Universiteit Utrecht

Asymmetrical Activity in the Frontal Brain in Relation to Dominant-Submissive Eye Gaze Behaviour

An EEG/Eye Tracking Study

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Abstract

Asymmetrical activity of the frontal brain is linked with several different behavioural characteristics and traits. Various studies have found a connection between the Behavioural Inhibition System (BIS)/ Behavioural Activation System (BAS) scales and this brain asymmetry. The BIS scale is thought to give a strong indication of withdrawal tendencies, whereas the BAS scale gives strong indications of approach tendencies. The approach tendencies are associated with relative greater left frontal brain activity as well as dominant behaviour. It is hypothesized that dominance can be attributed to, as well as linked with frontal asymmetry in the brain.

25 students were recruited at the Utrecht University. This experiment attempts to find a connection between dominancy and asymmetrical activity of the brain. The N170, a neuronal response seen in occipitotemporal sites of the brain around 170 ms after human faces are shown, was used to verify if subliminal faces were processed by the individual. After analyzing the data, the expectations set prior to the experiment were not met. However, the N170 was confirmed to be a reliable indicator of faces processed by the brain. Also, several correlations were found between the N170 and brain asymmetry as well as the N170 and the BAS.

Keywords: Frontal Asymmetry, Dominant Behaviour, Gaze Aversion Task, N170

Introduction

Naturally occurring asymmetrical activity in the frontal cortex of the human brain correlates to differences seen in an individual's approach- and withdrawal-related behaviour (Schutter, De Weijer, Meuwese, Morgan & Van Honk, 2008). Certain personality characteristics are associated with this approach-and withdrawal-related behaviour (Elliot & Thrash, 2002), as well as personality traits (Muris, Meesters, De Kanter & Timmerman, 2005). Relative greater left frontal brain activity is related to traits with propensities to an overall appetitive, approach, or behavioural activation-motivational system, whereas a relative greater trait right frontal brain activity is linked with propensities to a general avoidance or withdrawal system (Coan & Allen, 2003a; Davidson, 1993).

The approach/withdrawal motivational model of emotion by Davidson (Davidson, 1993; Davidson, 1998a,b) states that relative greater left frontal activity has a tendency to initiate behaviour that results in approaching or engaging a stimulus, while a relative greater right frontal activity leads to the opposite behaviour, namely the tendency to withdraw or disengage from a stimulus.

Carver and White (1994) evaluated Davidson's approach/withdrawal model of frontal EEG asymmetry. In order to accomplish this, they used Behavioural Inhibition System (BIS)/ Behavioural Activation System (BAS) scales, which measure the behavioural inhibition and activation systems BIS and BAS (described by Gray (1972, 1987)) as human traits. These BIS/BAS scales are divided into four subscales, namely the BIS scale, BAS Reward Responsiveness (BASR), BAS Drive (BASD) and the BAS Fun Seeking (BASF) scales. The BIS scale measures punishment sensitivity. BASR focusses on the positive responses to the occurrence/anticipation of rewards, whereas BASD has items measuring the pursuit of desired goals. The BASF scale has items which reflect a desire for new rewards as well as the readiness to engage in a potentially rewarding occurrence on the spur of the moment (Carver & White, 1994).

The underlying drive to pursue dominance has been related to the BAS (Gray, 1990). Furthermore, deviation in trait BASD and BASR seem to predict several other traits as well; dominance behaviour (Putman, Hermans & Van Honk, 2004; Terburg, Hooiveld, Aarts, Kenemans & Van Honk, 2011), neural responses to challenge (Beaver, Lawrence, Passamonti, & Calder, 2008; Hermans et al., 2010) as well as self-report measurements of aggressive drive (Carver, 2004; Carver & Harmon-Jones, 2009).

Several studies found a connection between the BIS/BAS systems and frontal EEG asymmetry (Coan & Allen, 2003b; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). Some showed an increase in left frontal cortex activation during anger and aggression provocation examples (Harmon-Jones & Sigelman, 2001; Harmon-Jones, 2003). Harmon-Jones and Allen (1998) found that trait anger is linked to increased left frontal brain activity and decreased right frontal brain activity. Additionally Rybak, Crayton, Young, Herba and Konopka (2006) found that symptoms of aggression were linked to greater relative left frontal brain activity.

