Examining Eysenck’s Arousal Hypothesis: An ERP Study on the Relationship Between Extraversion and Cortical Arousal

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Abstract

This study examined the Brebner-Cooper model and Eysenck's Arousal Hypothesis of Extraversion. Eysenck's arousal theory suggests that extraverted individuals have by default lower levels of cortical arousal compared to introverted individuals. Brebner and Cooper proposed with their model that brain processes in different levels of extraversion are related to differences in performance. In this model extraverted individuals are expected to show a worse performance on a vigilance task compared to introverted individuals. Knowledge about the biological basis of extraversion can be implemented in neurofeedback therapy. To assess the theories, 35 university students with an average age of 22,5 (*SD* = 5.85), completed the Continuous Performance Task while they were connected to the Electroencephalography (EEG). Cortical arousal was measured by analysing event-related potentials in reaction to the Continuous Performance Task on the EEG. Performance was measured by analysing the error-rates and the reaction times on the Continuous Performance Task, and extraversion was measured using the Big-Five Inventory-2. Three multiple regression analyses were performed to examine the relationship between extraversion and performance. A repeated measures ANCOVA was performed to examine the relationship between extraversion and cortical arousal. Extraversion was added as a covariate. Extraversion was not related to cortical arousal, but higher extraversion scores were related to a better performance. The main weakness of this study was, among others, the lack of variance in extraversion scores. The findings of this study were not in line with the hypotheses.

Extraversion; Performance, Vigilance task; Cortical arousal; Electroencephalography; ERP; P300

Introduction

Each individual is built out of different characteristics, a complicated system that defines our strengths and weaknesses. Personality is one of the pieces that distinguish us from other humans, it makes us unique. A complex phenomenon, which scientists have been investigating for many years (Allport, 1938; Cattell, 1943; Roberts & Yoon, 2022). But not only academics have an interest in it, but most of us have also been thinking about our personality to some extent too. Roberts et al. (2007) showed in their study the importance of understanding our personality, as it helps improve our weaknesses and exploit our strengths. This can lead to better life outcomes. For example, someone can excel in his efficient workstyle and have effective communication skills; understanding these skills may benefit him in choosing the right career (Roberts et al., 2007). There are a whole variety of traits within humans, and some of them are more salient and universal (McCrae & Costa, 1997). A well-known framework to understand personality is the Five-Factor model, also known as the Big Five (Ober et al., 2021). This theory considers five universal personality traits, which characterize individuals on a broad level. The five traits are as follows: Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness to experience (Costa & McCrae, 1992).

Interest in the neurological basis of personality dates back to the 1930s (Allport, 1938). Among the five personality traits, the neurobiological basis of extraversion has received much attention, but the findings remain inconclusive (Beauducel et al., 2006; Ditraglia & Polich, 1991; Doucet & Stelmack, 2000; Eysenck, 1967; Fink & Neubauer, 2004; Gale, 1983; Gale et al., 1969; Hagemann et al., 2009; Matthews & Amelang, 1993; Roslan et al., 2017; Tran et al., 2001). Clarification about personality traits and their neurological basis can be useful for individuals who want to develop their cognitive performances based on the knowledge they have of their personality. For example, with neurofeedback, which is a brain-based therapy that enhances attention (Alkoby et al., 2018; Egner & Gruzelier, 2001; Gruzelier, 2014; Kadosh & Staunton, 2019; Robineau et al., 2017; Vernon et al., 2003).

Jung, a Swiss psychiatrist, and psychoanalyst was the first to introduce the term extraversion (Jung et al., 1977). He defined extraverts as people who prefer the external world of things, while introverts prefer the internal world of their thoughts and feelings. Extraversion is characterized by sociability, excitability, talkativeness, assertiveness, and high amounts of emotional expressiveness (Goldberg, 1993). People who score high on this trait are more likely to seek social interactions and be more outgoing, as these are situations that energize them. On the contrary, individuals that are low on extraversion, introverts, tend to be more reserved in social settings. Introverts are more likely to seek solitude or withdraw themselves, as social events drain their energy (Bainbridge et al., 2022; Bell et al., 2019; Pervin & John, 2001).

Eysenck was one of the first psychologists that investigated the neurological underpinnings of extraversion. He formulated the Arousal Hypothesis of Extraversion (Eysenck, 1967), and proposed that extraverts have lower cortical arousal in comparison with introverts. One of the brain systems most relevant to this hypothesis is the ascending reticular activating system (ARAS), a brain system responsible for maintaining behavioral arousal and consciousness. According to Eysenck (1967), differences in the ARAS are related to differences in excitation and inhibition thresholds. Extraverts are expected to show lower levels of arousal in reaction to stimuli compared to introverts. Furthermore, low arousal would be accompanied by an unpleasant experience, prompting extroverts to engage in typically extraverted behaviors to increase their cortical arousal. Therefore, extraverts and introverts differ in the external stimulation they need to deliver an optimal performance. Eysenck assumed that extraverts perform best in highly stimulating environments, in contrary to introverts who perform better in environments with lower external stimulation. Several studies confirmed Eysenck’s Arousal Hypothesis (Brocke et al., 1997; Fink et al., 2005; Fink & Neubauer, 2008; Gale, 1983; Gale et al., 1969, 2001; Hagemann et al., 2009; Matthews & Gilliland, 1999; Ortiz & Maojo, 1993; Roslan et al., 2017; Smith et al., 1995).

