# THE RELATION BETWEEN RESTING ALPHA POWER AND BEHAVIOURAL ACTIVATION SYSTEM SENSITIVITY

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The behavioural activation system (BAS) and the behavioural inhibition system (BIS) have been found as neural systems that seem to regulate approach or withdrawal behaviours. These two systems are suggested to be two fundamental motivational systems that control e.g. affective states, behaviour and personality. Since the alpha asymmetry has in earlier EEG (electroencephalographic) -studies been found to correspond to neuronal activation and being related to motivational direction systems, we were interested to measure the alpha activation with more accurate MEG (magnetoencephalography) –method. The aims of the present report were to clarify if there are differences in alpha power between hemispheres and eyes closed or eyes open –conditions and if the behavioural activation system (BAS) relates to resting alpha.

This study was part of a larger project started in fall 2015 that was conducted at the Jyväskylä Centre for Interdisciplinary Brain Research with collaboration between the Department of Psychology and the Faculty of Sports and Health Sciences at the University of Jyväskylä. Data was collected using MEG and a questionnaire from a sample of 46 participants. The resting state was measured during 12 minutes with MEG and a tendency for behavioral inhibition vs. activation was evaluated by BIS/BAS questionnaire.

Study showed, that effects in different hemispheres differed according to whether eyes were closed or open. Alpha power seemed stronger in left hemisphere in frontal lobe when eyes were open and stronger in the right hemisphere in temporal lobe when eyes were closed. The main result of the present study is that the value of behavioral activation system BAS (BAS Drive) was correlated with a level of alpha oscillation in frontal areas. The finding indicates that frontal alpha activation increases when the BAS score decreases. This means that those who have stronger resting alpha activity are less motivated by following one's goals.

Although recent studies do not coherently yield the relation between the lateralized alpha activity and BAS sensitivity, the relation between BAS and frontal activity in general is supported by this study. More MEG studies are needed to clarify this relation between resting alpha and behavioral tendencies.

Key words: behavioral activation, behavioral inhibition, resting alpha, MEG, lateralization

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Käyttäytymistä aktivoiva systeemi (BAS) ja käyttäytymistä inhiboiva, eli jarruttava systeemi (BIS) ovat neuraalisia järjestelmiä, joiden on havaittu säätelevän lähestymis- ja välttämiskäyttäytymistä. Näiden käyttäytymisjärjestelmien on havaittu liittyvän motivaation suuntaa määrääviin ominaisuuksiin, jotka puolestaan säätelevät mm. mielialaa, käyttäytymistä ja persoonallisuutta. Koska aivojen alpha-aaltojen toiminta näyttäisi EEG:lla (elektroenkefalografialla) mitattuna liittyvän myös neuraalisen aktivaation asymmetriaan ja käyttäytymiseen, olimme kiinnostuneita mittaamaan aivojen lepoaktivaatiota (alpha-aaltoja) tarkempia tuloksia antavalla MEG (magnetoenkefalografia) -tutkimuksella. Tutkimuksen tarkoituksena oli selvittää, eroaako alphan voimakkuus eri hemisfäärien tai silmät auki-silmät kiinni -tilanteiden välillä, ja onko käyttäytymistä aktivoiva systeemi yhteydessä aivojen alpha-aktiivisuuteen.

Tutkimus oli osa laajempaa, syksyllä 2015 Jyväskylän Yliopiston Psykologian laitoksella alkanutta tutkimusta, joka toteutettiin yhteistyössä Jyväskylän Yliopiston Liikuntatieteellisen tiedekunnan kanssa. Data kerättiin käyttäen MEG-mittausta ja kyselylomakkeita yhteensä 46:lta osallistujalta. Lepoaktiivisuutta mitattiin MEG:lla yhteensä 12 minuutin ajan ja käyttäytymistaipumuksia mitattiin BIS/BAS kyselylomakkeella.

Tutkimus osoitti, että alphan voimakkuudet eri hemisfäärien välillä erosivat sen mukaan, oliko koehenkilöllä silmät kiinni vai auki. Alfa näyttäisi olevan voimakkaampaa vasemmalla aivopuoliskolla, kun silmät ovat auki ja oikealla aivopuoliskolla silloin kun silmät ovat kiinni.
Tärkein tulos on, että käyttäytymistä aktivoiva systeemi (BAS-Drive) on yhteydessä aivojen etuosan aktivaatioon. Tutkimus osoittaa, että aivojen etuosan alfa-aktivaation noustessa käyttäytymistä aktivoiva taipumus laskee. Tämä tarkoittaa, että ne, joilla on voimakkaampaa alfa-aktivaatiota aivojen etuosissa ovat vähemmän motivoituneita toimimaan ovien tavoitteidensa eteen

Vaikka viimeaikaiset tutkimukset eivät aukottomasti kerro aivojen alfa-aaltojen lateralisaatiosta ja yhteydestä erilaisiin käyttäytymistaipumuksiin, yhteys käyttäytymistä aktivoivan (BAS) systeemin ja aivojen etuosien välillä on saanut tukea tästä tutkimuksesta. MEG –tutkimuksia tarvitaan lisää selventämään luotettavasti yhteyttä alfa-aaltojen ja käyttäytymistaipumusten välillä.