Structural and functional brain studies suggest that psychopathic individuals have a hypo-functioning right prefrontal cortex (PFC) and a dominant left PFC. For example, Yang and Raine (2009) presented that psychopathic individuals only have reductions in the right uncinate fasciculus – which is a major fiber tract connecting the amygdala with the orbitofrontal cortex (OFC). In addition, reduced right frontal brain activity was found in psychopathic individuals (Hecht, 2011). Ross et al. (2007) found that there are positive associations with all psychopathy measurements and BAS attributes, which lead them to conclude that there is a common role of BAS in psychopathy.

In another study, volunteers participated in a thief role-play where they stole money and then attended an interrogation. During the interrogation they received one of three conditions of transcranial direct current stimulation (tDCS), where the cathodal condition lead to decreased neuronal activity, anodal condition to increased neuronal activity and the sham condition had no neuronal influence (Nitsche & Paulus, 2001; Nitsche et al. 2008). An increase of deceptive behavior together with decreased guilt feelings were observed along with decreased inhibition of the right PFC after cathodal tDCS to the right PFC (Karim et al. 2010). Meaning that a relative lower right PFC activity correlates with an increase in deceptive behaviour and a decrease of guilt feelings.

Electrophysiological studies have shown evidence of a neurological process that shows a negative peak around 170 ms (N170) after stimulus onset. This N170 occurs after human faces are perceived in occipitotemporal sites of the brain (Bentin, Allison, Puce, Perez & McCarthy, 1996). There is no agreement however on the trigger of the N170, as inconsistent results were found by researchers who varied the stimulus content (Vuilleumier & Pourtois, 2007). Ashley, Vuilleumier and Swick (2004) as well as Campanella, Quinet, Bruyer, Crommelinck and Guerit (2002) found for example that fearful, happy and disgusted faces all had an effect on the N170. Consequently, the suggestion has been made that variation of attention causes the modulatory effects on the N170, rather than inter-stimulus (various emotions) differences (Eimer & Holmes, 2007; Vuilleumier & Pourtois, 2007). As a result, the interaction between the observer and stimulus is thought to be important for the N170. It can therefore be used to determine if participants have indeed processed a facial expression during subconscious exposure to faces.

Facial expressions are important in human interaction. Angry facial expressions, for example, can work as an important threat signal in dominance encounters (Öhman, 1986). Dominant behaviour can also be used to achieve certain desires or goals, even when realised through aggression (de Waal, 2000; Nelson & Trainor, 2007). An alternative manner of affirming dominance over others is sustained eye contact, more even when provoked with social challenges. Competitors try to out-stare one another until one of them averts gaze (Mazur & Booth, 1998). The automatic keeping of eye contact with angry faces is considered to be a factor that can be predicted by dominance motives conveyed in BAS (Putman, Hermans & Van Honk, 2004; Terburg, Hooiveld, Aarts, Kenemans & Van Honk, 2011).

Dominance can be measured by using the BASD and BASR scales. Although dominance itself isn't mentioned in the scales, they do predict dominant behaviour (Putman, Hermans & Van Honk, 2004; Terburg, Hooiveld, Aarts, Kenemans & Van Honk, 2011). Another way to measure dominant traits is by using a Gaze Aversion Task. Terburg, Hooiveld, Aarts, Kenemans and Van Honk (2011) showed that during the Gaze Aversion Task, gaze responses to masked angry, happy and neutral facial expressions could be directly measured. Participants were shown a fixation screen, after which a backward-masked colorized facial expression was presented. They had to respond by a saccadic eye movement towards the dot of the same colour as the face. By using an eye-tracking device they could follow the eye movements of the participants and measure the delay the various emotions caused because of varying prolonged eye gazing. They found that higher dominance traits predicted a longer gaze to masked anger, which could also be described as an unwillingness to avert ones gaze from masked angry facial expressions. It was shown that higher scores on the BASD and BASR scales predict a prolonged gaze to masked angry facial expressions (Terburg, Hooiveld, Aarts, Kenemans and van Honk, 2011).