In an attempt to improve Eysenck’s theory, Brebner and Cooper proposed a different model of extraversion which is related to performance (Brebner & Cooper, 1974). They assumed that brain processes can be either in a state of excitation or inhibition. Excitation is characterized by continuing a certain behaviour and inhibition is characterized by attenuating a certain behaviour. Both states can be induced by stimulus analysis and response organization. In the Continuous Performance Task, which was used in this study, stimulus analysis would be observing the presented stimuli, and response organization would be the action taken upon a presented stimulus. The Brebner-Cooper model assumes that individual differences in extraversion may affect the balance between the stimulus analysis and response organization. Extraverts are expected to respond more strongly (excitation) to response organization, while introverts are expected to respond more strongly to stimulus analysis. And the opposite, extraverts are assumed to show inhibition to stimulus analysis and introverts to response organization. This can result in a less accurate response and a relatively slower reaction times for extraverts. And this effect would increase when more time on a task passes. An overall better performance is expected for introverts compared to extraverts. Brebner and Flavel (1978) defined extraverts as ‘geared to respond’ and introverts as ‘geared to inspect’. Several reviews and studies show an extended list of findings implying that introverts outperform extraverts on vigilance tasks (Matthews, 1999; Rose et al., 2002; Schmidt et al., 2004) The study of Pascalis et al. (2018) suggested that the Brebner-Cooper model may still be accurate. Understanding the relationship between extraversion and the environment in which individuals perform best might be helpful. For example, by creating work and study places for individuals that stimulates an optimal performance (Mateo et al., 2013; Westerman & Simmons, 2007).

To investigate the neurological basis of extraversion, the EEG is a useful instrument. The EEG is a non-invasive technique that measures the electric field activity of the brain produced by cerebral activity, by using electrodes mounted on the scalp (de Beeck et al., 2019). Electricity in the brain is produced by neurons which can be either excitatory or inhibitory. The postsynaptic potentials in the dendrites of cortical pyramidal neurons are the major contributor to the generation of the electric activity that is registered with EEG (de Beeck et al., 2019). In the current study, the operationalization of cortical arousal was done by looking at event-related potentials (ERP). ERPs are EEG signals that represent cortical responses after a stimulus is shown to an individual. By presenting multiple stimuli, the ERPs can be averaged, and a consistent waveform becomes detectable. The components of the ERP can be distinguished on their latency, polarity, amplitude, and scalp distribution (de Beeck et al., 2019; van Dinteren et al., 2014). They can be represented as the following: ‘P’ for a positive voltage and ‘N’ for a negative voltage. The digits behind the letter indicates the number of milliseconds the wave occurs after the given stimulus. For example, the P300 is an easily detectable waveform, it has a large positive component with the peak amplitude at approximately 300 milliseconds after the stimulus was presented (de Beeck et al., 2019). Several studies tried to find a relationship between extraversion and ERPs by using different types of cognitive tasks, and one of them is the Continuous Performance Task (CPT). The CPT is a test that measures attention and vigilance (Karamacoska et al., 2019). In the CPT, a series of stimuli are presented on a monitor, and participants are asked to respond to most of them by pressing the spacebar (Go). However, by a minority of the stimuli, participants must refrain from pressing the spacebar (NoGo). The relationship between extraversion and ERPs in response to the CPT is unclear due to contradictory results. A negative relationship between extraversion and the P300 amplitude can be associated with lower cortical arousal. That would result lower P300 amplitudes for extraverts compared to introverts (Ortiz & Maojo, 1993). However, multiple studies showed a higher P300 amplitudes for extraverts (Cahill & Polich, 1992; Gurrera et al., 2005; Stauffer et al., 2012; Stenberg, 1994), while others found low P300 amplitudes for extraverts based on visual stimuli tasks (Brocke et al., 1996; Fink et al., 2002, 2005; Ortiz & Maojo, 1993).

There can be named multiple reasons to explain these inconsistent findings. First, there were differences in sample sizes and the age of the subjects within studies. For example, Brocke et al., (1997) tested university students, while others included participants in a wider age range (Doucet & Stelmack, 2000; Gurrera et al., 2005; Rammsayer & Stahl, 2004; Stenberg, 1994). Secondly, the studies used different questionnaires to measure extraversion and the operationalization of extraversion differed between questionnaires (Cahill & Polich, 1992; Ditraglia & Polich, 1991; Gurrera et al., 2005; Polich & Martin, 1992; Roslan et al., 2017). For example, introversion in the Meyer-Briggs Personality Inventory is related to neuroticism in the NEO-FFI (Furnham et al. 2003). Furthermore, cortical arousal is dependent on external factors such as time of the day or emotional events, which are difficult to control (Hagemann & Naumann, 2009). In addition, the intensity of the testing conditions influences the levels of arousal (Hagemann & Naumann, 2009). Extraverts tend to seek out more arousing experiences to compensate for their lower cortical arousal. This means that in low-intensity test conditions extroverts would over-stimulate themselves to increase their arousal and that introverts would engage in relaxing behavior to reduce their arousal (Gale, 1983). If extraverts have lower levels of cortical arousal, a worse performance would be expected on the CPT, which is by nature a more monotonous and boring test. Considering this, testing Eysenck’s arousal hypothesis would be optimal with the CPT because it has a low level of external stimulation.

In the current study, we explored the following questions: What is the relationship between extraversion and performance on a vigilance task; and what is the relationship between extraversion and cortical arousal? In line with the Brebner-Cooper model, we expect that (H1) extraversion has a negative relationship with performance on a vigilance task. This would result in more error-rates and longer reaction times, which indicates a worse performance on the CPT for extraverts. In line with Eysenck's Arousal Hypothesis, we expect that (H2) extraverts exhibit lower levels of cortical arousal. This would result in a negative relationship between extraversion and P300 amplitudes, shown by lower P300 amplitudes for extraverts.

Method

Participants

A total of thirty-five participants took part in this study (sex: 9 (26%) male, 26 (74%) female, age range: 19-53, M = 22.58, SD = 5.85). The participants were undergraduate psychology students of Tilburg University, friends and relatives of fellow psychology students who were writing their thesis. Both international and Dutch participants were included in this study. The participants were gathered using the Sona system and by convenience sampling, e.g., asking around in our social network. In return for participating, the first-year students received course credits, the others received nothing.

