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INTENSITY OF THE STIMULUS RATHER THAN ITS AFFECTIVE MEANING ELICITS CHANGES IN EEG RECORDED FRONTAL ALPHA ASYMMETRY

Master's thesis

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Running head: Stimulus affective meaning and frontal alpha asymmetry

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Abstract

A constantly growing body of literature has so far not reached a common understanding of which aspects of the affective state modulate frontal EEG alpha asymmetry. To explore these effects the monetary incentives delay paradigm was modified to enable direct comparison between the most prominent dimensions of emotion (valence, approach-avoidance, motivational intensity). The intensity of the stimulus was varied through a separate independent variable indicating the stakes (high/low) participants were playing for. The results showed no emotion dimension having a significant effect on the changes in the EEG recorded frontal alpha asymmetry scores during stimulus presentation. Analysis did however reveal the stimulus intensity having a significant effect on the change in asymmetry scores remaining even after accounting for stable and situational individual differences. These results lead to the conclusion that emotional stimulus intensity rather than their affective meaning can affect the changes in frontal alpha asymmetry scores elicited by an emotional stimulus.

Keywords: Frontal alpha asymmetry, emotion construct, affective state, stimulus intensity

Kokkuvõte

Töö pealkiri: *Stiimuli intensiivsus, mitte tema afektiivne tähendus, kutsub esile muutusi EEG-ga salvestatud frontaalses alpha asümmeetrias*

Senises teaduskirjanduses pole tänaseni jõutud üksmeelele küsimuses, millised afektiivse seisundi elemendid mõjutavad frontaalse EEG alfa asümmeetriat. Selle uurimiseks loodi rahalise tasu edasilükkamise paradigma eeskujul hasartmängu simuleeriv katsedisain, mis võimaldas võrrelda kõige tuntumaid emotsiooni dimensioone (valentsus, motivatsiooniline suund, motivatsiooniline intensiivsus). Katses manipuleeriti eraldiseisvalt ka stiimuli esitamise intensiivsust läbi erinevatele panustele (kõrged/madalad) mängimise. Tulemused ei näidanud ühegi emotsiooni dimensiooni mõju olulisust frontaalse alfa asümmeetria skooride muutusele afektiivsete stiimulite esitamise ajal. Analüüsid näitasid aga stiimuli esitamise intensiivsuse olulist mõju frontaalse alfa skooridele, mis säilis ka pärast tulemuste individuaalsete ja situatsiooniliste erinevuste kontrollimist. Nendest tulemustest lähtuvalt võib väita, et emotsionaalse stiimuli intensiivsus, mitte tema afektiivne tähendus, kutsub esile frontaalse alfa asümmeetria muutu.

Introduction

It has been well established that the frontal cortex plays a significant role in emotion modulation (Bechara, H. Damasio & A. Damasio, 2000; Beer, Knight & D'Esposito, 2006; Rolls, 1995; Morgan, Schulkin & LeDoux, 2003). An important area of research has therefore focused on the effects that emotional stimuli have on frontal alpha asymmetry.

Frontal alpha power (usually measured at 8-13 Hz) is associated with inactivity or in more recent theories inhibition (See more Uusberg, Uibo, Kreegipuu & Allik, 2013), with higher alpha power scores indicating less frontal cortical activity (Coan & Allen, 2004). Frontal alpha asymmetry scores provide a simple one-dimensional scale representing the relative activity of the right and left hemispheres. Higher asymmetry scores usually indicate more power on the right hemisphere (calculated: ln[Right] – ln[Left]). Since alpha power is inversely related to activity higher scores are putatively indicative of relatively greater left frontal activity (Allen, Coan & Nazarian, 2004).

For several decades now, researchers have reported systematic relationships between emotional states and alpha asymmetry. For example Wheeler, Davidson and Tomarken (1993) discovered that the F4-F3 alpha asymmetry scores had a significant positive correlation with self-reported positive affect intensity, with also the independent F4 score having a positive and the F3 score having a negative correlation with the affect intensity. Similarly, Harmon-Jones and Allen (1998) found that the F4-F3 asymmetry scores positively correlated with the trait anger and the residualised F4 and F3 scores had a positive and a negative correlation to the trait respectively.

Note however that these findings already contain controversy. While Wheeler et al. (1993) reported that positive emotions elicit greater left frontal activation, Harmon-Jones and Allen (1998) observed the same effect created by anger which is classically categorized as a negative emotion. To account for this and other discrepancies, several hypothesis have been put forward linking asymmetry to different emotion dimensions. However, up to this day there is no consensus in the question which affective components contribute to these effects (Allen et al., 2004; Miller, Crocker, Spielberg, Infantolino & Heller, 2013).

Paradigms and problems

It has been suggested that frontal alpha asymmetry is influenced by the valence of an emotional stimulus, with left frontal activation associated with positive and right frontal activation associated with negative stimuli (Tucker, 1981; Heller, 1990; Heller, Nitschke & Miller, 1998; Wheeler et al., 1993). This proposal relates asymmetry to the valence dimension postulated in the circumplex theory of affect based on the robust finding that people's subjective descriptions of emotional states follow the positive-negative divide (Russell, 1980, 2003).