Avain sanat: käyttäytymisen aktivaatio, käyttäytymisen inhibitio, alfa, MEG, lateralisaatio

**CONTENTS**

# INTRODUCTION

One of the main questions in psychophysiology research concerns how the activity in different areas of the brain is related to individual differences in motivation and personality. Within the past few decades, intensive research has been conducted especially on the relation between the activity in the frontal part of the brain and three different constructs: motivational direction (approach/withdrawal), valence of emotion (positive vs. negative) and behavioural activation and inhibition (Hewig et al. 2006). The behavioural activation system (BAS) and the behavioural inhibition system (BIS) have also been found as neural systems that seem to regulate approach or withdrawal behaviours (Gray, 1970). These two systems (BIS and BAS) are found to be two fundamental motivational systems that are responsible for affective states, behaviour, personality and even some psychopathological diseases (Li et al., Shinagava et al., 2015). The frontal asymmetry in the alpha band has been also suggested to correlate with trait BAS (Wacker et al., 2010). In turn, literature on the association between resting frontal alpha asymmetry and trait BAS has not been consistent (e.g. Coan & Allen, 2004) and these results confirming the relations arise mainly from studies using EEG measuring which makes the reliability of these results questionable.

As it has been suggested that resting alpha activation may reflect an affective style with a tendency to general activation or inhibition behaviours, and as the resting frontal alpha has been supposed to relate to BAS-sensitivity, we were interested in relation between the resting alpha activity and the BAS, more specifically BAS-drive. Does the tendency to behavioural activation relate to differences in alpha activity? Moreover, does this relationship show differently in distinct regions of the brain?

## Behavioural activation and behavioural inhibition systems

There are few theories that have led the research of motivation and personality over the years. Psychologist Jeffrey Gray and his colleagues have been guiding this research since 1970 showing originally that there are two systems that underlie human behaviour; the systems of behavioural activation and behavioural inhibition. The first system is suggested to mediate the experience of approach-related behaviour and positive emotion in response to reward cues (Pascalis et al., 2013). A second system is sensitive to signals of fear, punishment or nonreward. It operates by increasing attention toward aversive stimuli as well as interrupting an ongoing behaviour while processing potential threat cues (Pascalis et al., 2013). Later, Gray added the third dimension, the fight-flight-freezing system (FFFS) to his theory. Wacker et al. (2003) presents that along with BAS, the FFFS activates a goal-directed behaviour. The BAS mediates approach behaviour and its function is to operate by stimuli signalling reward or safety while FFFS mediates avoidance behaviour activated by stimuli signalling punishment or nonreward. Pascalis et al. (2013) have suggested that each system can only be used separately and which system is employed depends on whether the behaviour will result in a punishment or a reward.

Along with Gray, Davidson (1992) suggested in his model of anterior asymmetry and emotion that BAS corresponds to an approach system and BIS to a withdrawal system (Hewig et al. 2004). Davidson's (1985, 1998) model of an approach and a withdrawal system posits that the approach system is activated by goals and initiates appetitive behaviour towards these goals (Hewig et al. 2006). The withdrawal system, instead, is activated by repulsive stimulation leading to withdrawal behaviour. According to Davidson, approach and withdrawal are tendencies of motivational direction that directs the action to move toward or away from something. Therefore, our active behaviour is controlled by BAS, that refers to relation between behavioural activation and behavioural approach systems (Wacker et al. 2008). It thus becomes obvious that the two frameworks have some similarities according to underlying motivational systems. However, the distinction in Gray's theory, in contrast to Davidson's, is the notion that motivated goal-directed action is irrespective of the direction of behaviour (Wacker et al. 2003). Still, it has been proposed that BIS and BAS may interact when facing a goal-conflict. A common type of goal conflict is the requirement to approach danger to obtain reward. This view of interaction posits that the BIS system operates by inhibiting the on-going goal-directed behaviour (Wacker et al. 2006) and/or by activating the BAS –system and approaching the conflict (Rasmussen et al., 2012).