Procedure

This study was approved by the Tilburg University Ethical Review Board Social and Behavioral Sciences. After receiving information about the study, participants gave written informed consent. The information was given in either Dutch or English. Data collection took place from February 28th till March 25th, 2022. The participants gave permission to measure their temperature by entrance of the lab, as part of the Corona safety protocol. After the temperature was determined the participants were prepared for the EEG measurements. The skin where the flat sensors were placed got cleaned with alcohol. The size of the EEG cap was determined by measuring the participant’s head circumference and the cap was attached by closing a chin strap. Electrode gel was inserted to the sensors to reduce noise and the sensors got inserted in the cap. The participants were individually tested in a sound-attenuated and dimly lit room and were observed via closed-circuit television. The age, language, gender, and handedness were asked from each participant. The EEG cables were connected to the A/D converted, and before starting the experiment the A/D converted was turned on the check whether the sensors were attacked properly. The participants were seated in front of a screen monitor that was positioned at eye level. The resolution of the monitor was 1920px x 1080px and had a black background color. The participants were asked to complete three behavioral tests in the following order: the Stroop Color and Word Test, the CPT, and the Emotional (Affective) Pictures Task. After the tests, the resting state EEG of the participants was measured with eyes-open and eyes-closed. Only the CPT was relevant to answer the research questions of this study, so the exact procedure and analysis of the other tests will be left out. Instructions about the experiment were shown on the monitor and for questions the intercom could be used. After completing the tests and the resting state, the participants were asked to fill in eight questionnaires on a computer, of which the BFI-2 was only relevant to this study.

Personality Questionnaire

The questionnaire used to measure extraversion was The Big Five Inventory-2 (BFI-2) (Denissen et al., 2019; Soto & John, 2017). Because the participants were either Dutch or international, both Dutch and English translated versions of the questionnaire were available. The BFI-2 is a measurement of the Big Five personality traits. It consists of 60 statements that certain represent a certain personality trait. For example, a statement can be ‘I am someone who is outgoing, sociable.’ The participant could answer using a 5-point Likert scale, in which 1 represented ‘disagree strongly’ and 5 represents ‘agree strongly’. The domain scales of BFI-2 are extraversion, agreeableness, conscientiousness, negative emotionality, and open-mindedness. The continuous variable extraversion was obtained by summing up the answers to the domain scale extraversion. Some of the statements were coded reversed. The BFI-2 has a strong internal consistency (Cronbach’s α =.80, domain scale extraversion Cronbach’s α = .84), as well as a convergent and discriminant validity for both the English and Dutch translation (Denissen et al., 2019; Soto & John, 2017).

Continuous Performance Task (CPT)

Design. The CPT was used as a measurement for vigilance and sustained attention over time. It consisted of two conditions, named the Go and NoGo condition. In each condition a series of stimuli was presented, and the instructions participants got were to press the spacebar when they got presented any letter (Go stimulus) and to refrain from pressing the spacebar when presented with the letter ‘B’ (NoGo stimulus). The correct answer for a Go stimulus was ‘SPACE’ and for a NoGo stimulus ‘None.’ Every unique stimulus was repeated 80 times in a random order. This made up 400 stimuli in total. One out of five stimuli contained the NoGo stimuli. The CPT was divided into four blocks of each 100 stimuli. Each block started with a black screen which had a duration of 1350 ms, followed by the stimulus (150 ms), and ended with a black screen (0 ms). Each block started automatically after 400 milliseconds. The participants got 10 practice trials in advance to familiarize themselves with the task, and they could take a break in-between block. The error-rates and reaction times (RT’s) for each participant, in both conditions were measured and reported in an excel file.

Stimuli. The five stimuli that got presented were H, R, S, P, (GO), and B (NOGO). The location of the stimuli was at the center of the screen with a viewing distance of approximately 60 cm. The color of the stimuli was white with a font size of 100.

EEG measurement and preprocessing

The EEG was sampled at 512 Hz from 32 locations using a BioSemi Active-Two amplifier system (BioSemi, Amsterdam, The Netherlands). The electrodes were mounted in an elastic cap according to the 10/20 system. During the measurement, the reference electrode (Common Mode Sense: CMS) was located between Cz and C3, serving as the online reference electrode. The ground electrode was located between Cz and C4. Two electrodes were placed on both the left and right mastoids, serving as offline references. Four EOG electrodes were attached to detect the horizontal and vertical eye movements. Two electrodes measuring vertical EPG signals, one above and one underneath the eye, and two electrodes measuring the horizontal EOG near the outer canthi of each eye. The ECG was measured using two ECG electrodes. One was placed on the middle of the sternum and one on the left of the rib cage under the armpit. Both electrodes were placed on the same height.

The data were processed with the program Brain Vision Analyzer 2.1. Data was re-referenced offline to the average of left and right mastoids and band-pass filtered (low cutoff .01 Hz: high cutoff 30 Hz). The (residual) 50 Hz interference was removed by a 50 Hz notch filter. The data were segmented into 1100 ms epochs (including a 100 ms prestimulus baseline) relative to stimulus onset. The procedure of Gratton & Coles was used to correct for eye movements (Gratton et al., 1983). Epochs were rejected if within each epoch at any EEG channel the difference between the most negative and positive value was larger than 200 micro-V. Each epoch was averaged and corrected separately per condition and baseline (-100 to 0 ms). The average number of trials after artifact detection was for the Go condition 283.5

(*SD* 50.9) and for the NoGo condition 72.1 (*SD* 10.5). The average amplitude in the time window of P300 was at 350-700 ms and the topographical maximum was at electrode Pz (see figure 1).

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics 27. Only variables relevant for answering the research questions of this study were analyzed. The independent variable was the score on extraversion, which was a continuous variable. The dependent variables for hypothesis H1 were error-rate Go, error-rate NoGo, and RT. The ERP analysis for hypothesis H2 was limited to the P300 amplitudes of the Pz, Fz and Cz electrodes following literate recommendations (Ortiz & Maojo, 1993). The variables Pz Go, Fz Go, Cz Go, Pz NoGo, Fz NoGo and Cz NoGo made up the six dependent variables for hypothesis H2. Four independent sample t-tests were performed to check for sex differences in all variables. A paired sample t-test was performed to compare the means of the variables error-rate Go and error-rate NoGo. A repeated measures ANOVA was performed to check whether the P300 amplitudes differed between regions and conditions. Condition (Go vs. NoGo) and Region (Pz vs. Fz vs. Cz) were introduced as within-subject factors. Three multiple regression tests were performed to test hypothesis H1. Extraversion was included as a continuous predictor, age and sex were included as covariates. The assumptions for regression were checked. Linearity was met and tested by computing and analysing scatterplots. The absence of multicollinearity was met and tested by computing and analysing the Variance Inflation Factor. Independence was met and tested by computing the Durbin-Watson test. The assumption of homoscedasticity was met and checked by analysing scatterplot with the predicted values and standardized residuals. The multivariate normality was met and checked by analysing Q-Q plots.

