontal cortical activity during resting-state and a *negative* correlation between the personality trait neuroticism and greater relative left frontal cortical activity during resting-state. The research question is: are there any statistically significant correlations between resting-state FAA and the Big Five personality traits?

Methods

Participants

In this study, 24 right-handed students at the University of Skövde, male and female (9 males and 14 females), 18-40 years old (mean age 25,30), fluent in English, and with normal or corrected-to-normal vision, participated. The exclusion criteria for participants were neurodivergent or psychiatric diagnoses such as epilepsy, depression, dyslexia, or ADHD, use of pharmaceutical or psychiatric drugs, sleep deprivation, or use of alcohol, caffeine, or nicotine before the experiment. The participants were recruited in person, via e-mail, social media, and posters at the University of Skövde. The Swedish Ethical Review Authority's support templates (Etikprövningsmyndigheten, 2023) were used for the information sheet (see Appendix A) and the informed consent form (see Appendix B).

Design

The design of the study is correlational since I explored correlations between resting-state FAA and the Big Five personality traits. There was a total of three 60-minute-long sessions with 2 weeks between each session. The experiment included two separate parts: resting-state EEG recording and self-report personality questionnaires. All three sessions included resting-state EEG recording but only the first and third sessions consisted of also answering the personality questionnaires. Participants were tested in the afternoon (12:00-5:00 pm) to control the EEG recording and minimize the effects of fatigue and circadian rhythms on the EEG frequency composition (which can contribute to significant alpha band variability); (Aeschbach et al., 1999).

Materials

Brain activity from the left and right frontal regions was recorded using the active EEG electrode system g.GAMMAsys (g.tec medical engineering GmbH, Austria). Conductive electrode gel was applied to each EEG recording site. The system transformed active electrode impedances into output impedances of about 1kOhm. 32 active g.SCARABEO electrodes were positioned by the international 10/20 placement system [Cz, Fz, FCz, AF3, AF4, F7, F8, F5, F6, F3, F4, C3, C4, CP1, CP2, P3, P4, PO3, PO4, PO7, PO8, O1, O2, CPz, Pz, POz, Oz]. Three pairs of electrodes from the frontal regions were measured pairwise and cluster-wise: mid-frontal F4-F3, lateral frontal F6-F5, and F8-F7 (following the recommendations of Reznik & Allen, 2018). The electrode cap that was used was either medium (54-58 cm) or large (58-62 cm). Two electrodes were applied with adhesive tape (designed for attaching electrodes) to the left (LM) and right (RM) mastoids. The online reference was the vertex (Cz), and the ground electrode was the AFz. An electrooculogram (EOG) was used to record eye movements and blinks. Four electrodes were placed around the participant's eyes: two about 1 cm below and above the right eye, one about 1 cm to the right of the right eye, and one about 1 cm to the left of the left eye. The average of the mastoids was re-referenced offline. The g.USBamp amplifier (g.tec) with 24-bit A/D conversion rates in the -250 mV to +250 mV range was utilized to amplify the EEG. A 100Hz low pass filter and a 0.01Hz high pass filter were used together with a 512Hz sampling rate.

Two personality questionnaires were used in this study: the English version of the BFI (John et al., 1991, 2008); (See Appendix C) and The Behavioral Inhibition and Activation Systems (BIS/BAS) Scales (Carver & White, 1994). The latter personality questionnaire was a part of my colleague's study and was not a part of my investigation. The BFI measures the Big Five personality traits: openness, agreeableness, conscientiousness, extraversion, and neuroticism. These traits are the five broad dimensions of personality, known as the "Big Five" or the "Five Factor Model" (FFM). The BFI is a 44-item questionnaire that uses sets of 8–10 items to assess each of these five aspects of personality. The 5-point Likert scale ranges from disagree strongly, disagree a little, neither agree nor disagree, agree a little, to agree strongly (John et al., 1991, 2008). The participant's answers determine where they fall on the scales of the Big Five personality traits: openness vs. closedness to experience, agreeableness vs. antagonism, conscientiousness vs. lack of direction, extraversion vs. introversion, and neuroticism vs. emotional stability (John & Srivastava, 1999).

Procedure

At the beginning of the first session, the participants read the information sheet about the experimental protocol and signed the informed consent form. The participants began by answering the personality questionnaires and continued doing the resting-state EEG recording experiment. The personality questionnaires (BFI and BIS/BAS) were divided into two separate parts and the BFI was administered first. One question at a time was displayed on a white background on the screen and the participants were able to continue to the following question when they were ready by clicking on a button named "continue" with the computer mouse. A total of 68 questions, whereof 44 questions from BFI and 24 questions from BIS/BAS were displayed and answered. No break was planned. E-prime 3.0 (Psychology Software Tools) was used to program the personality questionnaires.

When recording the resting-state, participants were seated in a dimly lit, separate EEG room, in a chair in front of a computer screen (19") with a refresh rate of 60 Hz and a resolution of 1920 x 1080. The participants were instructed to relax and remain still. The distance between the chair and the computer screen was approximately 105 cm. The EEG cap was attached to the participants' scalps and a keyboard was placed in their laps. Before the recording, the participants were given instructions verbally. During the experiment, they were given instructions digitally and pressed ENTER on the keyboard when they were ready for the following instructions and ready to begin the experiment. Before recording their resting-states, the participants were instructed to watch a one-minute video of outer space (colored stars flashing on a black background) to encourage a similar state among them.

During the resting-state EEG recording, the participants were given instructions about eyes opening and eyes closing. The recording of the resting-state was conducted under two different and randomized conditions; either the participants were instructed to focus on a black fixation cross on a grey background in the center of the screen or to keep their eyes closed. The participants were given a short beep sound from loudspeakers to let them know when the eyes-open and eyes-closed sessions would begin and end. Each of the conditions lasted for one minute, for a total of four times in each condition, giving a total of 8 minutes for the resting-state EEG recording, following the recommendations of Allen et al. (2004b). No break was planned. E-prime 3.0 (Psychology Software Tools) was used to program the entire task.

EEG Pre-Processing and Data Reduction

The EEG pre-processing steps were followed by recommendations from Smith et al. (2017) and Makoto's preprocessing pipeline (Makoto's preprocessing pipeline – SCCN, n.d.). The offline analysis was performed in MATLAB R2022a using the EEGLAB v2022 toolkit (Delorme & Makeig, 2004). The EEG data were re-sampled at 256 Hz and filtered using a windowed sinc FIR filter along with a 1 Hz high-pass filter and a 40 Hz low-pass filter. Channel locations were imported, non-EEG channels were excluded, and bad channels were rejected using the joint probability of the electrodes. Empty channels that had not recorded any electrical activity were rejected, as well as channels with activity 5 SD above the probability activity limits. After interpolating the channels, the clean line plugin was used for

EEGLAB's default settings to re-reference the data to the average and reject line noise at 50 Hz. The EEG data were segmented into epochs for both eyes open and closed for one second, and bad epochs were rejected using a standard deviation activity kurtosis threshold of 5. Independent Component Analysis (ICA) was employed to correct any residual artifacts. ICA finds a group of independent neural sources that are distinguished by scalp distribution (Keil et al., 2014). Parts that had a likelihood of being non-brain parts greater than 85% were marked and excluded.