In this experiment it is hypothesized that dominance can be attributed to, as well as linked with frontal asymmetry in the brain. As mentioned earlier, research shows that there is a connection between BAS and frontal EEG asymmetry (Coan & Allen, 2003b; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), and that BASD and BASR not only measure dominancy (Putman, Hermans & Van Honk, 2004), but also predict prolonged gaze towards masked angry faces when BASD and BASR scores are higher (Terburg, Hooiveld, Aarts, Kenemans and van Honk, 2011).

EEG will be used to monitor brain activity, specifically the frontal brain and the N170. A BAS questionnaire will be given as well as a Gaze Aversion Task. The expectation is that more dominant participants will score higher on the BASD/BASR scales and will have a prolonged gaze when confronted with angry faces. Furthermore, it is expected that these participants will have relative higher left frontal brain-activity compared to non-dominant participants.

Methods

Participants

25 students were recruited at the Utrecht University. The inclusion criteria consisted of right handedness and naivety to the aim of the study. The exclusion criteria were that the student had no history of psychiatric and/or neurologic conditions.
All the participants had to comply with the informed consent.

Task and Stimuli

BAS questionnaire. The BAS questionnaire was given after the informed consent. It only took a few minutes to complete and was given once.

Resting state EEG. The resting state EEG took a total of four minutes during which the eyes were consecutively open, closed, open and closed for one minute. During the eyes open the participant was asked to focus on one area of a screen.

Gaze Aversion Task. During the gaze aversion task (GAV) EEG was measured to monitor if the subliminal faces were processed. The GAV method was mostly similar to the one used by Terburg, Hooiveld, Aarts, Kenemans and Van Honk (2011) and existed out of stimuli which were colourized (blue, green and red) faces. The faces belonged to 10 actors (five female, five male) and depicted three emotions (angry, happy, and neutral). A non-face stimuli was presented as an unrecognizably scrambled face of the actors. The 120 stimuli were once randomly presented to the participants. Every trial began with a fixation screen, followed by a 33-ms appearance of a colourized face stimulus after which a mask of the same colour was presented. This was on the screen until the participant responded with a saccadic eye movement. In order to have contrast and luminance levels constant during the trial, the masked stimuli were cut up and randomly reconstructed faces. During the gaze-fixation phase a gray mask stimulus was shown with a fixation cross. Three gray dots were presented below the masked stimulus during the fixation phase. Each dot was randomly assigned to a colour (blue, red or green) during the masked phase. The participant was supposed to respond to the task by looking as quickly as possible to the dot with the same colour as the preceding face stimulus. Before actually beginning the trial, participants would complete 10 practice trials with neutral faces.

Terburg, Hooiveld, Aarts, Kenemans and Van Honk (2011) give an explanation what the rationale behind this task is. They explain that the demonstration of masked emotional faces can induce dominance (angry faces) and reward-seeking (happy faces) reactions that can suspend looking away from the mask (the location of the face). As a result, the difference between delays on angry-face trials and happy-face trials can be used as a measurement of indirect dominance or non-dominance approach motives.

The eye movements were recorded via a Tobii-1750 binocular infrared eye tracker with an integrated LCD display.

The GAV was given three times. Once masked (subliminal), once unmasked (supraliminal) and once as an awareness check. The duration of the GAV took approximately 50 minutes.

Procedure

After the participant entered, he/she was given the informed consent form. Hereafter the BAS questionnaire (Carver and White, 1994) was given followed by the resting state EEG. The participant then began the masked GAV, followed by the unmasked GAV and ended with the awareness check. In the end there was a debriefing, where the participant could ask questions about the specifics of the test.

The total duration of the test lasted approximately one hour. The participant was given instructions before each task, so they knew what was expected of them. They were uninformed about the masked facial expressions, but became aware of these during the awareness check.

