

A psychophysiological study of approach and avoidance

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Abstract

Despite their importance, processes that govern affect and behavior are sensitive to disruption. This is evident at a clinical level where internalizing and externalizing psychopathologies show dysregulation in inhibition of anxious/depressive symptoms and impulsive-antagonistic behaviors, respectively (Liotti et al,2007; Moadab et al,2010). Healthy participants show similar dysregulation when highly arousing stimulus characteristics detrimentally impact performance in cognitively-demanding tasks (López-Martín, Carretié, 2010). This suggests that cognitive and affective networks draw on similar neural structures wherein more demands on one causes a change in the other (Pessoa, 2008; Vuilleumier, 2005; Ochsner & Gross, 2005). This dissertation framed the intricate and complex pattern of brain activity within the framework of a dual-layer self-regulation mechanism defined by action and affect. This model of self-regulation results in behavioral tendencies that are related either to approaching a desired outcome or avoiding an unpleasant event. An emotionally evocative task manipulation was designed to induce changes in endogenous affect and interfere with cognitive processes. An additional exogenous affect manipulation was embedding within this task through the use of salient facial expressions as stimuli. Due to the implicit aversiveness of this paradigm a separate task was used to create a scenario where participants are driven toward a desired goal. Electrophysiology methods were used to record brain activity which was analyzed using traditional ERP analysis, time-frequency decomposition, beamforming source estimation, power spectrum, and Partial-Least Squares analysis. Results implicate approach and avoidance tendencies to predict brain activity and be differentially related to delta, theta, and alpha oscillations. Theta processes related to the central executive network and map onto action, delta processes related to salience and affective networks and map onto affect, while alpha processes related to both saliency and executive control networks (i.e. the interaction between cognition and emotion) and map onto both action and affect loops. This body of work was able to address three main categories of research questions: 1) the effect of endogenous and exogenous emotion manipulations and their relationship with approach and avoidance; 2) the dynamics and impact of ongoing emotional experience; and 3) the 5-dimensional role of oscillatory changes in response to endogenous affective manipulation.

Keywords: emotion-evocation; beamforming; ERP; oscillations; approach; avoidance

Dedication

This dissertation is dedicated to my father for getting me started and my daughter for inspiring me to finish.

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1. General Introduction

1.1. Overview of Approach and Avoidance

This work defines self-regulation of behavior in terms of approach and avoidance during multiple goal pursuit (Carver & Scheier, 1998, 2013). Animals, human and non-human, have numerous goals that are simultaneously active, to different degrees; however, the goals themselves, whether short-term definitive actions or long-term abstractions, are not the ultimate focus of this framework. Here, the crucial aspect is not the goal itself but rather the dynamic approach and avoidance processes during ongoing goal pursuit.

Inherent to understanding approach and avoidance mechanisms are the principles of feedback control, namely feedback loops. Feedback loops compare the current state to a reference value; if a discrepancy between the two is detected then the feedback loop will produce a signal (output) signifying a change is needed to bring the current state in line with the reference value. Temperature homeostasis is a prototypic example of a brain-based feedback loop. The hypothalamus compares current body temperature to a reference value (~98°F). If the current body temperature does not match the reference value, then the hypothalamus sends signals to other areas (such as the sweat glands) in order to bring body temperature closer to the reference value. Such loops are of course cyclic and ongoing. The principle of feedback loops can be extended into the psychological domain. The reference value can be defined as a goal or desired state of being and the product of a discrepancy between current state and the pertinent goal would be behavioral change. Self-regulation and behavioral inhibition are suggested to be driven by two separate but interacting feedback loops: the action loop and the affect loop (Carver, 2006, 2008; Carver & Scheier, 1998, 2013).

The first mechanism, or layer, is the action loop. When a discrepancy, or distance, between the current-state and the reference value is detected and an action is taken to reduce the discrepancy, this is described as a negative feedback loop. Such negative feedback loops are related to approach behavior because the loop results in movement towards a reference. Alternatively, when a discrepancy, or distance, is detected by the system and an action is taken to increase the distance, this is described

as a positive feedback loop. Such positive feedback loops are related to avoidance behavior as the loops lead to movement away from a reference. A negative loop decreases distance (approach goal) whereas a positive loop increases distance (avoid goal) thus output of the action loop is considered to be the psychological equivalent to distance (increasing or decreasing) resulting in two behavior mechanisms: approach and avoidance.