To extract the alpha power, recommendations from Smith et al. (2017) and Grandchamp and Delorme (2011) were followed. First, EEGLAB's newtimef() function was used to calculate the alpha power spectral density in the right (F4, F6, F8) and left (F3, F5, F7) hemispheres. The data were decomposed using The Fast Fourier Transform (FFT) with Hanning tapering to derive power spectra density between 8-13 Hz using the newtimef() function. Newtimef() function eliminates edge artifacts by employing a sliding window that starts from the center of each data trial. The alpha power of each trial was calculated within a time range of -500 ms to 60500 ms (0-6000 seconds when the edges are removed, equivalent to 1 minute for each eyes opened and closed trial). The Full-epoch length single-trial correction method was implemented. This approach initially applies full-epoch length single-trial correction and uses the full-trial length as a baseline rather than the pre-stimulus period. Each time-frequency point value (200) is divided (gain model) first by the mean spectral power value of the full trial length and then by the mean pre-stimulus baseline value at the same frequencies (for details, see Grandchamp & Delorme, 2011). The values obtained were absolute, and they were converted to decibels (dB) to get the alpha power density for each trial using the formula: 10 * log10. Subsequently, the FAA score was calculated by subtracting the left alpha power from the right alpha power after using natural log-transforming (ln) to normalize the data. The averaged FAA scores across the trials of each participant were calculated.

The exclusion criteria for data reduction were as follows: poor data quality such as unusual portions of EEG data due to broken electrodes, improper gelling, or too many artifacts such as eye movements, eye blinks, muscle activity, etc., missing data due to technical issues during data collection, participants dropping out or participants unable to complete the task for some reason, and data that was beyond 3 SDs from the participant norm since that may indicate spurious data and would be excluded as an outlier.

Results

I had one goal with the statistical analyses: to determine if there are any correlations between the average resting-state FAA scores and the average BFI scores. 24 participants were recruited. One of the participants decided to withdraw from the study, resulting in 23 participants. One of these 23 participants was excluded due to technical issues with the EEG data, resulting in 22 participants included at the beginning of the statistical analyses for resting-state FAA scores. Some of these 22 participants completed all three sessions while some completed only one or two. I computed descriptive statistics for the resting-state FAA scores for 22 participants, for all electrode sites (pairwise: F4-F3, F6-F5, F8-F7, and right-left cluster: F4, F6, F8-F3, F5, F7), for session 1 VS 2 VS 3 to compare the resting-state FAA scores between sessions. Descriptive statistics for the resting-state FAA scores are presented in Table 1. I also computed descriptive statistics for the BFI scores for session 1 VS 3 but for all 23 participants, to observe the consistency in the BFI scores across sessions, which are presented in Table 2.

Table 1

Descriptive Statistics for the Resting-State FAA Scores for All Three Electrode Sites Pairwise and Clustered for Session 1 VS 2 VS 3

Electrode Sites	N	Range	Min	Max	Mean	Median	SD	Skewness		Kurtosis	
								Statistic	Std. Error	Statistic	Std. Error
F4-F3 (S.1)	22	5.99	-4.20	1.78	-.07	-0.04	1.17	-1.94	.49	7.32	0.95
F4-F3 (S.2)	20	1.44	-.71	.73	.10	0.06	.37	-.35	.51	0.11	0.99
F4-F3 (S.3)	19	4.56	-2.51	2.05	.01	-0.09	.89	-.33	.52	4.34	1.01
F6-F5 (S.1)	22	6.49	-4.78	1.71	-.04	0.07	1.35	-2.09	.49	6.89	0.95
F6-F5 (S.2)	20	3.50	-1.14	2.36	.44	0.36	.82	.70	.51	1.07	0.99
F6-F5 (S.3)	19	3.27	-1.94	1.34	-.02	-0.04	.65	-.98	.52	4.25	1.01
F8-F7 (S.1)	22	7.04	-2.59	4.46	.17	0.04	1.28	1.48	.49	6.19	0.95
F8-F7 (S.2)	20	3.50	-2.16	1.34	.15	0.10	.81	-.91	.51	2.29	0.99
F8-F7 (S.3)	19	1.54	-1.10	0.44	-0.29	-0.21	0.42	-.50	0.52	-0.36	1.01
Right-left cluster (S.1)	22	8.63	-2.13	6.50	.25	-0.09	1.65	-.50	.49	10.21	0.95

Right-left cluster (S.2)	20	3.70	-1.60	2.10	.27	0.23	.75	2.78	.51	2.65	0.99
Right-left cluster (S.3)	19	2.62	-1.77	.85	-.13	-0.10	.52	.11	.52	5.64	1.01
Valid N (listwise)	15										

Notes. (S.1) = Session 1. (S.2) = Session 2. (S.3) = Session 3. The resting-state FAA scores demonstrate inconsistency from session to session.

Table 2

Descriptive Statistics for the Big Five Personality Traits for Session 1 VS 3

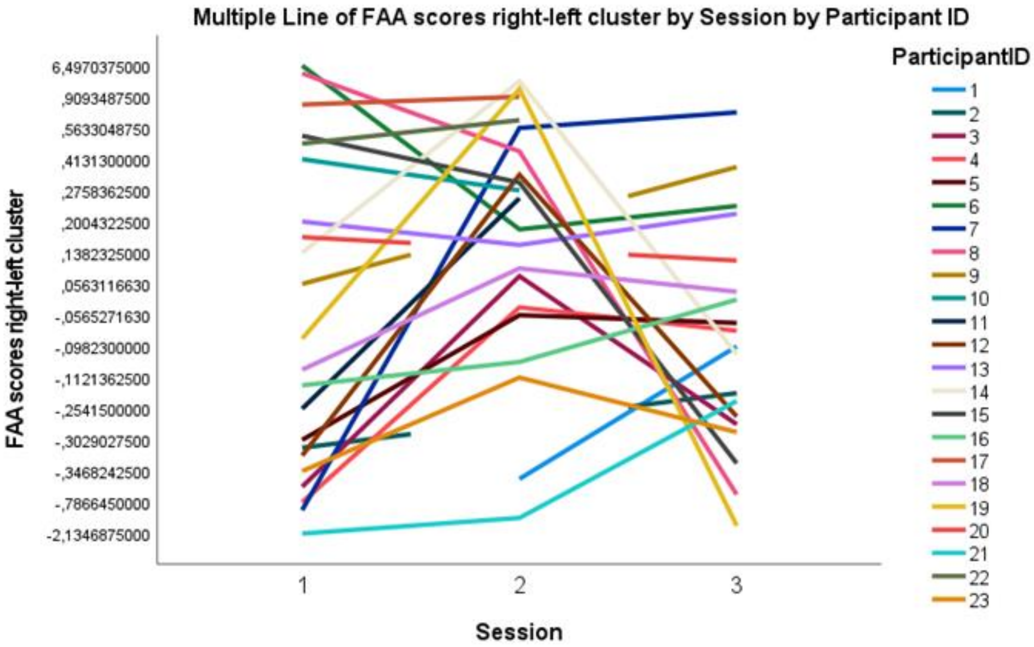
Big Five Personality Trait	N	Range	Min	Max	Median	Mean	SD	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error
Openness (S.1)	23	2.80	2.20	5.00	4.00	3.78	.67	-.55	.48	.68	.94
Openness (S.3)	19	2.40	2.20	4.60	3.60	3.68	.62	-.44	.52	.19	1.01
Agreeableness (S.1)	23	2.22	2.56	4.78	3.89	3.73	.70	-.05	.48	-1.34	.94
Agreeableness (S.3)	19	2.22	2.56	4.78	3.89	3.80	.63	-.12	.52	-.63	1.01
Conscientiousness (S.1)	23	1.67	2.56	4.22	3.44	3.48	.49	-.03	.48	-1.13	.94
Conscientiousness (S.3)	19	1.44	2.89	4.33	3.67	3.54	.44	-.09	.52	-1.03	1.01
Extraversion (S.1)	23	2.88	1.75	4.63	3.38	3.26	.71	-.16	.48	-.20	.94
Extraversion (S.3)	19	2.88	1.88	4.75	3.13	3.07	.65	.36	.52	1.74	1.01
Neuroticism (S.1)	23	2.75	1.88	4.63	3.25	3.08	.74	.31	.48	-.63	.94
Neuroticism (S.3)	19	2.25	2.13	4.38	3.25	3.24	.66	-.17	.52	-.70	1.01
Valid N (listwise)	19										