In 1994 Carver and White (Gray et al. 2016) developed measures of BIS/BAS –systems and constructed factor structures via measurements. Through experimentation of this factor structures they were able to share BAS into three subscales: Drive, fun seeking and reward responsiveness. Drive refers to motivation to follow one's goals, fun seeking to motivation to find novel satisfaction spontaneously and reward responsiveness refers to sensitivity to pleasant reinforces in the environment. Today this four-factor BIS/BAS scale is a much-used way to measure individual differences in temperament and is also used in this study as self-report questionnaire. In terms of specific facets of BAS, past research is less consistent. From the BAS –subdimensions, BAS-drive seems to have shown the most consistent relationship with the pursuit of appetitive goals and some disorder behaviour (e.g. Wadeson, 2011, Rasmussen et al., 2012). Rasmussen et. al. (2012), have also shown that BAS drive moderates the relation between BIS and conflict response. For the above reasons we were interested to focus our research to concern BAS-drive as a behavioural activation system.

Across the years the measures of the behavioural approach and inhibition constructs have been proposed as appropriate indicators of individual tendency to experience emotions and wellbeing (Pascalis et al., 2013). The previous literature has consistently implicated the BAS and BIS systems to clinical studies concerning e.g. neurodegenerative diseases (Shinagava et al., 2015), affective disorders as anxiety and depression (Rasmussen et al., 2012), drug and/or alcohol dependence (Krmpotich et al., 2013), eating disorders (Wadeson, 2011) and also to temperament (Kennis et al. 2013) showing divergent patterns of change in BIS/BAS activity. Further, the functional studies have established e.g. the association between gambling and reward/punishment sensitivity (Castumera et al., 2016) and have also found certain brain areas underlying these functions (Rahman et al., 2014). Despite the literature, that has combined asymmetric activation of the brain in behavioural activation-inhibition or, alternatively, approach-withdrawal motivation, there seems to be a lack of studies exploring reliably the association between these constructs and functional architecture of the brain.

## The alpha-band and trait-like tendencies

Over the past two decades the wide availability of high-density electrical and magnetic recordings has made it possible to characterize and localize different electrical rhythms in the brain with totally new efforts (Foxe & Snyder, 2011). Neural rhythms of the brain arise from the rhythmic electrical activity in a neural network. Brain activation with a periodic pattern at around 7-13 Hz has been called the alpha waves. Among different EEG frequencies the alpha band has been mostly studied (Hwang et al. 2008) and the role of brain waves at distinct frequency has been related to many aspects of human behaviour (e.g. Rimmele et al., 2018).

The weight of evidence suggests that fluctuations in the regional alpha power functionally correspond to neuronal activities in an inverse fashion (Hwang et al. 2008). I.e., an increased regional alpha power reflects a decreased regional neuronal activity and a decreased alpha power reflects an increased neuronal activity. It has also been shown that alpha power can be actively invoked within cortical regions across multiple sensory systems, especially when these regions are involved in processing information that should be ignored or selected against (Foxe & Snyder, 2011). As such, the central role of alpha seems to be as an attentional suppression mechanism. Moreover, Davidson and his colleagues have suggested that anterior alpha measurements reflect relative differences in activity between left and right hemispheres (Gotlib, 1998) and proposed that the hemispheric asymmetry in prefrontal activation is related to reactivity to affectively valenced stimuli (Gotlib, 1998). He has proposed further that this reflects a trait-like tendency to respond differentially to positively and negatively valenced stimuli.

## Why use MEG to measure the resting activity in the brain?

Human sensory processing, cognitive processes and social interaction rely on accurate neuronal timing ranging from submilliseconds to seconds (Hari et al. 2010). This kind of scales can be tracked with magnetoencephalographic (MEG) and electroencephalographic (EEG) methods. MEG and EEG are closely related since both reflect the same neuronal currents. However, they have important differences to take notice as well. MEG uses sensitive superconducting quantum interference device (SQUID) sensors, which can be used without physical contact to the person's head (Hari et al. 2010). The MEG signals, ranging from 50-500fT, result from the synchronized activity of tens of thousands of neurons.

We exploited magnetoencephalography (MEG) to measure the alpha activity for many reasons. First, compared with EEG, MEG can show more accurate functional localization of the neural sources of rhythmic activities such as alpha rhythms due to its more focal magnetic field. Unlike EEG, the magnetic field passes on the skull somewhat unchanged without severe distortion by the skull, blood circulation or other extracerebral tissues (Hari, 2001). In addition, with the measured distribution of a magnetic field the activation spot can be tracked more accurately. It also gives quantitative information of the amplitude of activation in different hemispheres (Hari, 2001). Second, MEG has the excellent submillisecond temporal resolution. This is important when measuring the brain, which works in real time. Third, MEG measures noninvasively the magnetic field generated by the electrical activity of neurons (Hari et al. 2010). Hari et al. (2010) suggests that the use of MEG is increasing in clinical medicine and gaining a settled role in human neuroscience although most MEG applications remain in basic brain research.