A repeated measures ANCOVA was performed to test hypothesis H2. Condition (Go vs. NoGo) and Region (Pz vs. Fz vs. Cz) were introduced as within-subject factors, and extraversion as a continuous predictor. The assumptions for a repeated measures ANCOVA were checked. Normality was met checked by visual inspection of the histograms and Q-Q plots and using the Shapiro-Wilk statistical test. Results showed that P300 amplitudes were normally distributed. The assumption of sphericity met and tested using Mauchly's test. In case of violation of this assumption Greenhouse-Geisser correction was used. Outliers in the data were checked by computing *z* scores for each variable. *z* scores above and below -3 were considered to be outliers. Three outliers were detected, one in variable Fz Go, one in variable error-rate Go and one in variable RT. The outliers were removed from the data set, leaving the three variables with one less data point. For one participant the EEG recording failed, and the EEG data was excluded from the ERP analysis. In this study, an alpha level of .05 was used for all statistical tests and Bonferroni was used as an adjustment for multiple comparisons.

Results

Preliminary analyses

Extraversion scores. Table 1 displays the means and standard deviations of extraversion scores for the total sample and for men and women separately. The scores on extraversion ranged between 26 and 58. There were no differences in extraversion scores between men and women ($t(33) = -.873$, $p = .389$).

Performance on the CPT. Table 1 displays the means and standard deviations for error-rate Go, error-rate NoGo and RT for the total sample and men and women separately. There were no differences for error-rate Go and error-rate NoGo between men and women (Go: $t(32) = -1.963$, $p = .060$, NoGo: $t(33) = 1.177$, $p = .248$). There were differences in the total sample between error-rate Go and error-rate NoGo ($t(33) = -10.014$, $p < .001$). There were no differences in RT between men and women ($t(32) = -1.213$, $p = .234$).

Table 1

Means and Standard Deviations for the Total Sample, Men and Women on Extraversion Score, Error-rate Go, Error-rate NoGo and RT

	Mean (*SD*)		
	Total Sample	Men	Women
Extraversion score	39.97 (7.39)	38.11 (7.81)	40.62 (7.2)
Error-rate Go	3.80 (3.28)	2.43 (1.89)	4.30 (3.55)
Error-rate NoGo	25.00 (12.52)	27.91 (5.59)	4.30 (3.55)
RT	234.47 (31.03)	223.79 (22.10)	238.32 (33.21)

Note: N = 33 for error-rate Go and RT, N = 34 for error-rate NoGo.

Table 2

Means and Standard Deviations for Introverts and Extraverts on Error-rate Go, Error-rate NoGo and RT

	Mean (*SD*)	
	Introverts	Extraverts
Error-rate Go	3.32 (2.49)	4.04 (3.62)
Error-rate NoGo	33.06 (10.95)	21.30 (11.58)
RT	219.21 (21)	241.77 (32.59)

Note: N = 11 for introverts for all variables. N = 23 for extraverts for error-rate Go and RT, N = 22 for error-rate NoGo.

Brain activation in response to the CPT. The repeated measures ANOVA showed the main effects of Condition (Go vs. NoGo, $F(1,32) = 82{,}297$, $p = <.001$, $\eta^2 = .720$), and Region (Pz vs. Fz vs. Cz, $F(2,64) = 31{,}445$, $p = <.001$, $\eta^2 = .496$), and the interaction between Condition and Region $F(2,64)=29.617$, $p <{,}001$, $\eta^2 = .481$. Overall, the P300 amplitudes were higher in the NoGo condition vs. the Go condition. Furthermore, the higher amplitudes in the NoGo condition were recorded in both Pz and Cz (Pz vs. Cz: $p > .999$ as compared with Fz, for both comparisons $p <.001$ (see table 3) (see figure 2-4).

Table 3

Mean and Standard Deviations for Pz Go, Fz Go, Cz Go, Pz NoGo, Fz NoGo and Cz NoGo

	Mean (*SD*)	
	Go	NoGo
Pz	5.87 (4,60)	12.88 (5.76)
Fz	3.60 (3,56)	8.10 (5,60)
Cz	6.16 (4.15)	12.39 (6.30)

Note: N = 34 for each variable except Fz Go, N = 33.

Extraversion effect on CPT performance

A multiple regression analysis was performed to predict the error-rate Go, error-rate NoGo and RT from extraversion, gender, and age (see table 4). These variables predicted for the error-rate Go $F(3,30) = .772$, $p = .519$, $R^2 = .072$; error-rate NoGo $F(3,31) = 2.253$, $p = .102$, $R^2 = .179$; RT $F(3,30) = .687$, $p = .567$, $R^2 = .064$. Higher scores in extraversion were related to less error-rates in the NoGo condition ($\beta = -.341$, $p = .047$) (see figure 5). Extraversion was not related to RT, $p = .422$.

Table 4

Multiple Regression Analysis for Error-rate Go, Error-rate NoGo and RT

	β	Std. Error	t	Sig.	Adjusted R
Error-rate Go	.079	.086	.447	.658	-.021
Error-rate NoGo	-.341	.279	-2.069	.047	.100
RT	.145	.871	.813	.422	-.029

Note: N = 34 for error-rate Go and error-rate NoGo. N = 35 for RT.