Others have argued that frontal asymmetry is not fundamentally related to the valence of an emotional stimulus but to the motivational system that is engaged by that stimulus. Under this theory the frontal asymmetry is created by the motivational approach-avoidance component underlying emotional stimuli, where the left frontal activation is associated with the propensity to approach a stimuli and right frontal activation to avoid it (Coan & Allen, 2004; Davidson, 1993, 2004; Gray, 1994; Harmon-Jones & Allen, 1998).

A third approach claims that the temporal meaning of the emotional stimulus (pre- versus post-goal) is the main determinant of its effect on frontal asymmetry. This is strongly associated with the motivational intensity and anticipatory models of affect categorisation according to which more left frontal activity is observed in affective states which precede or are targeted at an upcoming event or action (Gable & Harmon-Jones, 2010; Harmon-Jones, Price & Gable, 2012; E. Harmon-Jones, C. Harmon-Jones, Fearn, Sigelman & Johnson, 2008).

It is important to note that the aforementioned theories are not entirely mutually exclusive. There are many similar assumptions about specific emotions categorisation across the field. For example there is a rather large consensus that anxiety is a negative, avoidance oriented, high intensity affective state and pleasure is reversely a positive, approach oriented, low intensity affective state.

There are, however, two major issues that have hindered the rise of a common understanding of which emotion components contribute the frontal alpha asymmetry. Firstly, each school of thought emphasises the emotion component it is built around as the main contributor to frontal asymmetry. Secondly, and more importantly, regardless of recognising the existence of other dimensions very few studies so far have used experimental designs which include components of competing paradigms.

In other words the empirical research has so far mainly been focused on the effects specific affective components have on frontal asymmetry but have not tested controlled models that include the all the dimensions of competing paradigms which could potentially be the source of the observed effects that are simply moderated by the component being tested.

Aim of the study and hypothesis

In order to determine which emotion components elicit frontal alpha asymmetry a controlled monetary incentive delay (MID) experiment design was created (Knutson & Greer, 2008), which included all the emotion dimensions that have been discussed in prior literature as well as the affective stimulus intensity as a separate independent variable. In the experiment participants were presented with an affective messages before and after a gambling task (serving as the target for the stimuli) during which their frontal alpha EEG was recorded.

The design included 12 different affective stimuli. The messages before the gambling task indicated whether the participant will be playing to win (positive, approach, pre-goal) or to avoid loss (negative, avoidance, pre-goal) and the messages after the gambling task revealed whether the participant had won (positive, approach, post-goal), failed to win (negative, approach, post-goal), avoided a loss (positive, avoidance, post-goal) or failed to avoid the loss (negative, avoidance, post-goal) (Figure 1). All of the stimuli were varied in their intensity by being presented in both a high stakes and a low stakes condition which was varied by including an indication of the stakes in the affective messages (e.g. "*You can win A LOT!*").

	Pre-goal	**Post-goal**	
Approach	Possibility to win	Win confirmed	**Positive**
	-	Failed to win	**Negative**
Avoidance	-	Loss avoided	**Positive**
	Possibility to lose	Loss confirmed	**Negative**

Figure 1. Matrix showing used stimuli placement according to emotion dimensions.

The null-hypothesis in this study was that none of the previously discussed emotion components have a significant effect on frontal alpha asymmetry modulation. Assuming that the different affective states do elicit significant change in the frontal alpha asymmetry scores we can deduce one of the following depending on the pattern:

1) If asymmetry scores during messages indicating a possibility to win, confirming a win and revealing an avoided loss are positively correlated with one-another and negatively correlated with asymmetry scores during messages indicating a possibility to lose, confirming a loss or revealing a failure to win which, are positively correlate to each other, then the valence component is the main facilitator of frontal alpha asymmetry.
2) If asymmetry scores during messages indicating a possibility to lose, confirming a loss and revealing an avoided loss are positively correlated with one-another and negatively correlated with asymmetry scores during messages indicating a possibility to win, confirming a win or revealing a failure to win, which are positively correlate to each other, then the approach-avoidance component is the main facilitator of frontal alpha asymmetry.
3) If asymmetry scores during messages indicating a possibility to win and a possibility to lose are positively correlated with one-another and negatively correlated with asymmetry scores during messages confirming a loss or a win and messages revealing a failure to win or an avoided loss, which are positively correlate to each other, then the temporal meaning dimension is the main facilitator of frontal alpha asymmetry.

If any of these patterns emerge it will also to be possible to assess the effect that the specific emotion component has on frontal asymmetry and by extension on the frontal lateral activation. If an affective component is shown to elicit higher alpha asymmetry scores relative to others, it means that the stimulus creates higher left frontal cortical activity; if it is shown to have relatively lower asymmetry scores it is indicative of higher right frontal activity.

Method

Participants and procedure

The sample consisted of 28 students (10 men; mean age 21.38; SD= 1.92) from the University of Tartu. All participants signed written informed consent forms prior to the experiment which was accompanied by a verbal explanation of the procedure and all their rights. After the experiment participants filled out a post-experimental survey. The experiment and all of the related activities were conducted in Estonian and all participant spoke the language fluently. Participants were invited to the experiment through the social media and the university's mailing lists and were promised a gift certificate for the highest score in the experiment. Before the experiment participants were asked to fill out a personality test and a questionnaire about their gambling experience via the internet.