## The neuroanatomical asymmetry of behavioural systems

The brain (vertebrate cerebrum) is formed by two cerebral hemispheres that are separated by the medial longitudinal fissure. Each of these hemispheres has an outer layer of grey matter and an inner layer of white matter. The hemispheres are linked by the corpus callosum that is a very large bundle of nerve fibers, and other smaller commissures, which transfer information between the two hemispheres (Snell, 2009). Although the macrostructure of the hemispheres seems almost mirror images of each other, different composition of neuronal networks allows for specialized function that is different in each hemisphere (Snell, 2009).

There is some evidence to indicate that the left and right hemispheres of the human forebrain associate differentially with certain emotions and affective traits (Craig, 2005). According to Craig (2005), recent neurobiological studies show that subjectively experienced emotions might be based on higher-order re-representations of homeostatic activity in the forebrain. Such conclusion strongly indicates a lateralization. Further, it has been proposed (Craig, 2005) that forebrain emotional asymmetry is anatomically based on an asymmetrical representation of homeostatic activity that originates from asymmetries in the peripheral autonomic nervous system. This proposal indicates a homeostatic neuroanatomical model of emotional asymmetry: the left forebrain is associated with parasympathetic activity, so it reflects with nourishment, safety, positive affect and approach behaviour (Craig, 2005). It is also supposed that activation of the BAS is associated with approach behaviours and elicits approach related positive affect (Hwang et al., 2008). It has been consistently reported (Hewig et al., 2006, Kennis et al., 2013), that the neuroanatomical basis of this system is the left dorsolateral and medial prefrontal cortex and the basal ganglia in response to positive stimuli. The right forebrain, on the other hand, is suggested to associate with sympathetic activity and thus with negative affect, arousal, withdrawal behaviour and danger (Craig, 2005). However, these conclusions arouse mostly from EEG studies and, because of lack of conclusive support, should be questioned. Further, the activation of the BIS is assumed to be activated by negative stimuli and leading to withdrawal behaviour (Hewig et al., 2006). The neuroanatomical basis is suggested to be the right temporal polar region, the right dorsolateral prefrontal cortex, hypothalamus and the basal ganglia (Hewig et al., 2006) along with the septohippocampal system and amygdala (Fuentes et al., 2012, Kennis et al., 2013). Along with Craig’s theory, these findings of different brain areas being held responsible for different action tendencies have been criticised and has not been fully established.

## Aims of the study

With a method that shows the spatial distribution of rhythmic activity more accurately, the present study aimed to clarify the association between resting alpha and behavioural activation system. Thus, the aims of present report were: 1) to clarify if there is differences in alpha power between hemispheres and eyes closed or eyes open –conditions, 2) to see if there is differences in alpha power between subjects with opposite tendency to behavioral activation. Firstly, we predicted that we would see differences in alpha power between hemispheres and conditions; in line with previous findings (e.g. Kirstein, 2013) we assumed that alpha power is greater when eyes are closed. Further, we hypothesized that behavioral activation system is related to (frontal) alpha, which is in line with previous studies. Still, referring to concern about inaccuracy of EEG measurement, we were curious to see what results would arise from MEG study that has not been taken place earlier.

# METHODS

## Participants and procedure

This study was part of a larger project started in fall 2015 on interoception called 'body awareness, brain and exercise' that was conducted at the Jyväskylä Centre for Interdisciplinary Brain Research with collaboration between the Department of Psychology and the Faculty of Sports and Health Sciences at the University of Jyväskylä. The aim of the project was to investigate the connection between interoception, body awareness, personality and exercise. Further, the project aimed to look for group differences in brain functioning using Magnetoencephalography (MEG). Data was collected in two sessions. The first session consisted of the heartbeat detection task and questionnaires. Participants were brought into the lab and assented to participate. They responded to questionnaire concerning sensitivity to behavioral activation and/or inhibition (Carver & White, 1994) among with other questionnaires concerning the current project (physiological and exercise related background information, temperament and personality traits, wellbeing, emotion intensity clinical anxiety and depression symptoms). It was carried out in the laboratory in the faculty of psychology. The second session was MEG study with heartbeat detection task and it took place in the MEG laboratory.

Altogether 71 participants (29 male, Mage = 24.48, SD = 3.94) were recruited for the original study using mainly student mailing lists and notice boards at the university of Jyväskylä and the University of Applied Sciences. Criteria for participating in this study were age between 18 and 35, normal Body Mass Index and no metal in the body since it can disturb the MEG measurement. In this particular study only participants who committed to BIS and BAS questionnaire and to MEG measurement are reported referring to the aims of this study, which narrowed the sample to 46 participants (22 male, Mage = 24.46, SD = 3.89). Participants were divided into two groups based on median of their BAS Drive scores (see below). A group with high BAS Drive score had 27 participants and group with lower BAS Drive scores had 19 participants.

Participants provided an informed consent before the experimental treatment. An approval for the experiment was received from The Ethical Committee of the University of Jyväskylä. The research was conducted in accordance to the ethical standards of the American Psychological Association (APA).