Notes. (S.1) = Session 1. (S.3) = Session 3. The descriptive statistics for the BFI scores demonstrate some inconsistency from session to session.

A multiple line mean of resting-state FAA scores right-left cluster by session by participant is presented in Figure 1 to observe the mean resting-state FAA scores for each participant across sessions. This allowed me to compare the resting-state FAA scores from session to session.

Figure 1

Multiple Line of Resting-State FAA Scores for Right-Left Cluster by Session by Participant



Notes. Resting-state FAA scores for all electrode sites clustered are presented on the Y-axis. The number of sessions is presented on the X-axis. The colored lines represent the patterns of each participant's resting-state FAA scores right-left cluster from session 1 to session 2 to session 3.

After I visualized both the descriptive statistics and multiple line mean of the resting-state FAA scores, I concluded that the resting-state FAA scores varied too much between sessions. I also created a multiple line mean of the BFI scores by session by participant (see Appendix D) which also demonstrated inconsistency from session 1 to session 3. Thus, I excluded participants who did not participate in all three sessions to ensure that there was complete data for all participants across the sessions when I performed the correlations and that they were based on a more homogeneous sample of participants (which can increase the reliability and validity of the findings). 7 participants out of 22 were excluded from the resting-state FAA scores and 8 participants out of 23 from the BFI scores, resulting in the remaining 15 participants. Descriptive statistics for the resting-state FAA scores averaged across sessions for all electrode sites are presented in Table 3. Descriptive statistics for the BFI scores averaged across sessions are presented in Table 4.

Table 3

Descriptive Statistics for Resting-State FAA Scores Averaged Across Sessions

Electrode Sites	N	Range	Min	Max	Median	Mean	SD	Skewness		Kurtosis	
								Statistic	Std. Error	Statistic	Std. Error
F4-F3 (average)	15	1.50	-.81	.69	-0.03	.00	.48	-.154	0.58	-.82	1.12
F6-F5 (average)	15	2.30	-1.49	.81	0.10	.045	.59	-1.36	0.58	2.47	1.12
F8-F7 (average)	15	3.37	-1.84	1.54	0.01	-.034	.68	-.49	0.58	4.82	1.12
Right-left cluster (average)	15	3.63	-1.31	2.32	-0.06	.11	.77	1.43	0.58	4.81	1.12
Valid N (listwise)	15										

Notes. The average resting-state FAA score was calculated by taking the mean of the resting-state FAA scores from all three sessions for each participant.

Table 4

Descriptive Statistics for the Big Five Personality Traits Averaged Across Sessions

Big Five Personality Trait	N	Range	Min	Max	Median	Mean	SD	Skewness		Kurtosis	
								Statistic	Std.Error	Statistic	Std. Error
Openness (average)	15	2.25	2.20	4.45	3.70	3.66	.59	-.99	0.58	1.16	1.12
Agreeableness (average)	15	2.11	2.67	4.78	3.33	3.61	.68	.55	0.58	-1.08	1.12
Conscientiousness (average)	15	1.11	3.00	4.11	3.50	3.53	.38	.20	0.58	-1.40	1.12
Extraversion (average)	15	2.81	1.88	4.69	3.25	3.16	.71	.00	0.58	.68	1.12
Neuroticism (average)	15	1.94	2.13	4.06	3.18	3.17	.62	-.33	0.58	-1.05	1.12
Valid N (listwise)	15										

Notes. The average BFI score was calculated by taking the mean of the BFI scores from the first and third sessions for each participant.

I then created Quantile-Quantile (Q-Q) plots for the resting-state FAA scores for all electrode sites (pairwise and clustered) to observe the distribution of the data (see Appendix D). After I visualized the Q-Q plots, the data were normally distributed for electrode sites F4-F3 and F6-F5 and thus Pearson correlation coefficients were performed for these electrode sites. The data were not normally distributed for F8-F7 and right-left cluster and thus Spearman correlation coefficients were instead performed. Each pair of electrode sites + right-left cluster (= four separate resting-state FAA scores) were correlated with each Big Five personality trait (= five separate BFI scores), resulting in 20 separate correlations. All p-values are summarized in Table 5 in which the statistically significant value is highlighted, followed by Figure 2 where I created a scatterplot for the statistically significant correlation. All statistical analyses were conducted in SPSS (ver. 27).

Table 5

Pearson's R and Spearman's Rho and the P-Values for Respective Correlation Between Averaged Resting-state FAA Scores and Averaged BFI Scores

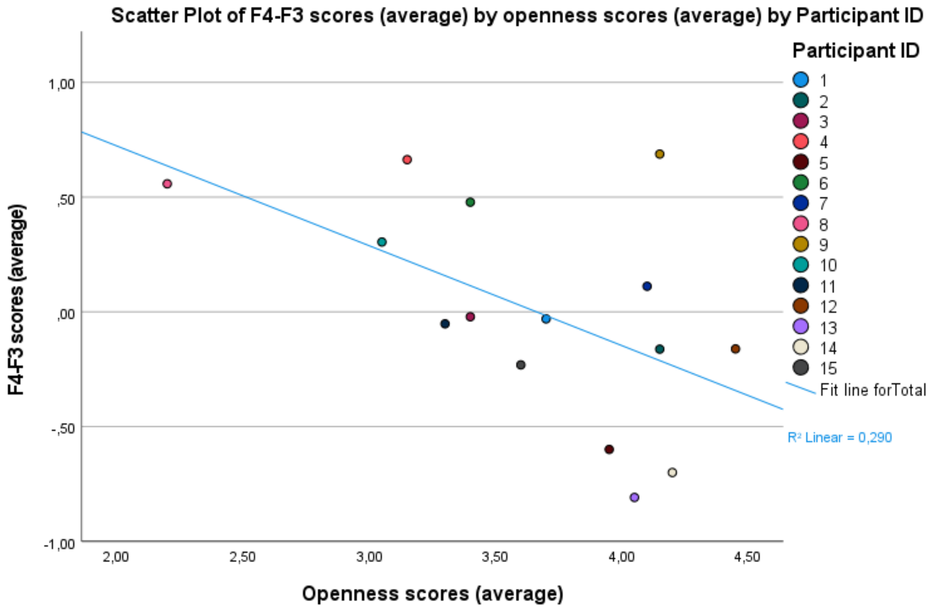
Electrode Sites	Big Five Personality Traits	Pearson's r	Spearman's rho	p-value
F4-F3 (average)	Openness (average)	-0.0539		**0.038**
	Agreeableness (average)	0.477		0.072
	Conscientiousness (average)	-0.213		0.447
	Extraversion (average)	0.225		0.421
	Neuroticism (average)	0.392		0.149
F6-F5 (average)	Openness (average)	-0.116		0.680
	Agreeableness (average)	0.384		0.157
	Conscientiousness (average)	0.036		0.899
	Extraversion (average)	-0.320		0.244
	Neuroticism (average)	0.105		0.710
F8-F7 (average)	Openness (average)		0.002	0.995