Extraversion effect on P300 amplitudes during the CPT

To test whether extraversion influenced the P300 amplitudes in response to the CPT, extraversion was added as a continuous predictor in the repeated measures ANOVA. The results showed that extraversion was not related to the P300 amplitudes. There was not an interaction with Condition (Extraversion x Condition, $F(1,31) < .001$, $p = .990$, $\eta^2 < .001$), Region (Extraversion x Region, $F(2,62) = 0.813$, $p = .448$, $\eta^2 = .026$), or between Condition and Region (Extraversion x Condition x Region, $F(2,62) = 0.225$, $p = .799$, $\eta^2 = .007$). Table 5 displays the regression coefficients and shows that extraversion was not related to P300 amplitudes in neither condition nor region.

Table 5

Regression Analysis for Pz Go, Fz Go, Cz Go, Pz NoGo, Fz NoGo and Cz NoGo

	β	Std. Error	t	Sig.	Partial Eta Squared
Pz Go	-.060	.114	-.529	.601	.009
Fz Go	.013	.093	.143	.887	.001
Cz Go	-.050	.105	-.479	.636	.007
Pz NoGo	-.058	.147	-.396	.695	.005
Fz NoGo	.030	.133	.225	.834	.002
Cz NoGo	-.073	.164	-.445	.660	.006

Note: N = 34 for each variable except for Fz Go, N = 33.

Discussion

In the current study, we made an attempt to find an answer for two research questions related to extraversion, performance, and cortical arousal. The first hypothesis examined the relationship between extraversion and performance on a vigilance task (H1). We expected that introverts would outperform extraverts, and this would result in more error-rates and longer RTs on the CPT for extraverts. The second hypothesis examined the relationship between extraversion and cortical arousal (H2). We expected to find lower cortical arousal in extraverts, and this would result in lower P300 amplitudes on the EEG for extraverts. However, our current findings did not show evidence for both the hypotheses. We did not find a difference in P300 amplitudes between introverts and extraverts, in both the Go and NoGo condition (H2). In addition, no significant relationship was found for extraversion on RT's, in both the Go and NoGo condition (H1). However, an unexpected finding occurred, showing a medium-size effect for a negative relationship between extraversion and the error-rates in the NoGo condition. This suggests that higher levels of extraversion were an indicator for better performance, and this is against the hypothesis that introverts would outperform extraverts (H1).

The hypotheses of this study were based on the theoretical model of Brebner and Cooper (H1) and Eysenck's Arousal Theory (H2). In brief, the Brebner-Cooper model suggests that brain processes can be either in a state of excitation or inhibition, and both states can be induced by stimulus analysis (observing the presented stimuli) and response organization (the action taken upon a presented stimuli) (Brebner & Cooper, 1974). Individual differences in extraversion may affect the balance between stimulus analysis and response organization. The brain processes of extraverts are expected to be in a state of excitation in reaction to response organization, and for introverts the brain processes are expected to be in a state of excitation in reaction to stimulus analysis. This would result in a worse performance on a vigilance task for extraverts compared to introverts. In brief, Eysenck's Arousal Theory suggests that individual differences in extraversion are related to the amount of cortical arousal an individual exhibits (Eysenck, 1967). Extraverts are expected to exhibit lower levels of cortical arousal, while introverts are expected to exhibit higher levels of cortical arousal. Cortical arousal can be related to P300 amplitudes, were low P300 amplitudes are an indicator for lower cortical arousal (Ortiz & Maojo, 1993).

The findings of the current study were not in line (H2) and against (H1) the hypotheses. The participants completed the CPT while their EEG activity was recorded. Performance on the CPT occurred as expected: higher error rates in the NoGo condition compared to the Go condition. Furthermore, as expected, we found higher P300 amplitudes in the NoGo conditions as compared with the Go condition. Differences that were more marked for electrode Pz and Cz than for the Fz electrode.

The positive relationship between extraversion and performance was surprising as previous studies have shown that introverts outperform extraverts on vigilance tasks (Rose et al., 2002; Schmidt et al., 2004). As well, the Brebner-Cooper model of extraversion suggests the opposite tendency (Brebner & Cooper, 1974, de Pascalis et al., 2018). Neither were the findings of this study in line with hypothesis H2 regarding the relationship between extraversion and cortical arousal based on previously described studies (Brocke et al., 1996, 1997; Fink et al., 2002, 2005; Fink & Neubauer, 2008; Gale, 1983; Gale et al., 1969, 2001; Hagemann et al., 2009; Matthews & Gilliland, 1999; Ortiz & Maojo, 1993; Smith et al., 1995). Besides the current findings that were not in line with the hypothesis, they were also not in line with studies that showed a positive relationship between extraversion and cortical arousal (Cahill & Polich, 1992; Gurrera et al., 2001, 2005; Stauffer et al., 2012; Stenberg, 1994). However, a few studies showed a null relationship between extraversion and the P300 (Doucet & Stelmack, 2000; Rammsayer & Stahl, 2004).

An explanation for why the current study failed to find support for both hypotheses may be related to the setup of our study. Conceivably, the variance of extraversion in our sample was not broad enough. The range of extraversion scores on the BFI-2 can be between 12-60. 12 represents the lowest possible level of extraversion and 60 the highest possible level of extraversion. The range of the scores in our sample was from 26 till 58. When dividing our sample in groups according to the extraversion scores, we got 11 (31.5%) introverts and 24 (68.5%) extraverts. Scores of 36 and below indicate for an introvert and scores above 36 indicate for an extravert. This shows us that most participants were above the boundary that separates extraverts from introverts, and that introverts were underrepresented in our sample. Because of the considerably low variance in our sample, the lack of variance can also be reflected in the dependent variables. Most of the scores were close to the mean and therefore, we could not make a clear distinction between extraverts and introverts. Given this, we can say that our sample mainly consisted of ambiverted individuals, which represented neither very strong introverted nor extraverted individuals. A suggestion for further research may be to select participants based on their extraversion score. For example, including only participants that score one standard deviation above or below the mean score of extraversion. When measuring individuals that are on the extreme ends of the extraversion scale you can make a better comparison between groups, and the outcomes of the dependent variable might be more distinct.