## Measurement of BIS and BAS

Tendencies to behavioral regulation concerning activation and/or inhibition were measured with questionnaire using Carver & White's (1994) BIS/BAS scales. Participants were asked to respond to 20-item scales ranging from 1 (strongly disagree) to 4 (strongly agree). Questionnaire provides one measure of BIS (seven items), that is, inhibition activity and three subcomponents of BAS activity, which indicate an approaching tendency: Drive (four items), Fun seeking (four items) and Reward responsiveness (five items).

## MEG recording

MEG was recorded at 1000Hz on a whole-head 306-sensor using MEG device Elekta Neuromag Triux (Elekta Neuromag™, Elekta Oy, Helsinki, Finland) and it was carried out in a magnetically shielded room at Jyväskylä Centre for Interdisciplinary Brain Research (CIBR). Participants completed 12 min of baseline resting MEG recording. 8 minutes they were asked to stay eyes open and 4 minutes with eyes closed. For further research, we took 4 minutes from each section. This

MEG recording was performed before interoception tasks, which were part of the larger project concerning body awareness, brain and exercise.

### Data analysis

To start with the data analysis, we used the MaxFilter™ software for the collected MEG data to remove magnetic interference and correct for head position movements. After the pre-processing the collected data was exported into Meggie software (GUI for MNE Python Analysis Software created in the Psychology Department of University of Jyväskylä). The ICA artifact detection was used for removing artifacts caused by eye-blinks and heartbeat. In addition, filtered data was visually inspected to detect any additional artefacts in MEG sensors. The power spectrum across frequencies from 0 to 40 Hz was calculated using Fast Fourier Transform. From this spectrum, the specific focus was on the alpha band (7-13 Hz), based on previous literature (e.g. Haegens et al., 2014)