	Agreeableness (average)		-0.136	0.630
	Conscientiousness (average)		-0.211	0.450
	Extraversion (average)		-0.108	0.703
	Neuroticism (average)		-0.324	0.239
Right-left cluster (average)	Openness (average)		-0.445	0.096
	Agreeableness (average)		0.257	0.355
	Conscientiousness (average)		-0.311	0.259
	Extraversion (average)		-0.186	0.506
	Neuroticism (average)		-0.190	0.498

Notes. Pearson correlation coefficients were performed for electrode sites F4-F3 and F6-F5. Spearman correlation coefficients were performed for the electrode sites F8-F7 and the right-left cluster. Correlation is significant at the 0.05 level (2-tailed). The highlighted p-value indicates a statistically significant correlation. The highlighted Pearson's r is negative but close to zero which indicates a weak negative correlation

Figure 2

Scatterplot of Average F4-F3 Resting-state FAA Scores by Average Openness Scores by Participants



Notes. The F4-F3 resting-state FAA scores averaged across sessions are presented on the Y-axis and the openness scores averaged across sessions are presented on the X-axis. The dots indicate each participant, and the line indicates the direction of the relationship between the variables. The R-squared (R2) value ranges from 0-1 where 0 indicates no alignment between the regression line and the data and 1 indicates a perfect alignment. The value is 0.290, showing a moderate degree of alignment. This scatter plot demonstrates a negative correlation in which openness scores decrease when F4-F3 resting-state FAA scores increase. However, the dot to the left (demonstrating participant 8) is considered an outlier and affects the direction of the line.

Discussion

I investigated the relationship between resting-state FAA and the Big Five personality traits: openness, agreeableness, conscientiousness, extraversion, and neuroticism using resting-state EEG recordings and the BFI in 15 healthy right-handed participants from the University of Skövde. I hypothesized a *positive* correlation between the personality trait extraversion and greater relative left frontal cortical activity during resting-state and a *negative* correlation between the personality trait neuroticism and greater relative left frontal cortical activity during resting-state. The research question was: are there any statistically significant correlations between resting-state FAA and the Big Five personality traits? The results in the present study showed inconsistency in the resting-state FAA scores and the BFI scores from session to session. There was only one statistically significant correlation out of 20; F4-F3 resting-state FAA scores correlated with openness scores ($p=0.038$). None of the other 20 correlations were found to be statistically significant.

The inconsistency and lack of stability in the resting-state FAA scores across sessions do not support resting-state FAA as a reliable trait measure (Coan & Allen, 2004). One explanation is the potential impact of variations in the resting-state condition that affects the resting-state FAA scores for each recording. The resting-state condition is not a standardized situation that is constant throughout research (Kuper et al., 2019). Vecchio and De Pascalis (2020) suggest that genetic and inherited factors, as well as environmental factors and situational factors such as the mental state or unconsciously occurring cognitive processes, can all combine to change behavior and brain dynamics. On that note, the inconsistency in the BFI scores across sessions also suggests that the BFI is not a reliable trait measure. This variability could potentially be attributed to situational factors as well since respondents have a propensity to give answers that undermine the accuracy of the response. One common response behavior when completing self-report questionnaires is Extreme Responding (ER), i.e., there are temporary increases in extreme reacting that are brought on by situational factors such as ambiguity, emotional arousal, and quick responding (Paulhus & Vazire, 2009, p. 231).

The direction of the relationship between F4-F3 resting-state FAA scores and openness scores was the opposite of what would be expected. Since openness is an approach-related trait (e.g., DeYoung et al., 2007), it would be expected to have a positive correlation with resting-state FAA (Davidson, 1992; Harmon-Jones et al., 2010) wherein both variables either increase or decrease, rather than a negative correlation. However, the presence of an outlier in the Scatter Plot of the significant correlation affects the position of the line, drawing the line towards it, and making it less representative of the majority of the data. It is possible that the only significant correlation found in this study is spurious, arising from multiple testing. Since I did 20 correlations at the $p<0.05$ significance level, one of these results could be a false positive (Kuper et al., 2019). Nevertheless, this statistically significant correlation does not support previous studies in which increased FAA has, for example, been associated with being prepared for unknown stimuli among high-openness individuals in an EEG study with 127-right handed participants (Käckenmester et al., 2018). It does not support the motivational direction model (Davidson, 1992; Harmon-Jones et al., 2010) nor studies that rely on this model (e.g., Huang et al., 2014; Minnix & Kline, 2004; Monni et al., 2022; Schmidt, 1999). Taken together, the results in the present study do not support the hypothesis and do not provide evidence for rejecting the null hypothesis.

The situational factors previously discussed, also influence the manifestation of personality traits in resting-state FAA. For example, if the resting-state conditions differ between studies, the association (or absence of association) between resting-state FAA and personality traits may vary significantly (Wacker et al., 2010). Wacker et al. (2010) discuss the interactionist models (which consider internal and external factors in shaping human behavior) and suggest that the biological processes underlying each trait are less likely to be activated in the resting-state. On that note, across all studies included in the meta-analysis by Kuper et al. (2019), resting-state FAA accounted for less than 0.4% of the variance in extraversion, neuroticism, and other variables.

It has been suggested the trait BAS, for example, which is related to extraversion (Sutton & Davidson, 1997), would be related to FAA only when the resting-state FAA is measured in a condition that elicits or involves approach-oriented motivation (Kuper et al., 2019). However, even then the correlations may be weak. A study by Wacker et al. (2013) showed that BAS is only associated with *slightly* increased left frontal cortical activity during the resting-state in male participants who interacted with attractive female experimenters (which may reflect an approach-motivational context); (Kuper et al., 2019). State FAA, as measured in contexts related to personality traits (i.e., during specific tasks or conditions that are relevant to the personality trait), has been suggested to be a more significant predictor of personality traits than resting-state FAA (Coan et al., 2006). Thus, to achieve the goal of personality neuroscience: understanding the neurological systems behind traits and the factors influencing their variation in individuals (DeYoung, 2010), a shift in the focus towards looking at FAA as a state variable when connecting it to personality traits is advised (Kuper et al., 2019).