The second layer, which operates in parallel to the first, is the affect loop. This layer uses the magnitude of the discrepancy between current state and goal state from the action loop to manifest a feeling. The feeling produced from the affect loop is then fed back into the action loop to manipulate the rate of change in distance (increasing or decreasing) in pursuing the goal. This output value, the feeling, is the psychological equivalent to velocity. Affects can change the speed of discrepancy reductions or enlargements regardless of the valence of the affect; a feeling of happiness or excitement may increase the rate of approaching a goal, but so might feelings of anger and frustration.

Appetitive motivational tendencies underlie the behavioral approach system. If goal-pursuit is going better than expected then positive affects arise, whereas if performance is below expectation then negative affects arise. Sadness and anger are two main negative approach affects, with differential velocities (Carver & Harmon-Jones, 2009). During a frustrative non-reward task in which participants were informed they may receive a greater reward than expected if they performed well, participants reported subjective frustration and anger when performing poorly but the goal was still within reach (greater reward could be earned); others reported feelings of sadness and despondency when goal attainment seemed futile and the potential reward was lost (Carver, 2004). The result of these diverse negative affects are varying shifts in action, with anger and frustration resulting in a surge of engagement and effort (distance reducing), while sadness and depression cause a withdrawal of effort and disengagement (discrepancy enlarging). Crucially, the action loop is adaptive to each context: if the goal is attainable then a signal to continue goal pursuit (communicated perhaps by anger) is appropriate, whereas if the goal is futile then the same signal would lead to a wasted effort. In this way, the impact of affect as velocity serves to put resources to good use, either remaining on the current action set to complete a goal or disengaging from the current goal and reallocating resources elsewhere. Against

intuitions, while some positive affects, like eagerness, result in a behavioral boost (distance reduction), stronger positive affects like joy can result in withdraw of effort towards goal pursuit, or coasting (Carver, 2003; Fulford, Johnson, Llabre, & Carver, 2010). Positive-affect induced coasting can be interpreted as satisfying the sense of having done well enough (Gigerenzer, Czerlinski, & Martignon, 1999), or to attention broadening – a redistribution of resources to other more pressing goals (Derryberry & Tucker, 1994; Wadlinger & Isaacowitz, 2006).

Aversive motivational tendencies underlie the behavioral avoidance system. This system is particularly interested in the constant detection and avoidance of potential danger, threats, and unpleasant experiences from the environment, ranging from social criticism to avoiding physical harm. When avoiding a goal is going poorly, negative affects like guilt, fear and anxiety arise (Carver & Scheier, 2013). Behavioral inhibition, or avoidance tendencies, strongly predict the amount of self-reported nervousness caused by anticipation of hand submersion in a cold pressor, a physically unpleasant punishment (Carver & White, 1994). Unlike the negative affects related to avoidance tendencies, the positive affects are more complex to interpret. This is because active, or successful, avoidance most often occurs through shifting actions to approach a more desirable goal (Carver & Scheier, 1998). Active avoidance is very effective at creating distance from an undesirable goal and results in strong positive feelings of relief and contentment (Carver & Scheier, 2013).

The neurobiology of the approach and avoidance systems dates back to Grey's model of personality (Gray, 1972) with an later update to the model (Gray & McNaughton, 2003). From early conception, aversive motivations were linked to the septo-hippocampal system, particularly as evidenced from anxiety research. The septo-hippocampal system is comprised of structures which receive direct inhibitory, theta-frequency controlling, GABAergic inputs from the septal area (Gray & McNaughton, 2003). The septo-hippocampal network receives direct monoaminergic afferents from the brainstem and extends to anterior neocortex, implicating these connections as a preferential threat alerting mechanism (Gray, 1972). Neuroimaging studies of avoidance behavior consistently find increased activity of the right prefrontal cortex and amygdala to threatening stimuli (Davidson, 1992; Nitschke & Heller, 2002). In contrast, catecholaminergic pathways, especially those with dopamine, are implicated for appetitive motivations, or behavioral approach (Stellar, 2012; Wise & Rompre, 1989).

Approach behavior is associated with increased activations in left prefrontal cortex, particularly in the alpha range over left frontal areas (Coan & Allen, 2003; Davidson, 1992; Davidson, Jackson, & Kalin, 2000; Harmon-Jones & Allen, 1997). Thus we have a psychological model of action and affect feedback loops which is compatible with known neural mechanism through differentiation between brain regions, neurotransmitters, and structural connections.