Analyses

A Pearson product-moment correlation coefficient was used to determine if there was a relation between dominance motivation, left/right asymmetry and the N170. It was expected that there would be a relation between dominance motivation and left/right asymmetry and between dominance motivation and the N170.

A repeated measures ANOVA (2x4 design) was executed. It was used to determine if there were interactions between the following conditions (Angry, Happy, Neutral and Non-face) and tasks (Supra- and Subliminal) for the N170 peaks and the reaction times. Also the following covariates were selected: Left/Right asymmetry and the BAS scales. When the Repeated Measures ANOVA showed any significant values this was further analyzed by using a paired T-test.

Left-Right asymmetry was calculated by averaging five corresponding electrodes form the EEG, namely C3,Fc1, Fc5 and F3 for the left frontal cortex and C4, Fc2, Fc6 and F4 for the right frontal cortex. The cz electrode was used as a reference. In order to evaluate the relative hemispheric contributions, the following formula was used: (right – left)/(right + left). This also controls for potential differences within or between individuals, for example skull thickness (Schutter, De Weijer, Meuwese, Morgan and Van Honk, 2008). When the formula gave a negative result it meant that the left frontal cortex had a higher activity compared to the right frontal cortex and vice versa.

Results

The results are based on 21 students (11 female, 10 male) varying from 19-24 years of age. Due to incomplete data and errors during testing four students were excluded from the results.

First, two tasks and four conditions are examined on possible differences via a Repeated Anova 2x4 design. There are several significant differences found.

Within each subject the two tasks (subli- and supraliminal) were significantly different (*p*=0.009), between the different conditions (emotions) a significant difference was seen (*p*=0.0) and there is a significant interaction between task and condition (*p*=0.0), as seen in Figure 1.

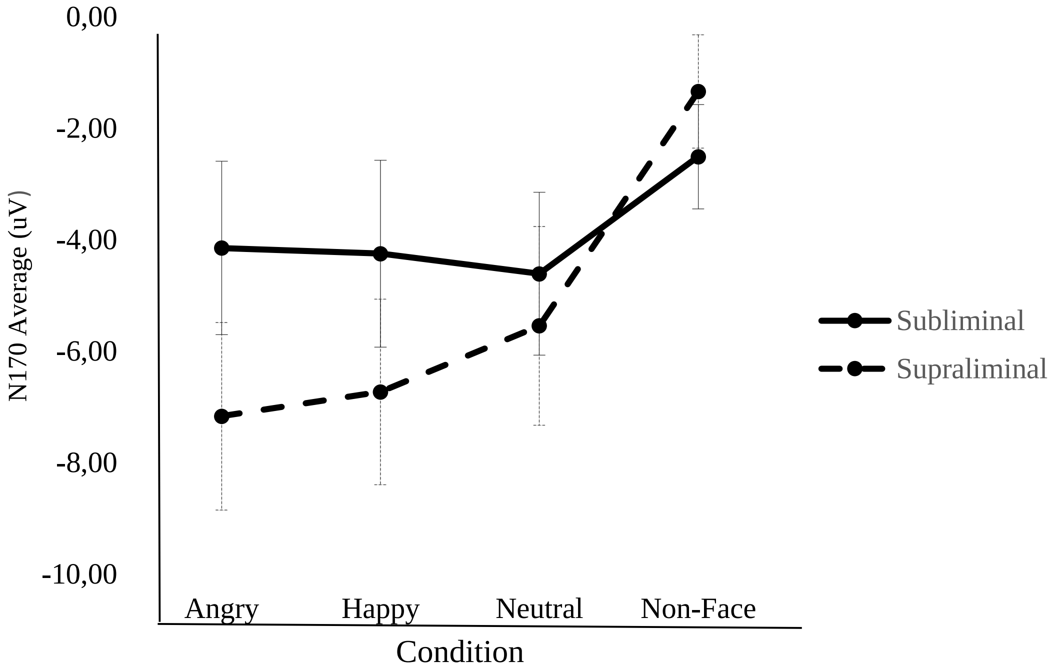

Figure 1. Visual representation of the Repeated Measures Anova 2x4 design: Condition set against the average micro voltage of the N170, per task. Error Bars represent Standard error of the Mean.