Limitations

This study faced some limitations which may have contributed to the current results. The absence of statistically significant findings in studies may be attributed to a small sample size. Kuper et al. (2019) argue that future FAA and personality studies should take into consideration the use of significantly larger samples to provide enough statistical power. They suggest that to detect a true effect or relationship between variables, with a significance level of 0.05 and a one-tailed test, a sample size of at least 153 is necessary. In that way, a statistical power of 0.80, i.e., an 80% chance of detecting a true relationship can be achieved. Small sample sizes can also increase the risk of a Type I error, where researchers mistakenly conclude that there is a significant effect when there is none (Ioannidis, 2022). As noted, many of the correlations between FAA and specifically extraversion and neuroticism have only been found in a few studies using small sample sizes (Kuper et al., 2019).

The small sample size in this study (n = 15), as opposed to the desired sample size (n = 153), is the most prominent limitation. This study initially aimed to have 40-60 participants, but the number had to be downgraded due to repeated measures, time constraints, and problems with the available EEG equipment which postponed the EEG recording. The final sample size of 15 participants is underpowered, meaning it does not have the required statistical power to either identify significant effects (Kuper et al., 2019) or reduce the risk of making a Type I error (Ioannidis, 2022). Furthermore, this study only included undergraduate students which decreases the generalizability. One way to increase the generalizability and apply the results to a wider range of people is to use pre-existing data which can also result in a larger sample size (Machery, 2010; Weston et al., 2019).

Moreover, the results of the BFI scores can be attributed to the limitation of only utilizing the English version of the BFI. Kuper et al. (2019) suggest in their meta-analysis that the analyzed self-report measures have a too-low construct validity for the evaluation of trait approach/withdrawal motivation in resting-state FAA- and personality research. For the present study, it was reasoned that Swedish and international students most likely will have the same basis when reading instructions since neither has English as their native language. Additionally, one of the inclusion criteria was fluent in English which increased the chance of having participants with the same conditions. However, both language and cultural factors can affect individuals' understanding of instructions, questions, and the meaning of the items in the measure (Beaton et al., 2000). Therefore, it would have been beneficial to adapt self-report measures to different languages and cultures to reduce the risk of incorrect answers and enhance the reliability of the scores.

Nevertheless, this study used repeated measures of both resting-state FAA and the Big Five personality traits which could minimize state fluctuations (Hagemann, 2004; Hagemann et al., 2002). The association between resting-state FAA and personality traits would be strongest for many aggregated recordings (Kuper et al., 2019). Furthermore, longer recordings of 8 minutes do produce slightly more reliable measures than shorter ones, (Kuper et al., 2019). Enough data can be collected to provide accurate estimates of resting-state FAA while minimizing participant burden (Allen et al., 2004b). Considering these factors, this study has used appropriate precautions to obtain reliable and valid findings. Despite the small sample size, it may be reasonable to propose that this study contributes to the current body of literature by providing support for the notion that resting-state FAA reflects states rather than personality traits.

Societal Aspects

The credibility of resting-state FAA as a reliable trait measure should be approached with caution in future research. Allen and Kline (2004) argue that the trait individual differences studied in FAA are associated with other trait individual differences that are indicative of individuals with depressive and anxious psychopathology, those at risk for psychopathology, and future emotional responses. For instance, two theoretically, psychometrically, and clinically diverse forms of anxiety seem to be linked to various neural mechanisms. Anxious apprehension, i.e., worry about far-off occurrences (Nitschke et al., 1999), is linked to more left-hemispheric activity, while anxious arousal, i.e., somatic tension and physiological hyperarousal to threats indicative of perceived immediate risk (Nitschke et al., 2000), is linked to more right-hemispheric activity (Allen & Kline, 2004). This suggests that these forms should be evaluated separately in psychopathology research and the development of treatments (Engels et al., 2007). However, it is of great importance to emphasize that resting-state FAA may not be a reliable trait measure, and hence, its proposed contribution to early detection, possible intervention, better outcomes, and decreasing stigma (Hayward & Bright, 1997) of mental illness should be taken with caution.

Ethical Aspects

It is important to consider ethical aspects in research for several reasons, such as minimizing physical, psychological, or emotional harm to participants, protecting their privacy and confidentiality, and enhancing the credibility and validity of the findings. In the present study, the Swedish Ethical Review Authority's support template was used for the information sheet and informed consent form: "Stödmall forskningsinformation" and "Stödmall samtyckesblankett" (Etikprövningsmyndigheten, 2023). The key elements in the information sheet were a detailed explanation of the background of the project and its general purpose, what participation entailed, what methods were being used, the number of visits, tests, the time required, what type of information would be collected, and how it would be handled and stored. It also provided information about potential effects, insurance coverage, and that the participation was voluntary and that they can withdraw at any time.

Conclusion

I investigated the relationship between resting-state FAA and the Big Five personality traits: openness, agreeableness, conscientiousness, extraversion, and neuroticism by utilizing resting-state EEG recordings and BFI across sessions. The results showed inconsistency in resting-state FAA- and BFI scores from session to session. The F4-F3 resting-state FAA scores correlated with openness scores but in the opposite direction of what would be anticipated. No statistically significant correlations between resting-state FAA and any of the other Big Five personality traits were found. Collectively, these findings failed to provide support for the motivational direction model, which serves as the foundation for my hypothesis and numerous other studies exploring FAA and personality (Davidson, 1992; Harmon-Jones & Gable, 2018; Harmon-Jones et al., 2010). Several factors may have contributed to the results of this study in which the most prominent one is the sample size which decreases the chance of detecting statistically significant correlations and increases the risk of finding spurious correlations. However, in light of previous research, it is plausible that the resting-state FAA scores reflect variations in states, rather than stable personality traits. A thorough strategy is needed that takes into account the complexity of human personality (DeYoung, 2010; Kuper et al., 2019). Hopefully, the relationship between the Big Five personality traits and FAA can be clarified, the research on FAA and personality can be improved, and the field of personality neuroscience can advance toward its goal.

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Appendix A

Information Sheet

This Appendix consists of the information sheet about the experimental control based on the Swedish Ethical Review Authority's support template (Etikprövningsmyndigheten, 2023).

Information sheet

What kind of project is it and why do we want you to participate?
The study aims to investigate the relationship between a specific brain measure referred to as "Frontal Alpha Asymmetry (FAA)" which is calculated from electroencephalogram (EEG), and its relation to the results of self-report questionnaires measuring different personality traits. We ask you to participate since you are a student at the University of Skövde and meet the inclusion criteria.

Potential consequences and risks of participating in the project
The recording session is short and the questionnaires should not take that long. We will also make sure that you are as comfortable as possible during your visit to the lab. However, if you experience any discomfort and decide to withdraw from the study, you are free to do so at any time.

What happens to your data?
The type of information that will be collected is data from the EEG recording as well as data from the questionnaires, both of which will be stored in an anonymous form. To protect your privacy and confidentiality, all data will be kept at the lab which can only be accessed through a keycard belonging to the researchers. The data will be stored until the end of the study, thereafter destroyed. The personality questionnaires will not be of any clinical value. No personal information will be required for this study itself - although we will need your email address to be able to contact you while the study is running, we won't tie it to EEG or questionnaire data. If you wish to access your data/results, you can contact us at any time. You also have the possibility of choosing not to see your data/results. We will delete your data at any time if you wish to have it removed.