Another explanation for both hypotheses might be related to the approach of which the BFI-2 data was analyzed and integrated into the statistical analyses. While the BFI-2 measures five personality traits, this study only examined the trait extraversion and excluded the other traits from the statistical analyses. However, it might be possible that these traits had an influence on the P300 amplitude and CPT performance. For example, the study of Gurrera et al. (2001) suggested that each different personality trait has its own electrophysiologic underpinnings and that besides extraversion, the P300 amplitude has also a negative relationship with neuroticism. In addition, the trait conscientiousness tends to predict an overall better performance and higher accuracy (Mateo et al., 2013). A suggestion for future research may be to consider potential relationships between with the other four personality traits.

In addition, the findings regarding the hypotheses regarding the relationship between extraversion and performance (H1), may also be explained by the condition of the environment in which the participants were tested. Extraverts perform better in relatively high stimulating test conditions, while introverts perform better in relatively low stimulating test conditions (Sočan & Bucik, 1998). For example, if an extravert works under noise levels that are optimal for an introvert, he will exhibit suboptimal arousal levels, which impacts his performance negatively (Brocke et al., 1997). However, the test conditions in which the CPT was performed were moderately low, in a closed cabin, without noise and with a dim light. Therefore, the testing environment probably did not affect the results, but these conditions should have been an advantage for introverts. However, the NoGo stimuli might have been more arousing compared to the Go stimuli, which may explain the better performance for extraverts in this condition. The effects of the environment in which the participants will be tested might be a variable to control for in further research. For example, by constructing a study with different test conditions in low, moderate, and high stimulation environments. This may reduce the side effects that are moderated by environment on both performance and cortical arousal.

Furthermore, an alternative explanation for the results hypothesis (H2) regarding the relationship between extraversion and cortical arousal, may be found in the Cognitive-Adaptive Trait Theory (CATT) (Matthews, 2017). This modern theory suggests that personality traits cannot be associated with causal brain processes, including the individual differences in cortical arousal. On the contrary, personality traits can change and develop in challenging environments. Skills and self-knowledge facilitate adaptation to those environments. CATT mentions the limits of natural sciences regarding personality, and it suggests that personality traits might not be as fixed to biological factors as assumed (Matthews, 2017). Questions for further research may contain external life factors, besides the biological approach, as influence on personality traits and performance.

The following explanations are related to the operationalization of cortical arousal, and how this can be improved in further research. This study used P300 amplitudes as measurement for cortical arousal; however, research suggests that alpha waves can be a valid measurement for cortical arousal as well. Low amplitude alpha waves occur in high cortical arousal and high amplitude alpha waves occur in individuals with low cortical arousal (Duffy, 1957). Several studies support the hypothesis (H2) that extraversion has a negative relationship with cortical arousal, based on measuring alpha waves in the resting state EEG (Hagemann et al., 2009; Tran et al., 2001). Future research regarding the measurement of cortical arousal might take this into account. By for example, constructing a study that takes both, the P300 amplitudes and alpha waves into consideration. Furthermore, there was no difference made in the export of P300 latencies during the data analysis. While various studies failed to show a main effect of extraversion on the P300 latencies (Cahill & Polich, 1992; Ditraglia & Polich, 1991; Doucet & Stelmack, 2000; Ortiz & Maojo, 1993; Polich & Martin, 1992; Stelmack et al., 1993; Stenberg, 1994), Rammsayer and Stahl (2004) suggested that introverts have shorter P300 latencies compared to extraverts.

A weakness of this study was among others the small sample size. With only nine males, they were underrepresented in our sample. Also, the sample was gathered with convenience sampling method. Hence, only a very select group of people had access to participate in this study. In addition, university students are not the best representation for the average population as they have an above-average socioeconomic status and intelligence. Because of the limitations in the sample, the results of this study cannot be generalized to the general population. For further research we suggest using a bigger sample with a relatively equal number of males and females, and to gather the sample with the random sampling method. In addition, the studies that have been referenced in this study were not up to date. Except for a few, no recent studies and reviews of quality have been found to support the theories in this study.

In conclusion, this study did not provide support for the hypothesis regarding the negative relationship between extraversion and performance on a vigilance task (H1), nor for the hypothesis regarding the negative relationship between extraversion and cortical arousal (H2). In order to answer the research questions further research is needed.