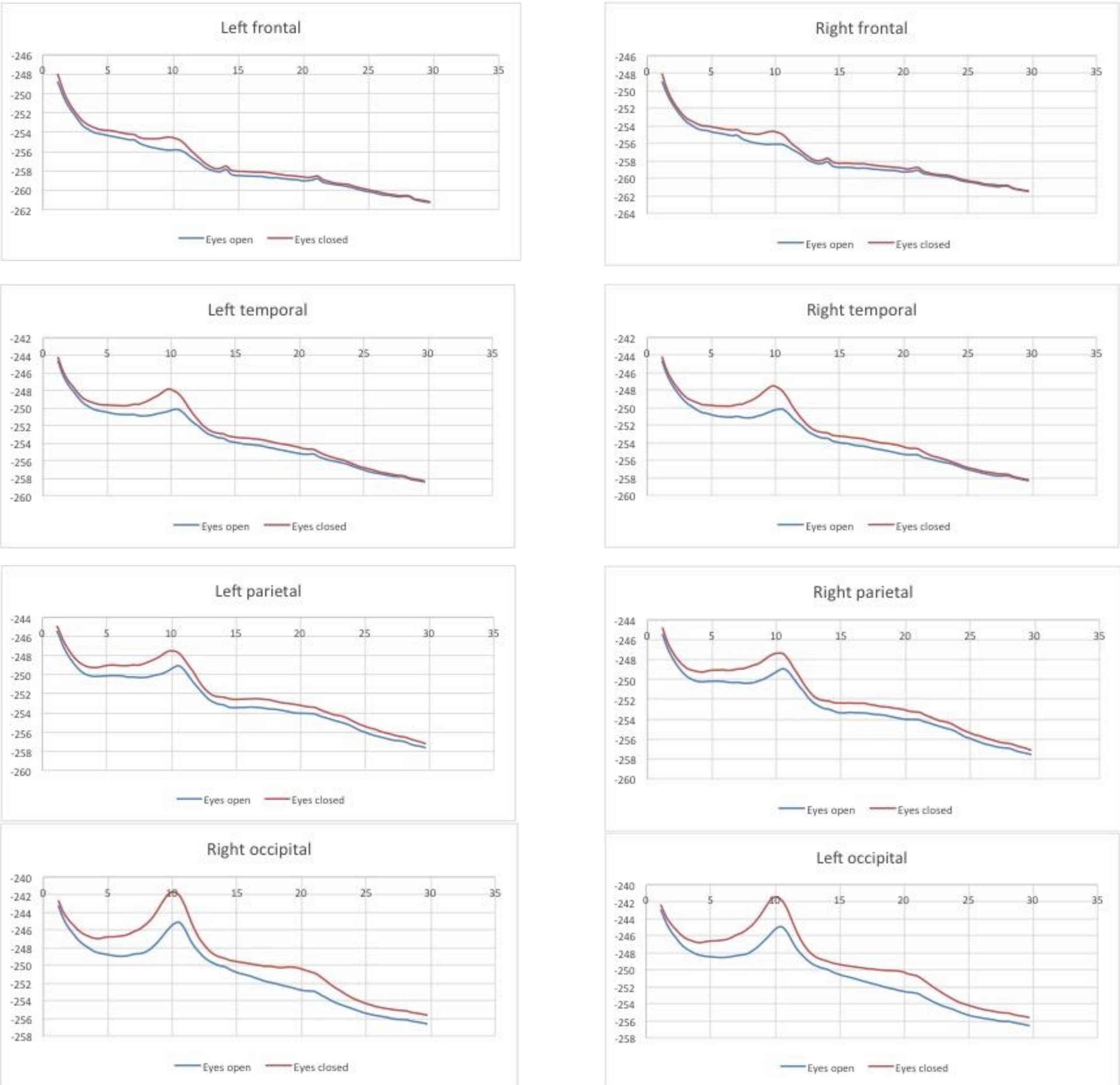
### Statistical analysis

The power of alpha oscillation (i.e. peak in the spectrum between 7-13 Hz) was collected separately for each individual. Repeated measures ANOVA with group (high BAS Drive, low BAS Drive) as between a subject factor and hemisphere (left, right) and condition (eyes open, eyes closed) as within subject factor was used to test the effect of a group. Separate repeated measures ANOVA was conducted for four different brain areas, namely frontal, temporal, parietal and occipital.

## RESULTS

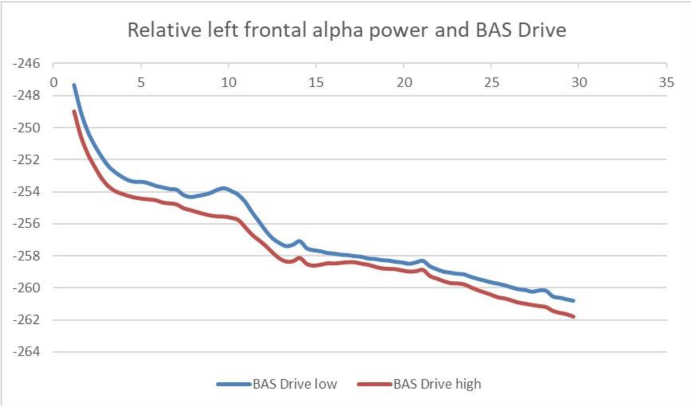
There was no difference between the hemispheres in the alpha power in any region (hypothesis 1); temporal ($F(1,44)=1.09$, $p>0.05$), parietal ($F(1,44)=2.48$, $p>0.05$), occipital ($F(1,44)=0.56$, $p>0.05$), frontal ($F(1,44)=1.58$, $p>0.05$). However, there was a significant interaction between condition (eyes closed vs. eyes open) and hemisphere (left vs. right). Effects in different hemispheres seemed to differ according to whether eyes were closed or open. Alpha power seemed greater in left hemisphere in frontal lobe when eyes were open ($F(1,44)=9.799$, $p=0.003$) and greater in right hemisphere in temporal lobe when eyes were closed ($F(1,44)=10.303$, $p=0.002$). In addition, there was a significant effect of increasing alpha in eyes-closed condition compared to eyes-open condition. The effect was significant in every brain area; temporal ($F(1,44)=55.6$, $p<0.001$), parietal ($F(1,44)=32.02$, $p<0.001$), occipital ($F(1,44)=71.21$, $p<0.001$), frontal ($F(1,44)=34.92$, $p<0.001$).

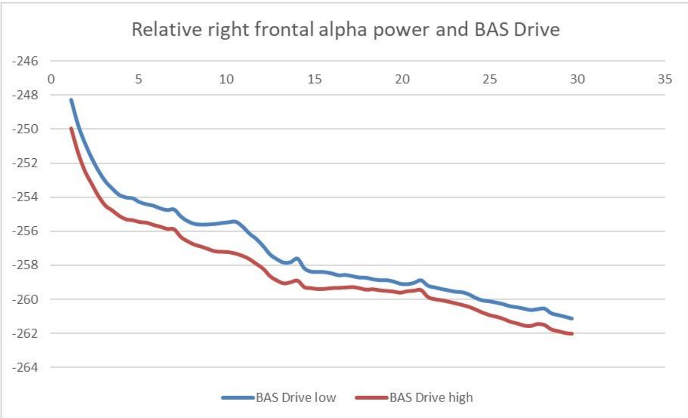
Table 2. Alpha power in different brain areas with eyes open and eyes closed conditions.



Instead, the difference in frontal activation was almost significant between groups divided by BAS Drive score (hypothesis 2). Main result was that the low BAS Drive group showed higher alpha values (F(1,44)=3.954, p=0.053). The difference in alpha power between groups based on BAS drive score was almost significance.

Table 1. Relative frontal alpha activation and BAS Drive. Frontal alpha activation increases in lower BAS Drive groups in both sides of the brain.