The theoretical work done by Charles Carver and Michael Scheier in combination with the strong evidence for independent cortical processes for approach and avoidance behaviors led to the construction of a self-report questionnaire, the Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) Scale (Carver & White, 1994). The BIS/BAS assesses an individual's approach and avoidance sensitivities. Since action and affect together are crucial to accurately measure these sensitivities, the items on the BIS/BAS scale were constructed by coupling behavioral scenarios with emotional reactions predicted by approach or avoidance. Items for the BIS scale reflect level of concern over an unpleasant event that has not yet happened or magnitude of negative emotional reactivity to unpleasant events that have occurred. The items on the BAS scale reflect emotional reactivity to potentially rewarding events. The rewarding events are broken into three somewhat independent subscales: Reward Responsiveness, Drive, and Fun Seeking. Internal consistencies of the BIS Scale and the BAS subscales are at acceptable levels, with initial tau-equivalent reliabilities ranging from .66 to .76 (Carver & White, 1994) and reliabilities from a later independent source ranging from .68 to .83 (Heubeck, Wilkinson, & Cologon, 1998). The BIS scale is better at predicting nervousness in response to punishment than self-report anxiety scales (Carver & White, 1994). Scores on the BIS are harmonious with other prevalent self-report measures. Consistent with Eysenck's personality measure, BIS scores predict Neuroticism while Drive and Fun Seeking predict Extraversion (Heubeck et al., 1998). In addition, BIS scores correlate strongly (.52) to scores on the State-Trait Anxiety Index and as well as scores on Neuroticism from the Five Factor Model (Segarra, Poy, López, & Moltó, 2014). There is also accordance between the Five Factor model and scores on approach. Reward Responsiveness relates to Openness, Conscientiousness, Extraversion and Neuroticism; Fun Seeking relates positively to Extraversion and Openness but negatively to Agreeableness and Conscientiousness; Drive relates positively to Extraversion and negatively to Agreeableness (Segarra et al., 2014). Just as scores on

the BIS have been better at predicting nervousness than competing scales, scores on BAS have been better predictors of positive feelings than Extraversion scores from competing scales (Carver & White, 1994). Recent studies have suggested a revision to the BIS/BAS scale to better measure approach and avoidance in diverse populations, but no formal revision has been published or adopted (Demianczyk, Jenkins, Henson, & Conner, 2014).

1.2. Overview of Affect

The rich field of affective science has studied the effects of exogenous (visual presentation) as well as endogenous (subjectively experienced) emotions on behavior, electrophysiology, and cerebral blood flow. The visual system is naturally drawn to affectively arousing stimuli to assess potential threats or a need for goal reprioritization (Schupp, Flaisch, Stockburger, & Junghöfer, 2006; Schupp, Junghöfer, Weike, & Hamm, 2003; Vuilleumier, 2005). The influence of emotive stimuli on perception occurs at both subliminal and conscious stages (Schimmack & Derryberry, 2005; Zadra & Clore, 2011) whether the stimuli are symbolic or non-symbolic (Carretié, 2014).

Studies on the neurodynamics of affective processing began subcortically and have since moved dorsally over time. The hypothalamus, ventral striatum, and especially the amygdala were the first structures to be identified in emotional processing and are thought to be automatically active, meaning the organisms may be unaware of affective processing at this stage (LeDoux, 2000; MacLean, 1949; Papez, 1937). Advanced neuroimaging technologies permitted the study of affective networks in superior brain regions such as the medial prefrontal cortex, cingulate and orbitofrontal cortex, with some valence specific activation: amygdala for fear and the subcallosal cingulate for sadness (for review, Phan, Wager, Taylor, & Liberzon, 2002). Emotional provocation of sadness results in increased activation in the subgenual cingulate and dorsal insula along with decreased activity in the right prefrontal cortex. Provocation of anxiety increases activity in ventral insula, orbitofrontal and anterior temporal cortices along with decreased parahippocampal gyri and inferior temporal cortex activity (Liotti et al., 2000). The functional significance of these cortico-limbic networks has improved due to research with mood dysregulated patients; for example, negative mood states in depression are caused by dysregulation in the right dorso-lateral prefrontal cortex indicating that that region is key for controlling the dynamics between affect and

cognition (Liotti et al., 2000; Liotti, Mayberg, McGinnis, Brannan, & Jerabek, 2002; Mayberg et al., 1999).