Insurance and compensation
When you study at a Swedish university, you are covered by personal injury insurance. The insurance applies if you are injured while traveling to and from your studies and during school hours. The insurance is free for the student. No compensation will be provided for your participation except for fika after the experiment and the possibility of winning a cinema ticket.

Participation is voluntary

Your participation is voluntary and you can choose to cancel your participation at any time. If you decide not to participate or wish to cancel your participation, you do not need to state why. If you wish to cancel your participation, please contact us.

The researchers responsible for the project

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Appendix B

Informed Consent Form

This Appendix consists of the informed consent form based on the Swedish Ethical Review Authority's support template (Etikprövningsmyndigheten, 2023).

INFORMED CONSENT FORM

Frontal alpha asymmetry and personality traits: An EEG-study on the difference in the brain activity between the left and right s
ides of the frontal cortex and its relationship to personality traits.

Division of Cognitive Neuroscience and Philosophy,
School of Bioscience,
University of Skövde.

I hereby confirm:

- … that I have received written and oral information about this research study. I can keep the written information.
- … that I have had the opportunity to ask questions about the study and that my questions have been satisfactorily answered.
- … that I consent to participate in the study and know that my participation is entirely voluntary.
- … that I am aware that I can withdraw from the study at any time and without giving an explanation.
- … that I allow my personal information to be registered according to the information I have received, and that collected data about me is stored and managed electronically by those responsible for the study. All information will be handled in accordance with the Personal Data Act.

____
Date & place

___________________________ ________________________
Participant signature Participant name

____
Participant date of birth

The researcher keeps the signed form of informed consent.

Appendix C

The BFI

This Appendix consists of the BFI and the scoring instructions (John et al., 1991, 2008).

How I am in general

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who *likes to spend time with others*? Please write a number next to each statement to indicate the extent to which **you agree or disagree with that statement.**

1 Disagree Strongly	2 Disagree a little	3 Neither agree nor disagree	4 Agree a little	5 Agree strongly

I see Myself as Someone Who...

___1. Is talkative

___2. Tends to find fault with others

___3. Does a thorough job

___4. Is depressed, blue

___5. Is original, comes up with new ideas

___6. Is reserved

___7. Is helpful and unselfish with others

___8. Can be somewhat careless

___9. Is relaxed, handles stress well

___10. Is curious about many different things

___11. Is full of energy

___12. Starts quarrels with others

___13. Is a reliable worker

___14. Can be tense

___15. Is ingenious, a deep thinker

___16. Generates a lot of enthusiasm

___17. Has a forgiving nature

___18. Tends to be disorganized

___19. Worries a lot

___20. Has an active imagination

___21. Tends to be quiet

___22. Is generally trusting

___23. Tends to be lazy

___24. Is emotionally stable, not easily upset

___25. Is inventive

___26. Has an assertive personality

___27. Can be cold and aloof

___28. Perseveres until the task is finished

___29. Can be moody

___30. Values artistic, aesthetic experiences

___31. Is sometimes shy, inhibited

___32. Is considerate and kind to almost everyone

___33. Does things efficiently

___34. Remains calm in tense situations

___35. Prefers work that is routine

___36. Is outgoing, sociable

___37. Is sometimes rude to others

___38. Makes plans and follows through with them

___39. Gets nervous easily

___40. Likes to reflect, play with ideas

___41. Has few artistic interests

___42. Likes to cooperate with others

___43. Is easily distracted

___44. Is sophisticated in art, music, or literature

SCORING INSTRUCTIONS

To score the BFI, you'll first need to reverse-score all negatively-keyed items:

Extraversion: 6, 21, 31

Agreeableness: 2, 12, 27, 37

Conscientiousness: 8, 18, 23, 43

Neuroticism: 9, 24, 34

Openness: 35, 41

To recode these items, you should subtract your score for all reverse-scored items from 6. For example, if you gave yourself a 5, compute 6 minus 5 and your recoded score is 1. That is, a score of 1 becomes 5, 2 becomes 4, 3 remains 3, 4 becomes 2, and 5 becomes 1.

Next, you will create scale scores by *averaging* the following items for each B5 domain (where R indicates using the reverse-scored item).

Extraversion: 1, 6R 11, 16, 21R, 26, 31R, 36

Agreeableness: 2R, 7, 12R, 17, 22, 27R, 32, 37R, 42

Conscientiousness: 3, 8R, 13, 18R, 23R, 28, 33, 38, 43R

Neuroticism: 4, 9R, 14, 19, 24R, 29, 34R, 39

Openness: 5, 10, 15, 20, 25, 30, 35R, 40, 41R, 44

SPSS SYNTAX

*** REVERSED ITEMS

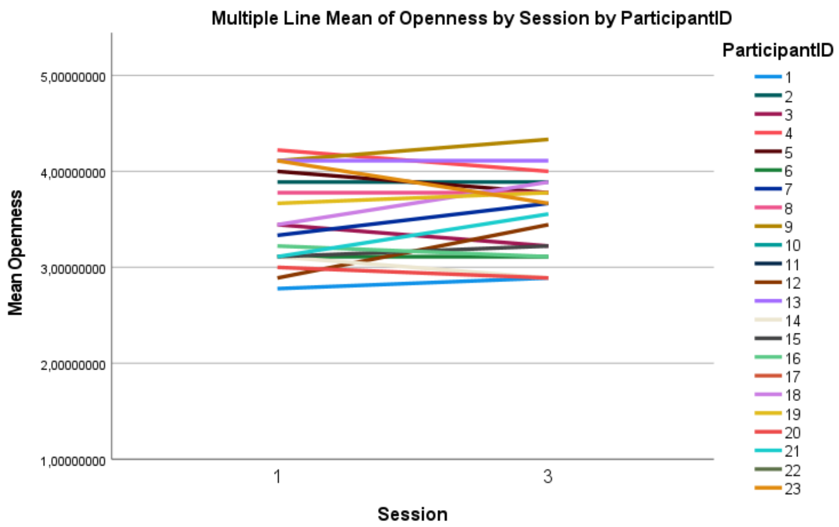
```
RECODE

  bfi2 bfi6 bfi8 bfi9 bfi12 bfi18 bfi21 bfi23 bfi24 bfi27 bfi31 bfi34 bfi35

  bfi37 bfi41 bfi43

  (1=5)  (2=4)  (3=3)  (4=2)  (5=1)  INTO  bfi2r bfi6r bfi8r bfi9r bfi12r bfi18r bfi21r bfi23r bfi24r

  bfi27r bfi31r bfi34r bfi35r bfi37r bfi41r bfi43r.

EXECUTE .


*** SCALE SCORES

COMPUTE bfie = mean(bfi1,bfi6r,bfi11,bfi16,bfi21r,bfi26,bfi31r,bfi36) .

VARIABLE LABELS bfie 'BFI Extraversion scale score.

EXECUTE .

COMPUTE bfia = mean(bfi2r,bfi7,bfi12r,bfi17,bfi22,bfi27r,bfi32,bfi37r,bfi42) .

VARIABLE LABELS bfia 'BFI Agreeableness scale score' .

EXECUTE .

COMPUTE bfic = mean(bfi3,bfi8r,bfi13,bfi18r,bfi23r,bfi28,bfi33,bfi38,bfi43r) .

VARIABLE LABELS bfic 'BFI Conscientiousness scale score' .

EXECUTE .

COMPUTE bfin = mean(bfi4,bfi9r,bfi14,bfi19,bfi24r,bfi29,bfi34r,bfi39) .

VARIABLE LABELS bfin 'BFI Neuroticism scale score' .

EXECUTE .

COMPUTE bfio = mean(bfi5,bfi10,bfi15,bfi20,bfi25,bfi30,bfi35r,bfi40,bfi41r,bfi44) .

VARIABLE LABELS bfio 'BFI Openness scale score' .

EXECUTE
```