The experiment was conducted in the university's Laboratory of Experimental Psychology. The duration of one experimental session was approximately 2 hours and all the sessions took place between 10 am and 8 pm. The sessions were conducted in a dimly lit, soundproof room. The participants were seated in front of a screen (19'' inch CRT), the chair distance was fixed at approximately 1.15 meters from the screen. The participant was asked to adjust the chair height so that the centre of the screen would be at their eyelevel.

EEG recording equipment was attached to the participant during which the experimenter gave explanations about the EEG measuring procedure and instructions for the participant (to avoid unnecessary blinking and vertical eye movements, not to move during the measuring procedure and to relax between task to avoid tension in the neck and shoulders). The participant was alone in the room during all the trials (excluding practice-trials during which the experimenter was present and answered clarifying questions). The experimenter only entered the room at the beginning of a new blocks (see below) to give detailed instructions and check the equipment.

Design and stimuli

Experimental design

The experiment consisted of pre- and post-session resting state EEG recording and the main experiment. The latter was comprised of four, approximately 10 minute long blocks during each of which the participant was presented with 256 trials. All the trials were structured as following: an affective message indicating a possibility to win or lose (1.75 seconds) – cognitive task measuring attentional scope (duration was dependant on subjects response time) – delay (black screen; 1.5 seconds) – a gambling task (duration was dependant on subjects response time) – a second affective message stating the outcome of the gambling task (1.75 seconds) – repeat of the cognitive task – black screen signalling the start of the next sequence (1.5 seconds) (Figure 2).

After each of the four blocks the participants were asked to fill out a mood and fatigue self-report which appeared on the screen in the form of an interactive scale. The scale was introduced and explained beforehand and the participant was instructed to use the mouse-pad to place the dot on the screen into the position which best represented their current state. The mood report consisted of two dimensions (valence on x-axis; arousal on y-axis) with valence ranging from "very negative" to "very positive" and arousal from "very excited" to "not excited at all". The fatigue self-report was presented immediately afterwards in a one dimensional form with the participant having to indicate their current state ranging from "very tired" to "not tired at all". All of the dimensions were numerically recorded on a 1 – 100 unit scale with higher scores indicating more valence, arousal and fatigue.

Gambling task

The gambling task which was the target of the affective stimuli was designed as slot-machine simulator. The outcomes of the gambling task were predetermined (unknown to the participants). A list of possible outcome values ranging 20% around the final value started appearing on the screen in random order with the number on the screen changing every 1 seconds. The participant was instructed to press the middle mouse-button to stop the sequence while aiming towards as high of an outcome as possible. The numbers were presented in colour with positive values being green and zero being red during the trials when the participant anticipated to win and vice-versa (negative values red, zero green) on the trials where the participant was trying to avoid a loss. The participant was assured that they were in control of the result and the result of the gambling was added to their total score which appeared on the screen after every eight trial (e.g. *"You have won +77.3 € so far"*).

Emotional stimuli

The experimental design included 12 different types of emotional stimuli. The affective messages before the gambling task indicated whether the participant will be playing to win (*win?*) or to avoid a loss (*loss?*) and the stakes they are playing for (high/low). The latter dimension was designed as a differentiation between the intensity of the stimuli that was independent from the affective state itself.

The massages after the gambling task revealed whether the participant had won (*win+*), failed to win (*win-*), avoided a loss (*loss+*) or failed to avoid a loss (*loss-*). These messages were presented correspondingly to the pre-gambling task condition with either of the former two appearing in trials the participant was anticipating to win. The outcomes of the gambling task were distributed equally with the results corresponding to the anticipated result during 50% of the trials.

The magnitude of the stakes in the two different conditions ranged around 20% of the established base value. In the high stakes condition the base value was 35.5 € and in the low stakes condition 7.5 €. The emotional stimuli conveying the affective states were presented verbally and in colour with (potentially) beneficial messages (e.g. *"You won +42.6 €"*) presented in green and (potentially) harmful messages (e.g. *"You can lose A LITTLE!"*) presented in red. The colours were added to further emphasise the valence of the affective message and to help the participant understand the message more easily. The colours used were balanced in brightness. For the same reasons the pre-gambling task stakes were presented in upper case characters and "+/-" signs were added to messages conveying the result of the gambling task (e.g. *"You lost -34.08 €"*).

Cognitive tasks

The cognitive task for the first two blocks was based on the Kimchi global-local paradigm (Kimchi & Palmer, 1982) (GBL) in which 3 objects appeared on the screen (one larger at the top and two smaller at the bottom). The participant was asked to indicate as quickly as possible which of the two smaller objects resembles the larger one more by pressing the corresponding mouse button (left/right) (See also Kolnes, 2014).

The task for the third and fourth blocks was self-designed attentional detachment test (DET). Firstly, a square appeared in the middle of the screen. After a 0.75+/0.25 second delay another square accompanied by a slightly crooked fixation cross appeared above and below the original square – the position differentiated through the trials with the fixation cross appearing at the top 50% of the times. The participant was instructed to indicate as quickly as possible whether the top vertical line of the fixation cross was left or right compared the bottom vertical line by pressing the corresponding mouse button (left/right). During half of the trials the original square disappeared from the middle of screen when the new square and fixation cross appeared while on the other half it remained visible. It was assumed that in the former condition the focus of attention could shift freely while in the latter it needed to be disengaged first.