To clarify if there are significant differences between the subliminal emotions and the supraliminal emotions, the average voltage of the N170 is used for comparison. Furthermore, the data is split into a subli- and a supraliminal part. This is further specified by emotions.

Subliminal task

A marginal significant difference (*p*=0.054) was found between the conditions on the subliminal level (Figure 1). To specify where possible differences lie, T-tests were done on each condition.

Between angry and non-face, a marginal significant difference was found (*p*=0.064) and between neutral and non-face a significant difference (*p*=0.014).

When the non-face condition is set out against the other conditions, it shows a significant difference (*p*=0.038).

Supraliminal Task

There is a significant difference between the conditions during the supraliminal task (*p*<0.000), see Figure 1. To specify where this significant difference lies, T-tests were used. This resulted in a significant differences between Angry – Non-face (*p*<0.000), Happy – Non-face (*p*<0.000) and Neutral – Non-face (*p*<0.005).

Left – Right Asymmetry

Subliminal task. A significant interaction effect was found between all four conditions and the Left – Right asymmetry (*p*=0.014).

To specify where this interaction effect lies, conditions were removed one by one. This showed an interaction effect between Happy-Neutral (*p*=0.035) and a marginal significant interaction effect between Happy-Angry (*p*=0.064).

Supraliminal task. No significant interaction effect was seen on the supraliminal task (*p*=0.692).

BAS Dominance

During the analysis the BASD and BASR scales were combined to create BAS Dominance. No significant interaction effects were found for both subli- and supraliminal tasks.

Correlations

Left-Right asymmetry. Several correlations were found. A significant correlation between Left – Right asymmetry and Subliminal-N170-Happy-Neutral-bias (*p*=0.035, r=-0,461), as seen in Figure 2.

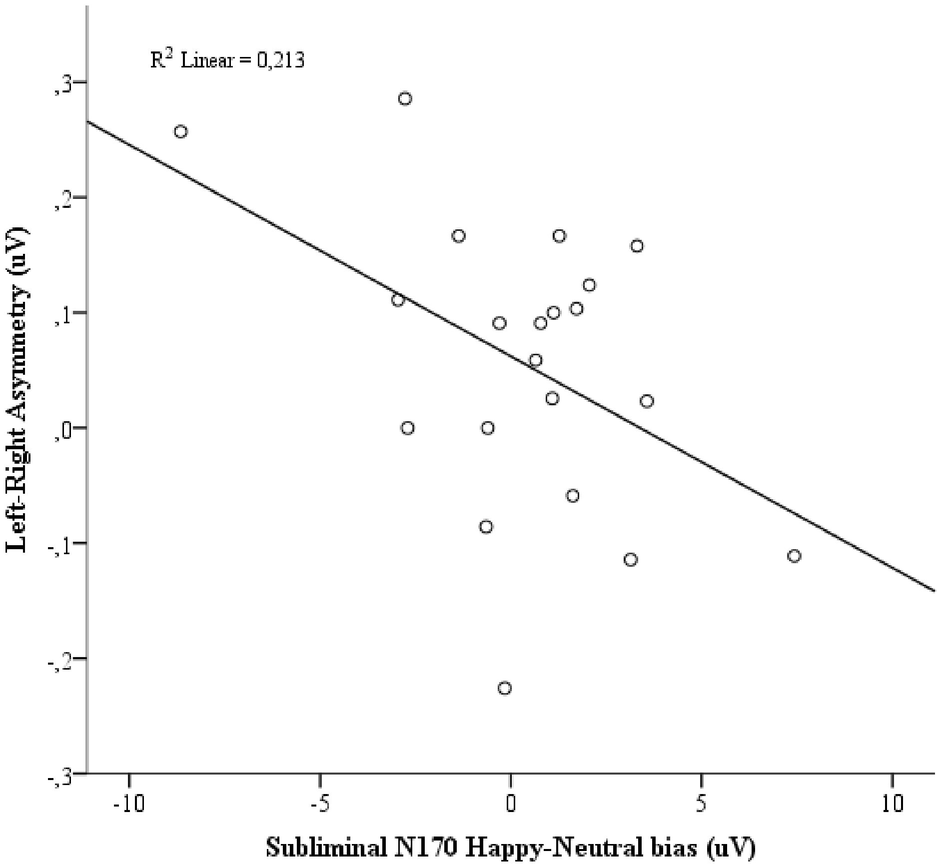

Figure 2. Visual representation of the correlation between Left – Right asymmetry and Subliminal-N170-Happy-Neutral-bias.