## DISCUSSION

Within the past few decades, intensive research has been conducted on the relation between the activity in the frontal part of the brain and behaviour, e.g. motivational direction. The behavioral activation system (BAS) is found to be one of the two fundamental motivational systems that are responsible for affective states, behaviour, personality and some psychopathological diseases. Frontal asymmetry in the alpha band has been suggested to correlate with trait BAS but the literature on the association has not been consistent. Importantly, findings suggesting the relations arise mainly from studies using EEG measuring which makes the reliability of these results questionable. We were interested in measuring the relation between the resting alpha activity and the BAS with more accurate MEG method. The aim was to clarify if the differences in behavioural activation relate to alpha activity and if this relationship show differently in distinct regions of the brain.

The first goal of the present study was to see if there is alpha asymmetry and/or diversity in different regions of the brain. Hypothesis was motivated by Sutton and Davidson (1997) and implied that behavioral tendencies are related to alpha asymmetry. Further aim was to assure whether the alpha power is stronger when eyes are closed as has been observed earlier (eg. Kirstein, 2013). The second goal was to investigate the relation between behavioral activation system (BAS drive) (as measured by Carver and White's, 1994, scale) and resting alpha power and see if the BAS differences relate to frontal resting alpha as reported in the literature (Hewig et al.2005). We implied that greater frontal alpha activity might be related to BAS drive, which measures how persistent one is in pursuing desired goals.

The present study failed to find any significant differences in alpha power between the two hemispheres. The hemispheres and BAS didn't show any interaction effect with alpha either. As assumed, the study showed a significant effect of increasing alpha in eyes-closed condition compared to eyes-open condition. The effect was significant in every region of the brain, which is in line with previous literature (e.g. Kirstein, 2013).

There has been wide evidence indicating a strong pattern of lateralization according to emotions and affective traits that has been explained by peripheral autonomic nervous system (e.g. Craig, 2005) or neuroanatomical basis (e.g. Hewig et al., 2006). However, these findings came from studies researching cortical or neurobiological activity and not the resting state as in the present study. Interestingly, in this study effects in different hemispheres differed according to whether eyes were closed or open. Alpha power seemed stronger in left hemisphere in frontal lobe when eyes were open and stronger in right hemisphere in temporal lobe when eyes were closed. Further studies will be necessary to evaluate this particular finding. Why does the effect differ in distinct regions of the brain with eyes-closed compared to eyes-open condition?

Given, that we were most interested in relation of resting frontal alpha and behavioral 'drive' activation we divided the BAS drive –factor into two groups of higher and lower scores on BAS drive. Importantly, high vs. low BAS Drive groups showed difference in frontal alpha levels. Even though the result was only almost significant, it is line with previous reports on a relation of greater frontal alpha activity and BAS (Pascalis et al., 2013). Interestingly the finding indicates that frontal alpha activation increases when the BAS score decreases.

Higher alpha score in groups with lower BAS drive could mean, that those who have stronger resting alpha activity, are less motivated by following one's appetitive goals (which is the definition of BAS drive). One explanation may be the positive relation of greater anterior cortical activity and BAS suggested by Hewig et al. (2006). That is, the stronger the frontal cortical activity, the more general aspects of behavioral activation such as BAS strength and approach tendencies (Hewig et al., 2006). As the regional alpha power fluctuations correspond to neuronal activities in an inverse fashion (Hwang et al., 2008), this may mean, that those whose neuronal activity is weaker, have increased resting alpha activity and are less activated behaviorally, which is line with the present findings. Increased alpha activity helps people to relax and gives the brain a chance to rest. Resting alpha may increase awareness and help to focus but it doesn't drive people to hardly work on their tasks. This makes the possible explanation of this particular finding reasonable.

Yet, it is important to note that this finding concerns only the relation between resting alpha and the BAS drive. It would be interesting to compare other specific facets of BAS (Fun seeking and reward responsiveness) with frontal alpha and see if they relate differently. Could it be, that there is something with the definition of BAS and its subdimensions that makes this result slightly different from past research (e.g. Pascalis et al., 2013)?

Previous studies, and the present one, have been providing rather weak support for the frontal asymmetry of the relation between BAS and resting alpha. It may be that behavioral activation and behavioral inhibition sensitivities differ from the approach/withdrawal responsiveness. However, greater left frontal cortical activity has been found to be associated with approach and greater right frontal cortical activity with active avoidance ie. withdrawal behaviour (Hewig et al., 2006). Furthermore, a conceptual similarity between the BAS encompassing approach and withdrawal tendencies has had plenty of support (e.g Wacker et al., 2008, Hewig et al., 2006, Sutton and Davidson, 1997). The withdrawal system and the BAS seem to share important structures in neuroanatomical basis such as the prefrontal cortex (Hewig et al., 2006). In addition, Hwang et al. (2008) reported of positive correlation between BAS and inversed left frontal activity. As the function of prefrontal cortex is in emotion regulation facilitating positive and inhibiting negative reactivity, the left frontal activity affects the inhibition to the amygdala in an inverse fashion, which in turn makes the function of the amygdala responsive to negative stimulus. Thus, together with these arguments we may see the above findings as support for the theoretical view outlined earlier by Wacker et al. (2008) to compound approach and withdrawal as common BAS. In addition, Hewig et al., (2006) presented, that the bilateral BAS model had more support from their study than the BIS/BAS model.