The current study does not show data of the behavioural results of either of the cognitive tasks. The results of the first task can be found in the work of Kolnes (2014) and results of the second task revealed no emotional stimuli effects on the participant's reaction times (RT).

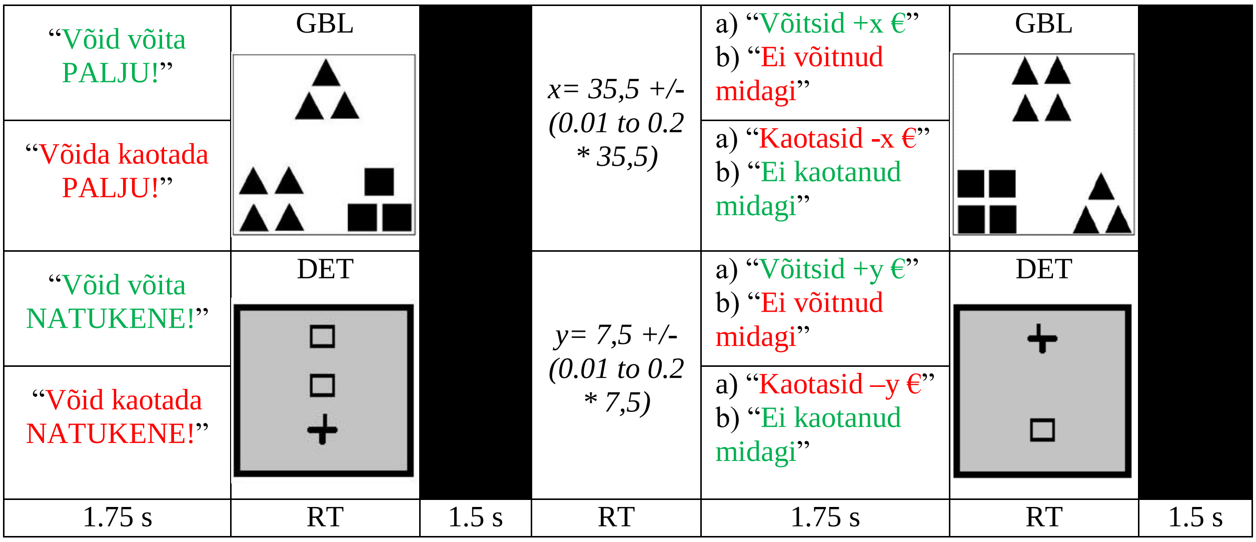

Figure 2. Structure of a single trial with all the stimuli variations.

EEG recording and processing

Continuous EEG was recorded from 32 scalp, 4 ocular and two earlobe reference electrodes at a 512 Hz frequency (with 0.16 – 100 Hz filters). Offline processing was implemented using EEGLAB software (Delorme & Makeig, 2004). After re-sampling to 256Hz faulty channels were removed automatically with the EEGLAB's *rejchan* algorithm and the data was high-pass filtered with 1 Hz cut-off.

Independent Component Analysis (ICA) was used to correct eye-movement artifacts. Components containing known features of eye- blinks as well as horizontal and vertical eye movements were rejected for each participant before reconstructing the continuous unfiltered data (Debener, Thorne, Schneider & Viola, 2010).

The ICA-pruned data for each experimental was cut into three segments. The first segment consisted of the signal measured during the 1.5 second delay between trials, the second segment covered the 1.75 second presentation of the first affective message and the third segment the second message. The first segment was used to compute the baseline alpha power that was later subtracted from both of the other segments. Any trial where any of the segments was deemed artifactual using the spectral criterion (15 – 30 Hz, -100 – 24 dB) was removed from further analysis. Overall 95.44% of the data was retained with the retention rate not being dependant on stimulus category.

The alpha power in the signal within each segment was estimated using the *Welch* algorithm, averaged between 8 and 13 Hz, and all the scores were natural logarithm transformed. Alpha asymmetry scores for all segments were calculated by subtracting the recorded alpha power from the electrodes on the left hemisphere (F3, F7) from the alpha power of the electrodes on the right hemisphere (F4, F8) correspondingly.

After that the baseline frontal alpha asymmetry scores were subtracted from the asymmetry scores recorded during the different emotional stimuli resulting in asymmetry scores that reflect the change in frontal alpha asymmetry elicited by the affective stimuli. Since the current study focused on frontal alpha asymmetry further analysis was conducted on asymmetry scores from F4-F3 and F8-F7 channels.

Statistical analysis

Statistical analysis on the collected data was performed using R© v3.1.2 (R Core Team, 2014).

To determine how different emotion components affect frontal alpha asymmetry a repeated measures ANOVA (*ezANOVA* command) was constructed using the dataset of the recorded frontal alpha asymmetry scores which reflected the change in frontal asymmetry during the presentation of emotional stimuli. The structure of the ANOVA consisted of 2 tasks (GBL, DET) x 6 affective states (win?; loss?: win+; win-; loss+; loss-) x 2 stakes (high/low) x 2 channels (F4-F3; F8-F7).