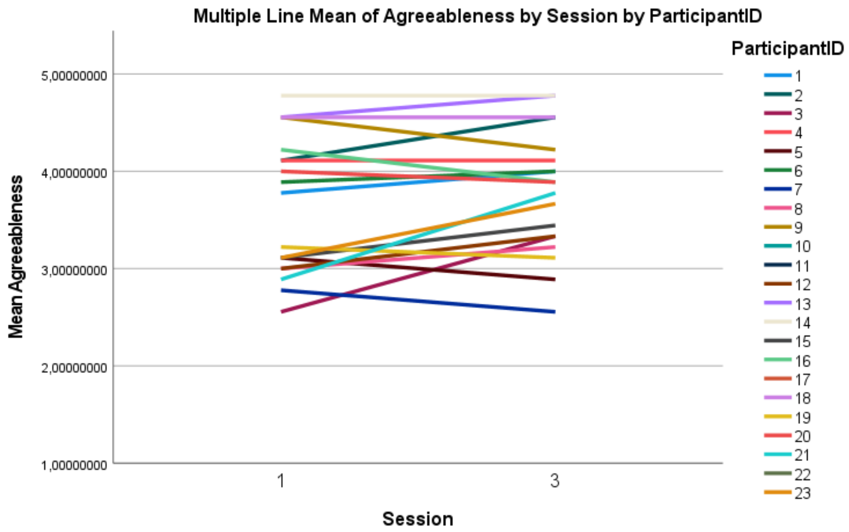
Appendix D

Line Plots of BFI Scores and Q-Q Plots of Resting-State FAA Scores

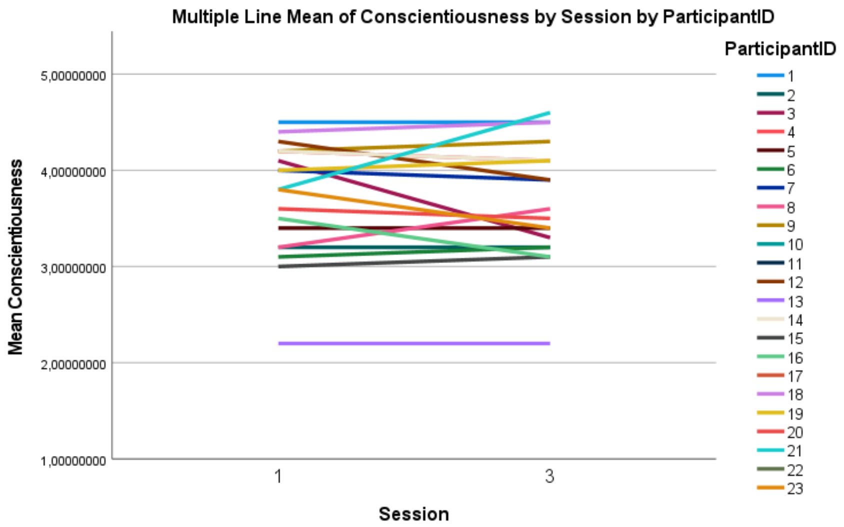
This Appendix consists of Multiple Line Mean of each Big Five personality trait score by session by participant, demonstrating inconsistency from session 1 to session 3. It also consists of Q-Q plots for resting-state FAA scores for all electrode sites pairwise and clustered which demonstrate normal distribution of the data for F4-F3 and F6-F5 and non-normal distribution for F8-F7 and right-left cluster.

Multiple Line Mean of each Big Five personality trait by session by participant:

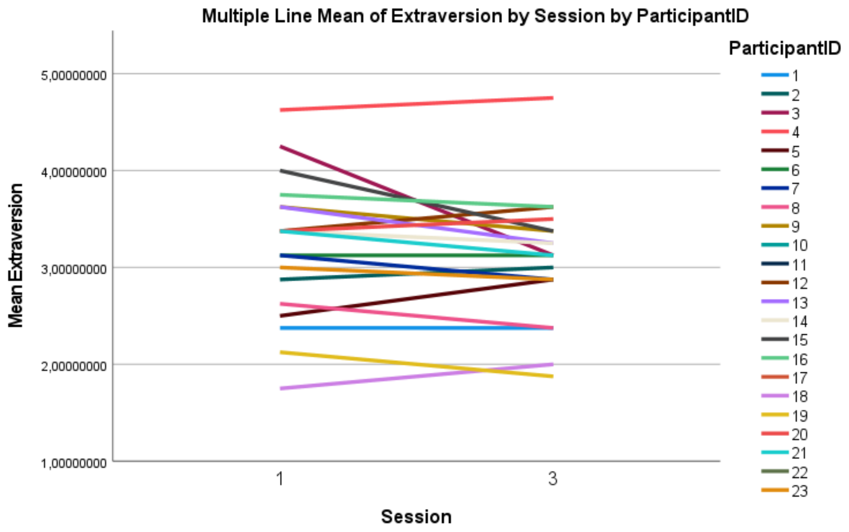


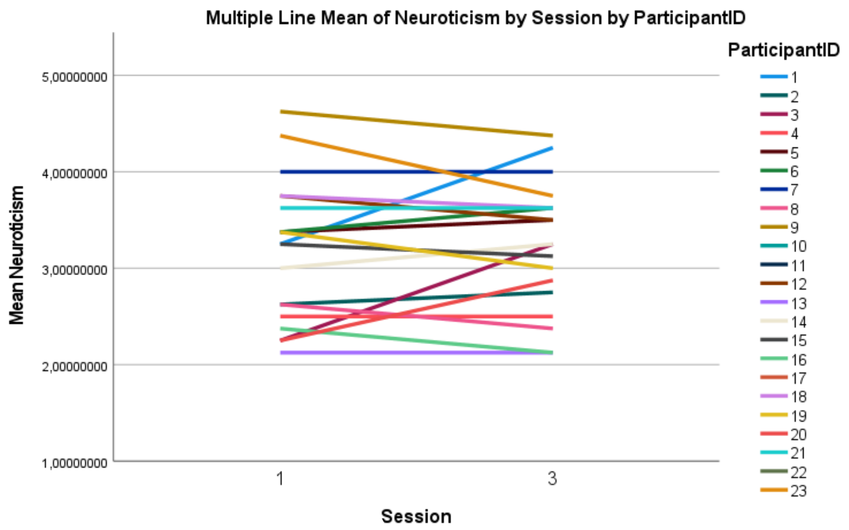


Multiple Line Mean of Agreeableness by Session by ParticipantID
Mean Agreeableness
5,00000000
4,00000000
3,00000000
2,00000000
1,00000000
1
3
Session
ParticipantID
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