Images which impart emotive information influence successful response inhibition, even when such information is irrelevant to the task; in turn, successful inhibition attenuates emotional effects on reaction time (Anderson, Siegel, White, & Barrett, 2012; Kalanthroff, Cohen, & Henik, 2013; Verbruggen & De Houwer, 2007). Amygdalar activity, which has largely been associated with automatic processing of negative information, has been shown to be sensitive to goal-dependent affective congruency. Evaluation of characteristics of famous people resulted in increased amygdala activation in response to favored and unfavored individuals as long as the characteristics were congruent. However if incongruent characteristics were presented (e.g. disliked person and positive aspects) amygdala activity did not increase (Cunningham, Van Bavel, & Johnsen, 2008). The impact of emotional stimuli can also be attenuated overtly via controlled attention (e.g. a distracting secondary task) or changes in the cognitive representation (e.g. reappraisal) of emotional stimuli (Goldin, McRae, Ramel, & Gross, 2008; Ochsner & Gross, 2005). This growing pattern of results has demanded a shift in the field of affective neuroscience towards identifying how functional cognitive-affective networks interact and perform in concert with each other (Pessoa, 2008).

Functional magnetic resonance imaging (fMRI) studies have placed limbic-cortical areas within interconnected functional network configurations. While this is particularly evident at a clinical level, this 'cross-talk' is present also in healthy participants, such as when highly arousing stimuli detrimentally impact performance in cognitively-demanding tasks (Albert, López-Martín, & Carretié, 2010). This suggests that cognitive and affective networks draw, at least in part, on similar neural structures wherein more demands on one causes a change in the other (Ochsner & Gross, 2005; Pessoa, 2008; Vuilleumier, 2005). Functional magnetic resonance imaging (rs-fMRI) studies have outlined three main large scale functional networks: the "off-task" default mode network, or DMN (Fransson, 2005); the central executive (CEN) or "on task" network (Fox, Corbetta, Snyder, Vincent, & Raichle, 2006), and the saliency network (Seeley et al., 2007), to which was later added the affective network, or AN (Ochsner & Gross, 2005). These large scale networks are strongly interconnected structurally (Bressler & Menon, 2010) and functionally (Menon, 2011) allowing one network to

facilitate or suppress activity in another. For example, activity in the CEN is accompanied by anti-correlated suppression of the DMN and AN (Rayner, Jackson, & Wilson, 2016). This understanding of functional networks, and particularly interactions between networks, has moved the theoretical framework away from interpreting behavior in terms of isolated brain regions into a rich connectionist framework where function and dysfunction can be explained in terms of damage within the network communication systems (A. C. Chen et al., 2013). For example, deficits in response inhibition caused by traumatic brain injury can be explained by damaged tracts between a hub in the saliency network (right anterior insula) and the default mode network (Jilka et al., 2014).

Evidence to date suggests that the saliency network provides the neuro-architecture necessary to act as a gain control mechanism where the competitive strength of affective signals are amplified to redirect resources towards new but pressing events or otherwise modulate perceptual, motor, or memory processes (Pourtois, Schettino, & Vuilleumier, 2013). Changes in cerebral blood flow in response to emotional information manifests through key regions of the saliency network (Barrett & Satpute, 2013; Goulden et al., 2014). Orbitofrontal activity occurs with endogenous affect state or the feeling of pleasure and disgust while potentially threatening, harmful or arousing stimuli preferentially activate the amygdala (Barrett & Satpute, 2013). This pattern of brain activity and the imperative to attend to, process, and integrate emotional information serves the exact function suggested by the theoretical action/affect feedback loops. Indeed, the dynamics between the central executive, default mode, and saliency network mirror the proposed relationship between action and affect (Carver & Scheier, 1998).

1.3. Review of Electrophysiological Effects

For temporal characterizations of brain activity electroencephalographic methodologies produce recordings with millisecond precision (Picton, Lins, & Scherg, 1995). Dense electrode arrangements and advances in source localisation techniques allow reliable estimates of the brain areas generating the recorded scalp activity (Green & McDonald, 2009; Gross et al., 2001; Scherg, Vajsar, & Picton, 1989).

This section will first describe the research on event-related potential (ERP) evidence of cognitive and affective modulations of scalp activity as well as affective-cognitive interactions. Specifically, this section will focus on the ERP components associated with perception (N170), cognition (MFN and P3) and affect (VPP, EAP/EPN and LPP). Next, the discussion will move to the recent shift in physiological research from ERP to time-frequency decompositions (TFs).