An identical repeated measures ANOVA was used on the dataset of recorded frontal alpha asymmetry scores during the presentation of emotional stimuli (baseline asymmetries not subtracted) to test whether the effects/interactions from the first ANOVA were caused by the stimuli or already present before their onset. The results of both repeated measures ANOVAs were checked with *Mauchly*'s test of sphericity and for the effect that failed this test, the *Greenhouse-Geisser* corrected p-values are reported. In cases where significant interaction emerged pairwise t-tests were conducted with the results corrected using the *Benjamini Hochberg* algorithm (BH) to account for multiple comparisons.

The data from the gambling experience questionnaire as well as the mood and fatigue self-reports was used to check the results for possible covariates. The gambling experience questionnaire contained question concerning the regularity of different gambling related activities the participant had engaged in the last year ranging from the lottery and bets to waging money in card-games, casinos and stock-markets (e.g. "*How often have you participated in lotteries and consumer games in the last year?"*).

Participant who indicated that they had either waged money in online gambling games (card games, casino games or skill-based games) or who had played in a casino, on a slot-machine or gambling tournament (usually with buy-ins) at least once in the last year were counted as having gambling experience while others were categorised as non-gamblers. The reasoning behind this sort of divide is two-fold. Firstly, these questions reflect a person's disposition to gamble better than questions concerning so-called every-day gambles which don't carry as high of a risk (e.g. buying a lottery ticket or making bet with a friend). Secondly, the listed situations are much more similar to the gambling simulation used in the experiment (compared to e.g. investing in the stock-market) which means familiarity with these sort of gambling-tasks might have a significant effect on the cortical activity under observation. Therefore, based on the aforementioned criteria, 9 participants were categorised as having gambling experience and 19 were categorised as not having significant gambling experience.

The valence, arousal and fatigue self-reported scores for each participant were averaged and controlled for normal distribution using the *Shapiro-Wilk* test. All of the four variables were checked for correlations using *Spearman*'s correlation. The result showed that valence, arousal and fatigue scores were all significantly correlated with valence and arousal having a positive correlation ($r = 0.61$, $p < 0.001$) and both having a negative correlation with fatigue ($r = -0.49$, $p < 0.01$; $r = -0.55$, $p < 0.01$ respectively). The gambling experience categorical variable had no significant correlation with any of the other variables (Table 1). Since the variables reflecting valence and arousal scores confounded with the variable reflecting fatigue the former two were excluded from further analysis. The reasoning behind the decision was based on the fact that valence and arousal scores were more likely to have been influenced by the outcome of the last trial preceding the mood and fatigue self-reports – the participant could have been more excited or more pessimistic depending on whether they had just won or lost, but fatigue as a constantly cumulating subjective sensation is less susceptible to permutations.

Table 1: *Correlations between measured individual difference scores*

Variable	Gambler	Fatigue	Valence	Arousal
	Spearman's rho (p)			
Gambler	-	-	-	-
Fatigue	0.24 (0.22)	-	-	-
Valence	-0.03 (0.87)	-0.49 (< 0.01)**	-	-
Arousal	-0.14 (0.49)	-0.55 (< 0.01)**	0.61 (< 0.001)***	-

Note. **, p< 0.01; ***, p< 0.001

Fatigue was transformed into a categorical variable with participants who's average fatigue score was below the overall mean fatigue score (M= 45.13, SD=15.35) were categorised as less tired than average (n=13) and those who's scores were above the overall mean were categorised as more tired than average (n=15). The two categorical variables (fatigue and gambling experience) were separately added to the original repeated measures ANOVA model as covariates.

Results

The repeated measures ANOVA conducted on the frontal alpha asymmetry scores reflecting the elicited asymmetry changes during emotional stimuli presentations revealed only the intensity factor (high/low stakes) main effect to be statistically significant ($F_{(1;27)} = 5.67$, p= 0.02 , η^2= 0.01) (Figure 3). The affective states main effect and all of its interactions were statistically insignificant ($F_{(1;\,135)} = 1.80$, p=0.14 , η^2= 0.01 to $F_{(5;\,135)}$= 2.67, p= 0.87 η^2= 0.001). No other statically significant effects or interactions also emerged.