As well as a marginal significant correlation between Left – Right asymmetry and Subliminal-N170-Angry-Happy-bias (*p*=0.064, r=0,411), see Figure 3.

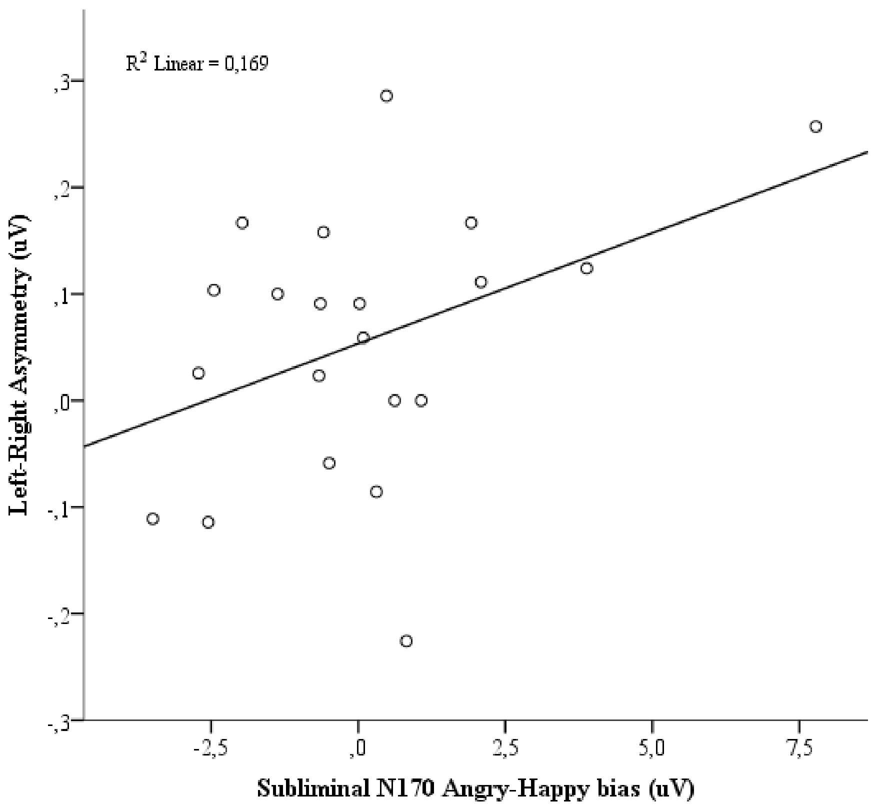

Figure 3. Visual representation of the correlation between Left – Right asymmetry and Subliminal-N170-Angry-Happy-bias.

BAS. A significant correlation was found between BAS Dominance and the Subliminal-N170-Angry-Neutral-bias (p=0.010, r=-0,547). There was also a marginal significant correlation found between BAS Dominance and the Supraliminal-N170-Angry-Neutral-bias (p=0.057, r=-0,444).

Finally, a significant correlation was found between BAS Dominance and the Supraliminal-N170-Happy-Neutral-bias (p=0.018, r=-0.537).

BAS

The 2x4 Repeated Anova showed no significant data for the BAS Dominance or the BASF values.

Reaction times

No significant results were found when comparing the reaction times and the conditions for both the subli- and supraliminal tasks.

There were no significant effects found with the Repeated Anova 2x4 design with covariates Left – Right asymmetry and BAS Dominance or BASF for both subli- and supraliminal tasks.