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Appendix

Figure 1

Topographic Distribution on the Pz Electrode

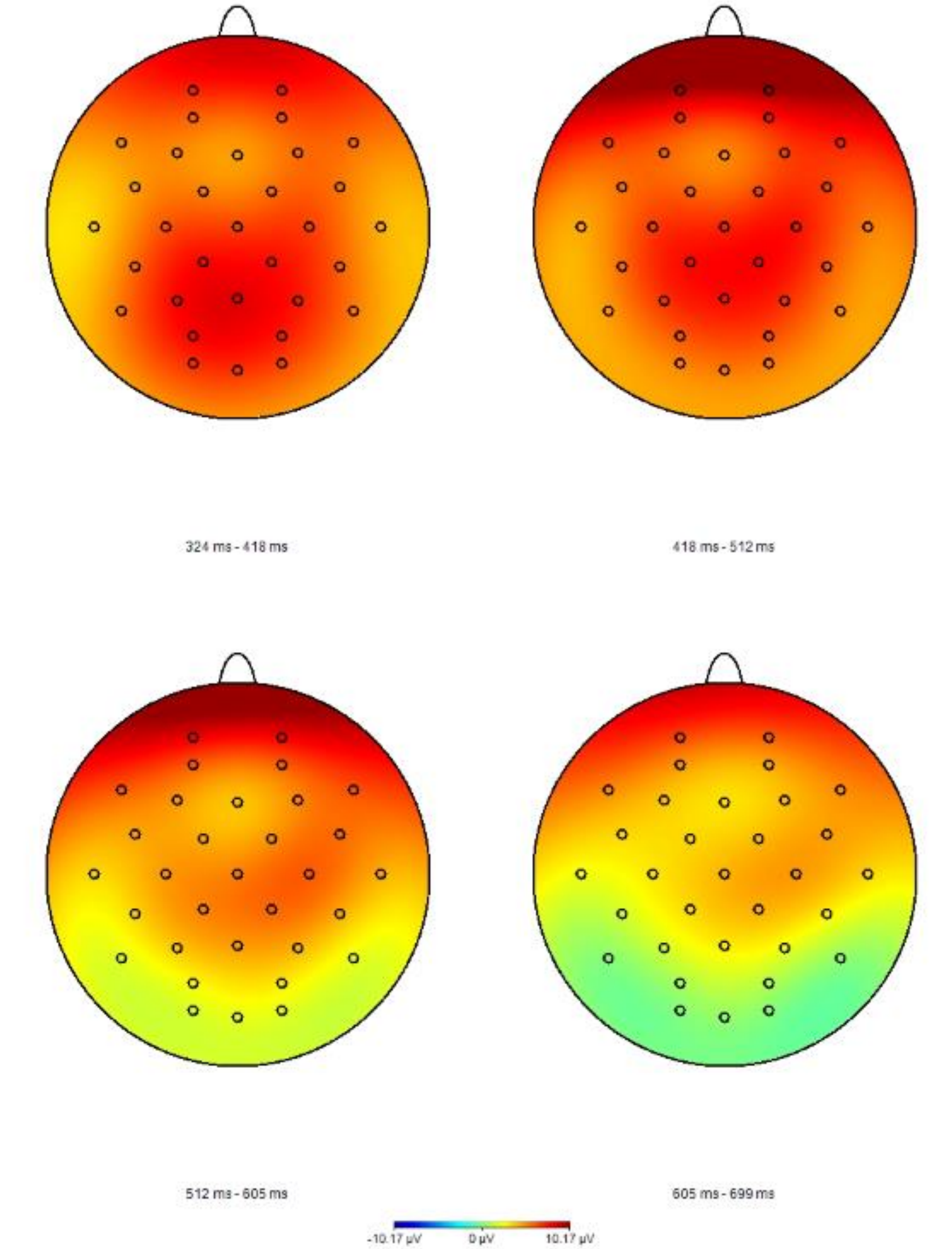
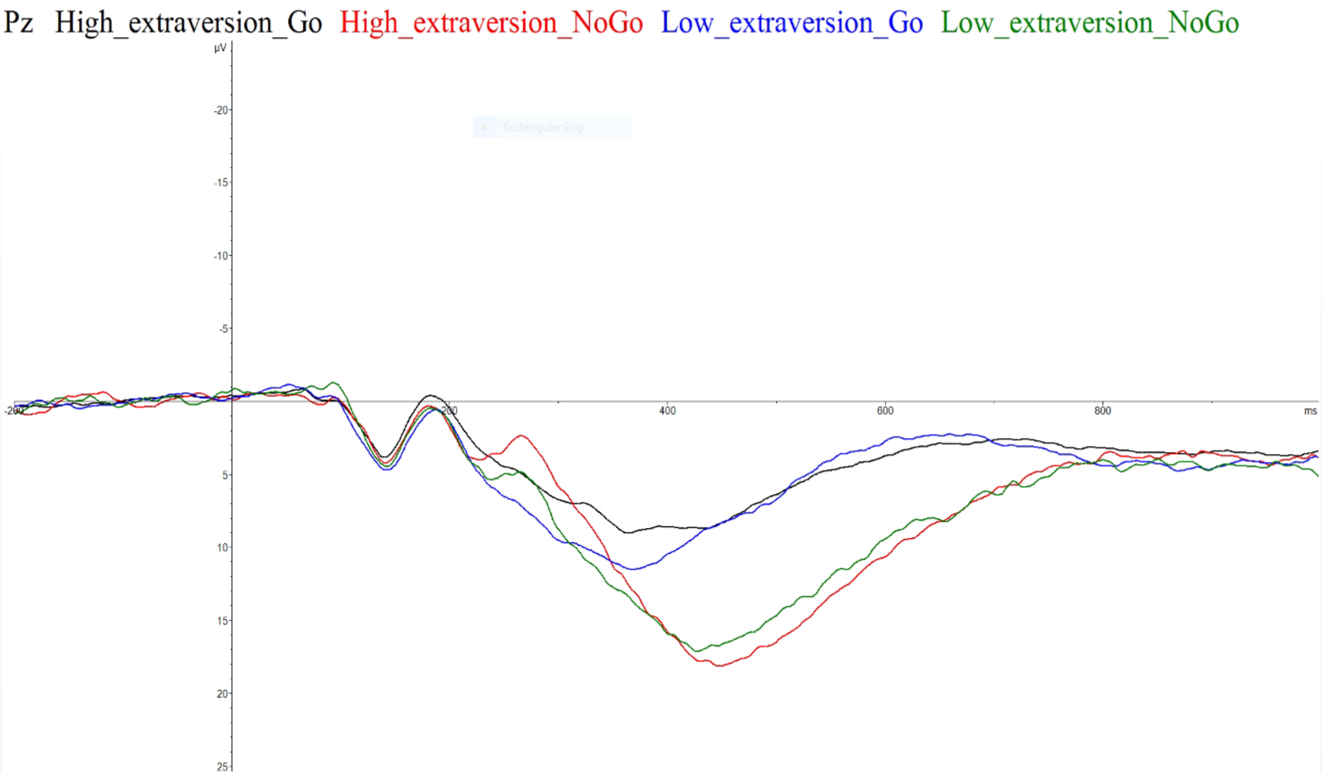


Figure 2

P300 Amplitude for the Pz Electrode, in Both Conditions



Note: The sample was divided into two groups, introverts (N = 11) and extraverts (N = 24). Introverts were selected on a score of 36 and below, extraverts were selected on a score above 36. The same division applies for figures 3 and 4.