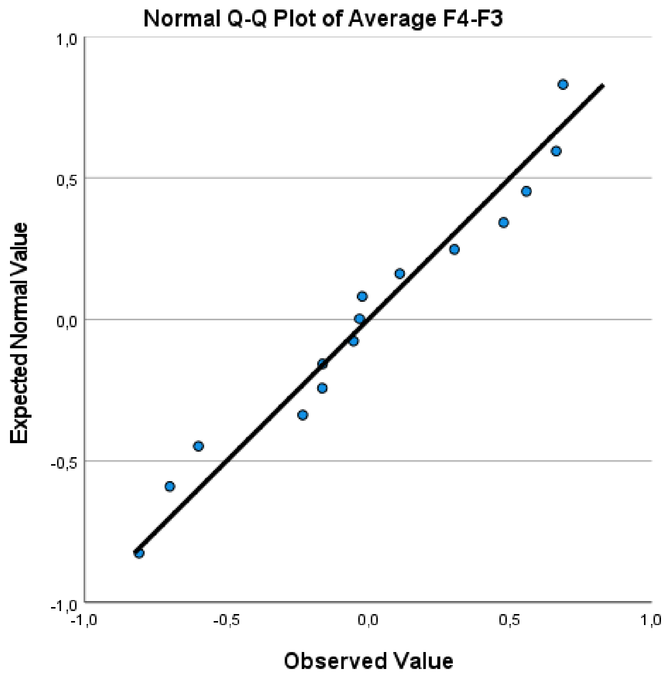


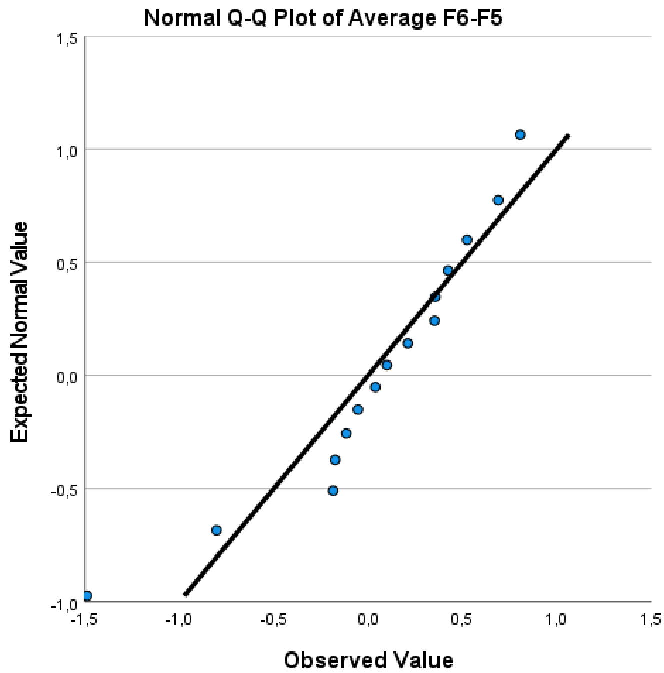
Multiple Line Mean of Conscientiousness by Session by ParticipantID
Mean Conscientiousness
5,00000000
4,00000000
3,00000000
2,00000000
1,00000000
1
3
Session
ParticipantID
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

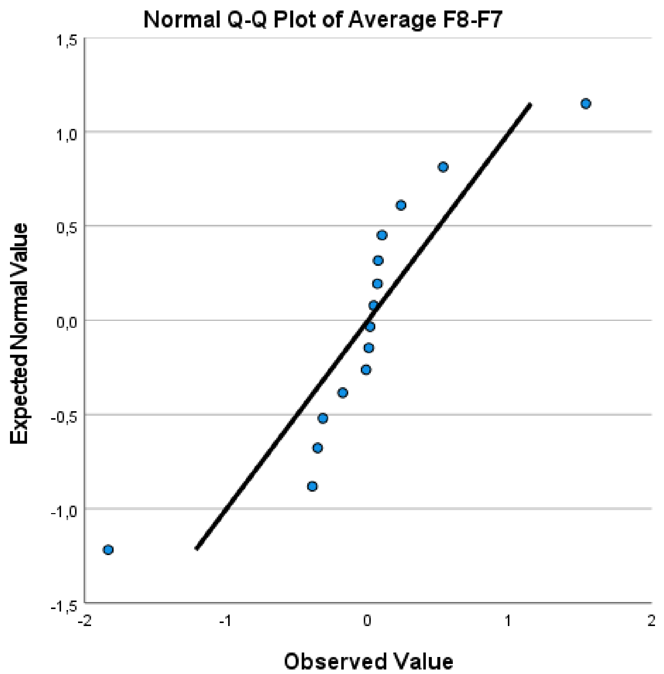


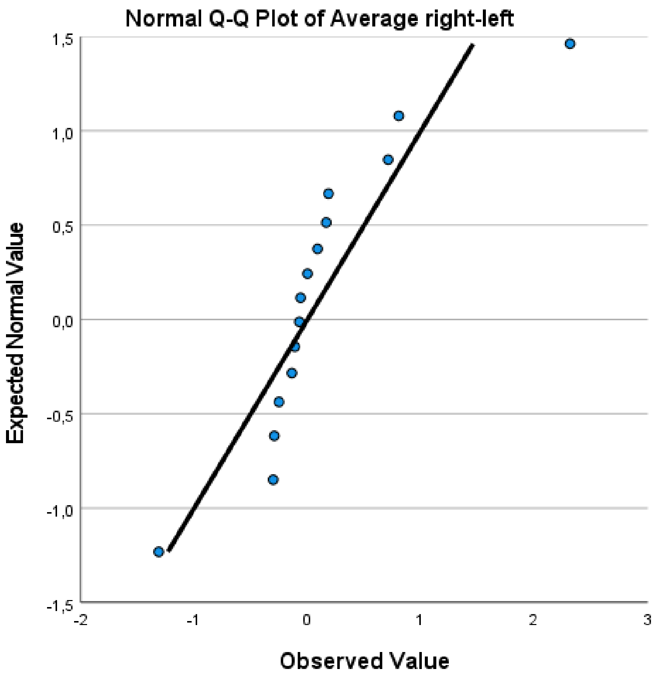


Q-Q plots for resting-state FAA scores:


Normal Q-Q Plot of Average F4-F3
Expected Normal Value
Observed Value
1,0
0,5
0,0
-0,5
-1,0
-1,0
-0,5
0,0
0,5
1,0


Normal Q-Q Plot of Average F6-F5
Expected Normal Value
Observed Value
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-1,0
-0,5
0,0
0,5
1,0
1,5


Normal Q-Q Plot of Average F8-F7
Expected Normal Value
Observed Value
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2
-1
0
1
2


Normal Q-Q Plot of Average right-left
Expected Normal Value
Observed Value
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2
-1
0
1
2
3