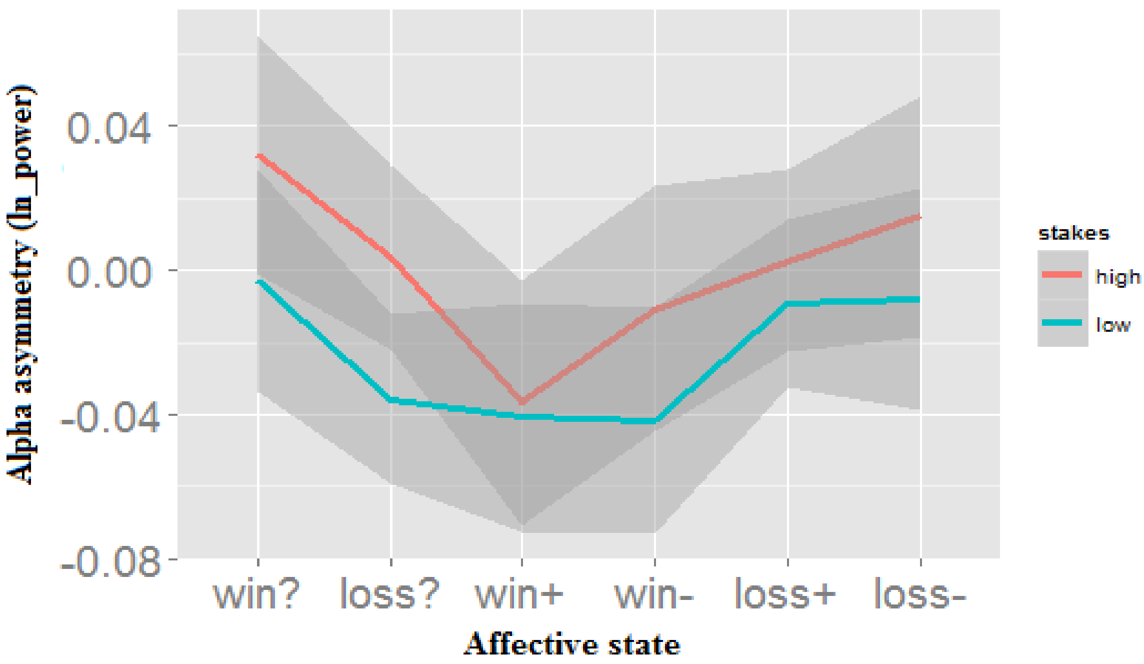

Figure 3. Emotional stimulus intensity main effect

The results of the control ANOVA conducted on the alpha asymmetry scores from which the baseline had not been subtracted revealed the affective state main effect of having no statistical significance ($F_{(1;27)} = 0.02$, p= 0.90, η^2= 0.66).

To test the results for stimulus based stable individual differences the categorical covariate reflecting the participants gambling experiences (gambler versus non-gambler) was added to the first ANOVA model. The results showed that the stakes main effect remained statistically significant ($F_{(1;26)}$ = 5.55 , p= 0.03, η^2= 0.01) with also the task, affective state and gambling experience interaction showing a statistical significance ($F_{(5;130)}$ = 2.55, p= 0.05 , η^2= 0.01). A post-hoc t-test was used to analyse the correlations of the affective states between the two tasks. The results showed that there were no statistically significant differences between any of the affective states under either condition.

To check the results for situational individual differences participants self-reported fatigue scores were added to the ANOVA model as a separate covariate. The results showed that the stakes main effect remained statistically significant ($F_{(1;26)}$ = 5.83 , p= 0.02 , η^2= 0.01) with also the task and fatigue interaction becoming statistically significant ($F_{(1;26)}$ = 7.65 , p= 0.01, η^2= 0.002) (Figure 4).

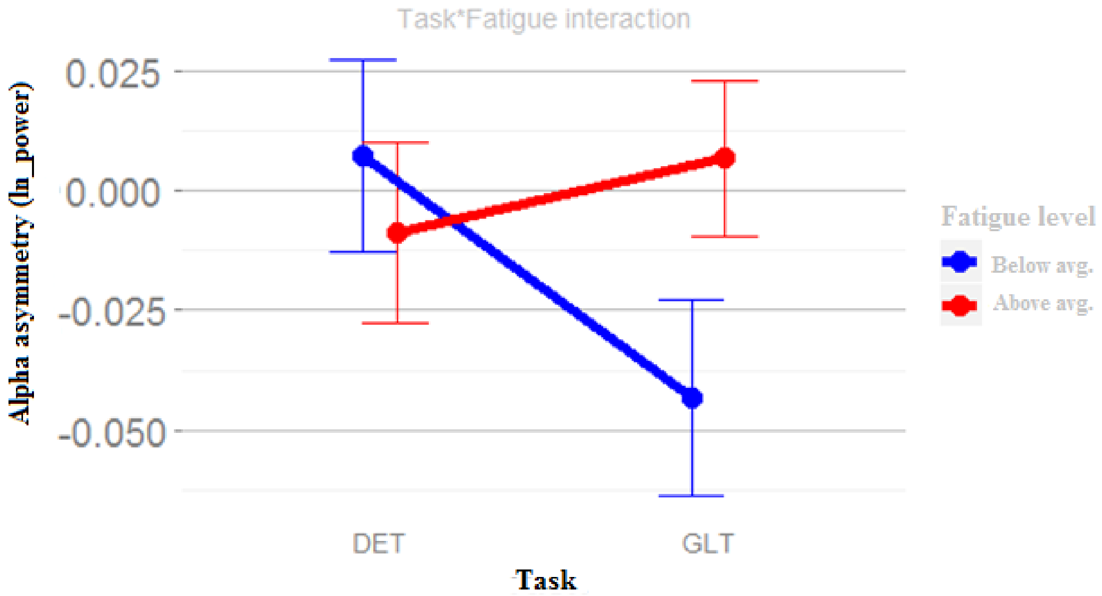

Figure 4. Fatigue covariate and task factor interaction

Discussion

The aim of the current study was to explore the effects that different emotion components have on frontal alpha asymmetry. Up to this day there are no conclusive evidence which affective components elicit the widely reported lateralisation in frontal activity during emotion processing. Several theories have emerged over the decades each claiming that either valence (Wheeler et al., 1993), motivational direction (Davidson, 2004) or the time placement and motivational intensity (Gable & Harmon-Jones, 2010) components are the main elicitors of observed frontal alpha asymmetry.