Discussion

The present study examined the possible connection between dominancy and asymmetry in brain activity.

There are several elements that stand out when looking at the results. The first thing that will be discussed are the significant spikes that the N170 shows when the subject is presented with both subli- and supraliminal faces. This occurs for all the faces (angry, happy and neutral), however, it does not for the Non-face condition.

Second are the correlations seen between left-right asymmetry and two different subliminal biases as well as the correlations between the BAS Dominance and several subli- and supraliminal biases. These correlations constitute medium to large effects (Field, 2009).

The findings of the N170 are a conformation of the expectations that were made based on the suggestions by Eimer and Holmes, (2007) and Vuilleumier and Pourtois, (2007) that variation of attention causes the modulatory effects on the N170, rather than inter-stimulus differences. When faces were observed subli- or supraliminal, the N170 gave a significant negative spike compared to the Non-face condition. The emotional content of the image does not seem to be of any influence. The subliminal Happy face condition however was the only condition that did not show a significant difference when compared to Non-face. This could be explained due to the reduced sample size of the experiment.

The correlations found were not the ones that were expected based on existing literature. Namely, a correlation between left-right asymmetry and BAS Dominance (BASD/BASR), and a correlation between the reaction times of the angry stimulus and BAS Dominance. The results showed correlations of left-right asymmetry and N170 biases and correlations of BAS Dominance and N170 biases. Which would suggest that there is a relationship between left-right asymmetry and the spike occurring in the N170 as well as a relationship between BAS Dominance and the spike of the N170. This, however, is not seen in previous research and was not anticipated. More likely would have been a correlation seen between left-right asymmetry and BAS Dominance, or between BAS Dominance and the reaction times of angry faces, based on research and findings done by Terburg, Hooiveld, Aarts, Kenemans and Van Honk (2011).

Looking to the research question 'Can dominance be attributed to, or linked with, frontal asymmetry?' it can only be concluded that, based on the results found during this experiment, no final answer can be given and that the hypotheses cannot be confirmed. None of the expected results were found, however, the N170 could be confirmed to be a strong indicator of faces processed on a subli- and supraliminal level. There are other results found, but they were not anticipated. The fact that negative correlations are found between BAS Dominance and N170 values could indicate a relation between the two that was not yet thought of. It could, for example, imply that the level of dominancy has an effect on the strength of the N170 for a certain emotion. Meaning that more dominant individuals react less strongly via the N170 spike compared to less dominant individuals.

There are several limitations in this experiment which can be improved. The current results are based on 21 individuals. Originally there were more, however, due to incomplete data and the fact that some individuals did not meet the inclusion criteria's, they had to be eliminated from the test. When a larger group is tested the results are expected to become more reliable.

During the testing phase data had to be removed because of failure of the equipment. In order to minimize these incidents, all the tools should be thoroughly checked on before testing. In this way the chance of excluding participants from the analyses because of measurement errors could be reduced.

When looking at large groups of people, characteristics and traits tend to follow a normal distribution. As a result there is a large group with average characteristics or traits, and a few individuals with extreme characteristics or traits. A normal distribution is expected when looking at the scores on the BAS scale. Most people will score average, with few scoring high and few scoring low. Because of this effect, the answer to the question asked in this experiment can be best answered when more high scoring BAS results are used in the analyses. This would naturally lead to a very large data set because, in order to attain the amount of individuals needed, a lot of subjects have to join with the experiment. However, this could be circumvented. By introducing the BAS questionnaire as an inclusion criteria, a selection can be made of individuals whom have high or low scores on the BASD and BASR scales. By selecting these individuals there will be a bigger contrast between the level of dominancy and possibly left-right asymmetry.

This is recommended in future research done in this field. By bypassing the average scoring individuals on the BASD and BASR scales, there will be more time for executing the experiment with individuals of whom the data will likely give clearer results. Of course, one has to realise that the results will not be based on a random sample of society, however, the question if high dominant individuals have a larger left-right asymmetry will more likely be answered.

To fully understand the significance of asymmetry in the brain in relation to dominant behaviour, further research must be done.

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