Although recent studies do not coherently yield the relation between the lateralized frontal cortical activity and BAS sensitivity, the relation between BAS and frontal activity in general has had plenty of support. Further MEG studies are needed, mainly focusing on comparing frontal vs. posterior resting alpha activity and its robustness as predictor of behavioral activation tendencies but also on comparing specific facets of BAS. Taken together, present study supports past research suggesting, that frontal alpha is related especially to the behavioral activation system (Hewig et al., 2006, Harmon-Jones & Allen, 1997, Pascalis et al., 2005).

There are few limitations concerning the past research to take notice. Past research has systematically used the EEG (electroencephalographic) to measure the resting alpha activity but in the last years the method has been intensively discussed mainly because of its lack of convergent validity of anterior asymmetry measures for different reference montages (Pascalis et al., 2013). The main advantages of MEG are the accurate submillisecond temporal resolution, the sensitivity to localized activation and advantages over EEG (Gharib et al. 1995). MEG provides, reportedly, accuracy in localizing current sources in a saline-filled sphere, at depths ranging from 1 to 6 cm, to within a couple of millimeters, while EEG estimates of the dipole are highly influenced by model parameters such as sphere radii and conductivity (Ciulla et al. 1999). As abundant sources of alpha rhythm have been localized predominantly near the longitudinal fissure to a depth of several centimeters beneath the scalp (Ciulla et al. 1999), we think it makes the use of MEG feasible. Despite all the named benefits of using MEG, alpha has been studied very little, if at all, with MEG, which may be explained by its expensiveness compared to EEG. MEG requires not only specialized equipment but also shielded areas for its sensitivity to ambient signals in the environment (Gregory et al., 2015). The present study was carried out in a magnetically shielded room at Jyväskylä Centre for Interdisciplinary Brain Research.

Limitations of this study concern firstly the measurement of BAS. The scale of Carver and White (1994) does not include both approach and active avoidance systems. In Gray's theory it has been noted that motivated goal-directed action could be moving towards something desired as well as actively moving away from something. The other limitation is, that neither Carver and White's scale nor our study regards the third dimension of behavioural action tendency FFFS, that Gray added later to his theory. Wacker et al. (2003) presents that the BAS mediates approach behavior and operates by stimuli of safety or reward and the FFFS conveys avoidance behaviour activated by punishment or nonreward. In the original theory, the BIS dealt with responses to aversive stimuli, but in the new model the FFFS was responsible for this role and BIS engages only when there seems to be a goal-conflict (Neal & Gable, 2017). However, it has also been proposed that BIS and BAS interact when facing a goal-conflict as the BIS operates by activating the BAS to approach the conflict. This makes division of roles between BIS and BAS slightly unclear and challenges the measurement of BAS's relation with distinct regions of the brain.

Considering, that the central nervous system responds to all sorts of situational challenges, the claim of a situationally stable trait seems generally rather strong. However, there might have been some moderating effects of situational context between alpha asymmetry and behavioral tendencies. For example, Pascalis et al. (2013) has reported findings that support a moderating effect of experimenters' gender on the associations between resting frontal alpha asymmetry and sensitivity to behavioural activation or inhibition. In addition, it has been noted (Crost et al., 2008) that variations in situational features of the recording, whether designed or not designed, may explain changes in relations between personality and resting alpha activity. For example, personality of the experimenter and a psychological atmosphere might be responsible for the variability. For this reason, Wacker et al. (2010) suggests that personistic model should not be adopted before situational invariance of the correlation has been demonstrated across various studies and across various situational contexts.

## Conclusion

The study showed, that there seems to be a relation between frontal alpha activation and behavioral drive activation system. It seems that frontal alpha activation increases when the score of behavioral activation decreases. The present study failed to find any significant relation between alpha power and the two hemispheres. Instead, alpha power seemed stronger in left hemisphere in frontal lobe when eyes were open and stronger in right hemisphere in temporal lobe when eyes were closed. Future research should focus on using MEG-measurement to give more accurate data of locations. More work will be necessary to clarify the role of BAS, its subdimensions and the relation with alpha power in different parts of the brain. In addition, future studies will be needed to evaluate the signification of relation between the alpha power and different action tendencies, e.g. in terms of affective disorders, clinical diseases, temperament and motivation.

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