To test the hypothesis of the aforementioned theories, a MID-based gambling task was designed which included the main components of different asymmetry hypothesis. The emotional stimulus intensity was also varied through a high versus low stakes condition. Based on the recorded frontal EEG alpha asymmetry scores a 4-way (2 tasks x 6 affective states x 2 stimulus intensities x 2 pairs of EEG channels) repeated measures ANOVA was conducted. The results from the ANOVA revealed that none of the affective components had a statistically significant effect on the participant's frontal alpha asymmetry scores. However, the emotional stimulus intensity did have a statistically significant main effect on the asymmetry scores.

These results were elaborated by running an identical ANOVA on the asymmetry scores from which the baseline asymmetry scores had not been subtracted (reflective of the total frontal alpha asymmetry during the stimulus, not just the change induced by stimulus onset). The results corroborated the findings of the first analysis with the stimulus intensity main effect not being statistically significant. From this we can infer that the observed significant stimulus intensity main effect was the result of the change in frontal alpha asymmetry induced by the stimulus.

The primary results were also tested for probable covariates which might skew or confound the results. Firstly, a variable testing for stable individual differences - participant's self-reported gambling experience - was added into the original ANOVA. Secondly, another variable controlling for situational individual differences - participants average fatigue scores - was also introduced as a covariate. The results in both cases showed the stimuli intensity main effect remaining significant with the task x affective state x gambling experience and a task x fatigue also emerging respectively. These finding suggest that the confirmation of the null-hypothesis of this study which is that emotion components do not have an innate effect on frontal alpha asymmetry cannot be explained by strong individual differences hiding the expected main effects.

Affect and frontal asymmetry

The results suggest a few important things. Firstly, and most importantly, the intensity of the emotional stimuli appears to be a significant contributor to the frontal asymmetry while different emotion components bare no significant self-standing effects. In other words, although at a visual trend level, different emotion components do have varying effects on frontal asymmetry, none of them seem to account for the lateralised activation that occurs during their offset. This result is contradictory to the previous findings because the theories so far have postulated that traits innate to the emotion dimensions are the main modulators of frontal asymmetry.

Reports from fMRI studies can be used to shed light on why the affective states of expecting to lose, losing and failing to win did not show a uniform effect on the change in frontal alpha asymmetry scores significantly distinct from the positive affective conditions. For example Engels et al. (2007) showed that different distinct regions of left prefrontal cortex (PFC) are involved in processing positive emotional words and in modulating the effects of anxious apprehension (worry) on processing words related to negative emotions. These findings explain the apparent contradictions in the early EEG studies (Heller, Nitschke, Etienne & Miller, 1997; Nicshke, Heller, Palmieri & Miller, 1999) reporting emotional lateralisation based on the positive-negative valence dichotomy. Similarly, Spielberg et al. (2011) demonstrated a close left-hemisphere frontal region showing the predicted positive relationship with approach temperament and a left-hemisphere region showing a positive relationship with avoidance temperament which is contrary to the traditional prediction of the latter being lateralised on the right hemisphere. This can be used to explain why the affective states of expecting to win, winning and failing to win did not manage to elicit a significantly distinct effect on frontal alpha asymmetry scores compared to avoidance related affective states.

The results from the current study also support these findings. It is probable that one of the reasons why affective states did not elicit a uniform effect pattern on frontal asymmetry is related to the localised functional differences in the frontal cortex. For example the affective state of worrying about possibly losing which can be similar to nervous apprehension elicits cortical activation in different brain regions than anger over, for example, not winning.

Because of the different localisation there is no similarity between activation patterns of two emotions categorised as being negative. However, intensity of the stimulus presentation modulates both uniformly with higher intensities leading to higher alpha scores (greater alpha power on the right hemisphere) which indicate higher left frontal activity during both emotional stimuli in corresponding regions.

More interestingly, viewing the current results in the context of the motivational intensity theory that encapsulates the time placement and anticipatory models of emotion construct, we end up in a(n) theoretical/empirical debate on whether the innate motivational intensity of a stimulus can be separated from the intensity is it presented at (or the arousal it causes) and if so which one account for the observed effects on emotion processing.

Harmon-Jones et al. (2012) have made an argument that since the nature of the stimuli (e.g. humour is an arousing state low in approach motivational intensity) effects cognitive processing (e.g. humour compared to amusement causes attentional broadening) the innate motivational intensity of the stimuli is the main factor affecting emotion processing (see also Fredrickson & Branigan, 2005). The second piece of evidence they provide for their theory is that arousal states prompted by physical or chemical stimulation (exercise and caffeine) do not have effects on the participant's attentional scope (cognitive processing) but appetitive pictures (pre-goal, positive valence, high motivational intensity) do elicit greater late positive potential (LPP) amplitudes in the left hemisphere which is associated with attentional narrowing (Gable & Harmon-Jones, 2013).