Figure 3

P300 Amplitude for the Fz Electrode, in Both Conditions

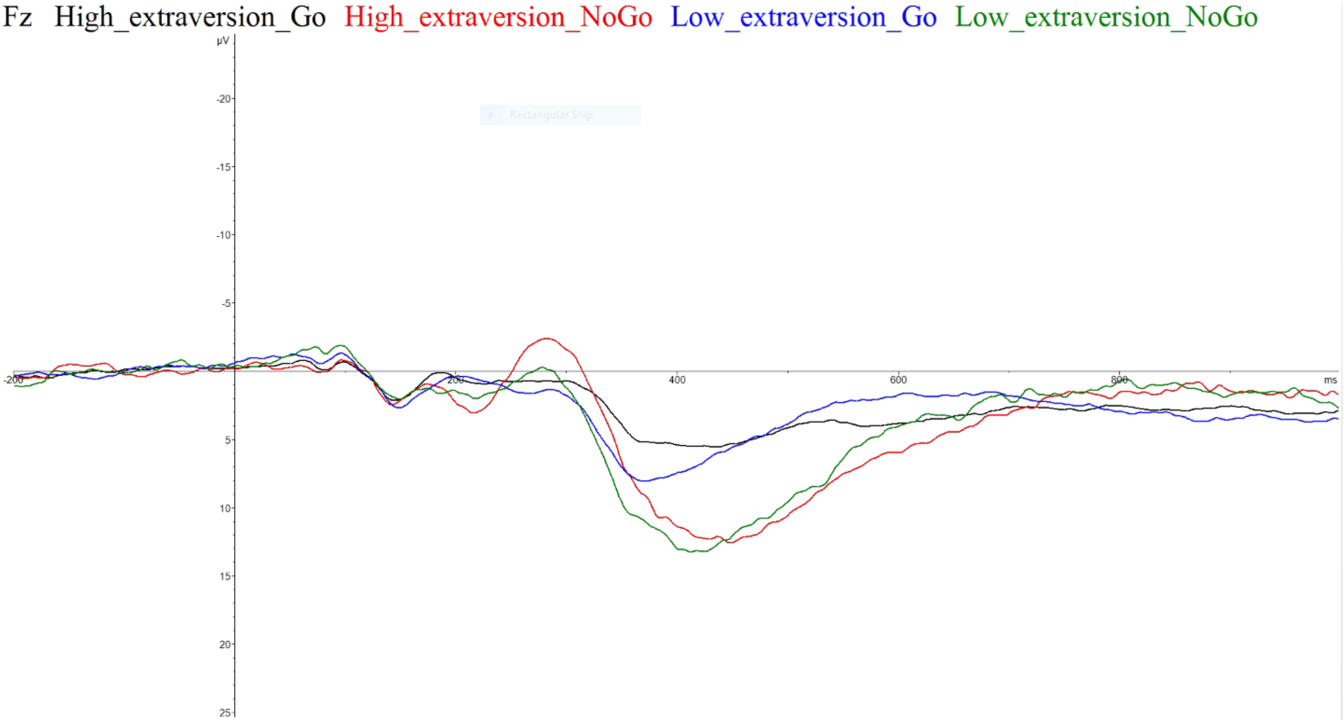


Figure 4

P300 Amplitude for the Pz Electrode, in Both Conditions

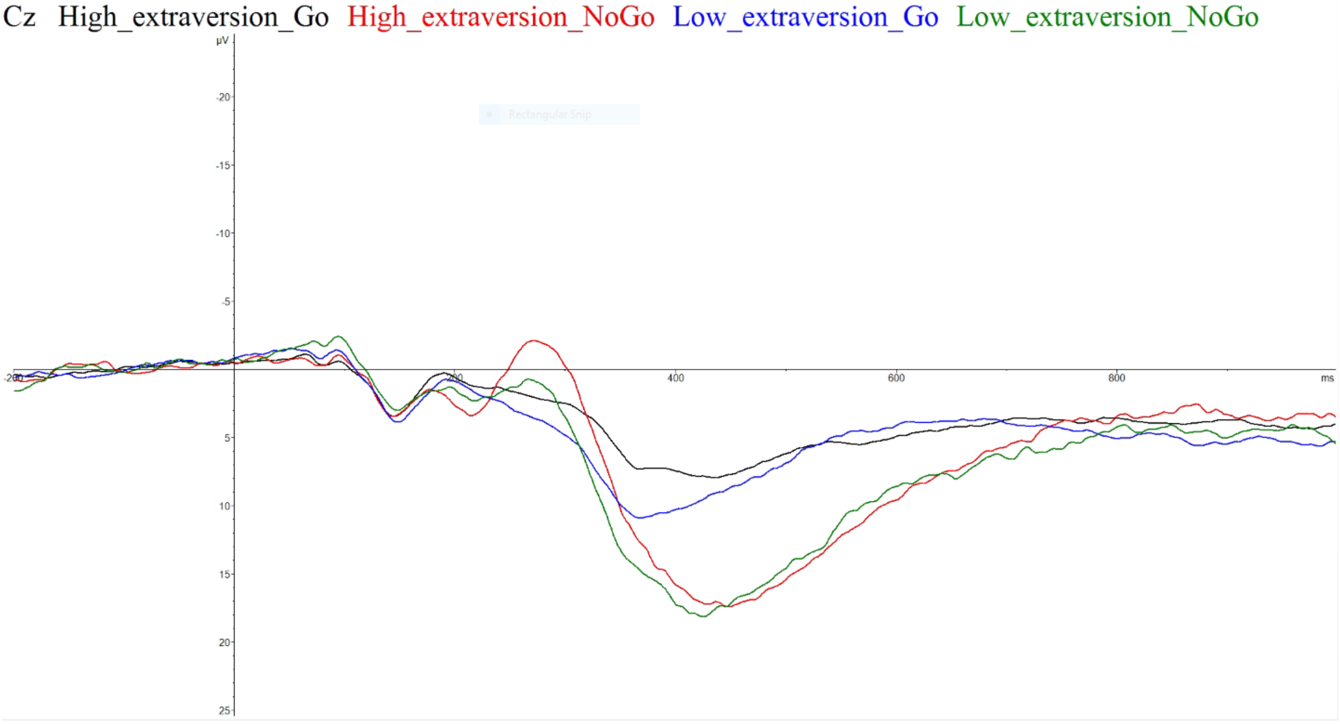


Figure 5

Extraversion Effect on CPT Performance in the NoGo Condition