Although the author agrees that physical arousal might not always cause cortical activation related to emotion processing and that the stimulus presentation intensity might only have a moderating effect on frontal asymmetry, the results of the current study still indicate that emotional stimulus intensity as a separate independent variable holds has a greater effect on frontal cortical asymmetry associated with lateralised activation. The arguments stemming from research on attentional scope broadening/narrowing are not necessarily persuasive since the alleged effects are premised on the neural underpinnings currently discussed. The results showing grater LPP power in the left hemisphere are not accompanied by the variation of the appetitive stimulus presentation intensity which means that it cannot be concluded that it's the innate motivational intensity of the affective state eliciting the observed changes in cortical asymmetry. In the original study (Fredrickson & Branigan, 2005) cited by Gable and Harmon-Jones (2012) the intensity of humour eliciting stimuli was however varied which means that future research into this empirical question is needed in order to identify the causes of the discrepancies between reported results of the cited experiment and the current study. One possible explanation could lie in the fact that film clips rather than affective messages with a goal-oriented meanings were used as emotional stimuli which could mean that the former failed to create meaningful distinction between the intensity levels of the stimuli.

Criticism and rebuttal

An argument can be made against this assessment by claiming against the presented conclusions that since the absolute values of the frontal asymmetry scores were rather small (including the effect sizes) the experimental conditions failed to successfully replicate meaningful affective states and therefore the stimuli did not elicit effects on emotion processing that would have otherwise been present.

The problem with this reasoning is two-fold. Firstly, that would assume that the stimuli failed to create varying levels of either positive or negative valence, motivation to engage or to avoid, or motivational intensity. That however should not be the case because the stimuli were able to elicit an intensity main effect. Since the stimulus intensity modulating effect on emotion processing can only emerge once the participant has engaged in affective processing means that it would not be able to facilitate frontal asymmetry changes independently.

Secondly, the behavioural data from the experiment (cognitive task reaction times) showed a pattern consistent with the motivational intensity theory where the stimuli high in motivational intensity narrowed the attentional scope of the participant compared to the low intensity stimuli (see Kolnes, 2014), which means that the stimuli were able to elicit their innate effects at least to a reasonable degree. Therefore if the motivational intensity component in the emotion construct is the main facilitator of effects the stimulus has on emotion processing a significant pattern would have had to emerge between expectation to win/lose affective states and the other states.

Individual differences

The results were also tested for stimulus based individual differences. Because of the experimental design participants previous gambling experience was assessed to be the most probable stable individual difference that might skew the results. The reasoning behind the assessment was based on findings that affective stimuli of more personal importance tend to have a stronger effect on emotion processing (E. Harmon-Jones, Lueck,, Meghan & C. Harmon-Jones, 2006). The results indicated that the participant's previous gambling experience had no effect on the previously discussed stimulus intensity main effect. However, a statistically significant interaction between the task, affective situation and the prior gambling experience arose, but a post-hoc pairwise t-test revealed no significant differences between different affective categories during different tasks.

The results of the first logistical regression model were also checked for situational individual covariates. Since the results of mood, valence and fatigue self-reported scores had a strong correlation only the latter was added to the ANOVA model (see Method). This did not diminish the stimulus intensity main effect but revealed and significant interaction between the task and fatigue scores. The interaction revealed that participants who were less tired than average had lower alpha asymmetry scores (less left frontal activity) during the first two experimental blocks compared to participant who were more tired than average. It is hard to draw conclusions from the existing data about the nature of this interaction but the most important insight it gives is that the difference in the participant's fatigue scores showed no interactions with the affective situation in the multiple regressions analysis. This means that the participant's fatigue did not inhibit possible the emotional stimulus effects on frontal alpha asymmetry which adds to the rebuttal to possible criticism above.

Although the covariates did reveal some interesting interactions that could possibly merit future research the main conclusions reached did not change.

Conclusion

The finding of the current study suggest that emotional stimulus intensity, rather than innate traits of specific emotion constructs, can affect the change in frontal alpha asymmetry during affective processing. These findings are, however, not conclusive as the study does suffer from a few shortcomings.

The sample was rather small and homogenous which might have resulted in some effects not emerging and results being skewed because of the lack of variety in individual differences. Also, the affective stimuli have not yet been validated which might contribute to the small asymmetry scores and the possibly the insignificance of the effects that the different affective states elicited.

Regardless of the aforementioned possible areas of improvement there are three important ideas stemming from the study that should be considered in future research. Firstly, combined with the results of previous findings, it does seem to be true that the different dichotomous emotion construct theories are no longer sufficient for explaining the effects that emotional stimulus have on emotion processing. Secondly, future research should make a greater effort by including constructs from competing paradigms in their experimental designs to test for possible moderating effects. And thirdly, it is important to distinguish innate traits of emotion constructs from traits influenced by their presentation.

Author’s contribution

As an addition to writing this thesis, the author participated in developing the theoretical framework and experimental design for the current study, conducted a third of the experimental sessions, analysed the collected data and drew the above conclusions.

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Lihtlitsents lõputöö reprodutseerimiseks ja lõputöö üldsusele kättesaadavaks tegemiseks

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1. annan Tartu Ülikoolile tasuta loa (lihtlitsentsi) enda loodud teose,

   INTENSITY OF THE STIMULUS RATHER THAN ITS AFFECTIVE MEANING ELICITS CHANGES IN EEG RECORDED FRONTAL ALPHA ASYMMETRY

mille juhendaja on Andero Uusberg,

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