1.3.1. Perceptual and Cognitive ERP components

N170. Approximately 170 ms after the onset of an overlearned stimulus there is a pronounced negative peak over occipital scalp sites, which has been termed the N170. Decades of research has suggested that the N170 is sensitive to the presentation of faces (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bötzel, Schulze, & Stodieck, 1995; Eimer, 2000), though research has also demonstrated an N170 for words, with word lateralizing to the left hemiscalp and faces to the right hemiscalp (Mercure, Dick, Halit, Kaufman, & Johnson, 2008). The N170 presents an interesting configuration of repetition effects, with a strong initial deflection for a presented face regardless of the familiarity of the face (Eimer, 2000), and a reduction in amplitude for repeated faces (Itier & Taylor, 2002, 2004) but only when faces are presented as a homogeneous category set (Mercure, Cohen Kadosh, & Johnson, 2011). The N170 can be modulated by emotional facial expression (Batty & Taylor, 2003; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Pourtois, Thut, de Peralta, Michel, & Vuilleumier, 2005) though this modulation is not always present (Eimer & Holmes, 2007)

Medial frontal negativities. There is a negative going deflection in the ERP waveform measured from central to anterior scalp locations peaking approximately 200-400ms after the onset of a stimulus related to an overall condition, goal, or rule. Several distinct contexts elicit medial frontal negativities: 1) during times of high conflict, such as the Go/No-Go task, the N2 is larger compared to low conflict trials; 2) when suppression of a prepotent response set is required (Donkers & van Boxtel, 2004; Gehring, Goss, Coles, Meyer, & Donchin, 1993), and 3) in response to error feedback (Holroyd & Coles, 2002). Larger N2 amplitude is correlated with a lower rate of false alarms (Folstein & Van Petten, 2008).

When the N2 is elicited in response to performance feedback it is called the *feedback error related negativity* (fERN). The fERN is related to reinforcement learning through dopaminergic pathways and the anterior cingulate cortex (Dehaene, Posner, & Tucker, 1994; Holroyd & Coles, 2002). Research has demonstrated that the fERN is more negative when an individual has been informed that an error has occurred, as opposed to when an individual has been informed that a correct response has occurred (Holroyd, Krigolson, & Lee, 2011; Holroyd, Nieuwenhuis, Yeung, & Cohen, 2003). This modulation is in addition to the magnitude of potential reward (gained/loss) and frequency of feedback (Sambrook & Goslin, 2015).

A distinctly separate component, also referred to as the N2, is elicited in a different context and does not have a medial frontal topography. An N2 with a right-anterior inferior distribution has been recorded during Stop-Signal tasks, where response inhibition – the act of withholding a correct prepared response – is required for overall task success (Liotti et al., 2007; Luus, Van Snellenberg, & Liotti, 2007; Pliszka, Liotti, & Woldorff, 2000). This distinct distribution suggests that the Stop-Signal N2 may represent a categorically different brain process than the Go/No-Go N2.

P3. Following the medial negativities is a large positive deflection in the ERP waveform. This positive wave peaks between 300 and 600 ms and is thus called the P3. A fronto-central P3 is associated with task processing, while a parietal P3 is associated with memory processing (Kiefer, Marzinzik, Weisbrod, Scherg, & Spitzer, 1998; Polich, 2007). This topographical distinction leads to the interpretation that P3s elicited under varying task demands reflect different underlying processes. In somewhat recent years, the P3 has been gaining favor as an index of response inhibition. As early as 2005, component-overlap analysis techniques were testing differences in the P3 between successful and failed inhibition trials (Bekker, Kenemans, Hoeksma, Talsma, & Verbaten, 2005; Wessel & Aron, 2014a, 2014b). However, the standard interpretation of the role of the P3 is that this component indexes either a post-inhibition compensatory mechanism, or conflict awareness (Lansbergen, Böcker, Bekker, & Kenemans, 2007).

1.3.2. Affective ERP components

VPP. While the N170 changes intermittently in response to emotional facial expressions, a simultaneously present ERP component is more consistently sensitive to

emotional expressions. Specifically, a positive going waveform over fronto-central scalp, the Vertex Positive Potential (VPP) increases in amplitude following emotional compared to neutral expressions (Eimer & Holmes, 2007; Schupp et al., 2004). The VPP typically is elicited simultaneously with and at the same latency as the N170. The differences in sensitivity to faces between the N170 and VPP suggests the VPP may be generated by additional brain regions, possibly regions from the saliency network, in combination with those generating the N170 (Joyce & Rossion, 2005). This interpretation is supported by parallel neuroimaging research on emotional faces with left amygdala activations found for fearful faces (Vuilleumier, Armony, Driver, & Dolan, 2001) with some indication that the amygdala received inputs from the pulvinar and superior colliculus, even for coarse faces (Vuilleumier, Armony, Driver, & Dolan, 2003). The early latency of the VPP combined with the findings from fMRI strongly suggests rapid, automatic, orientation to emotional expressions.

EAP/EPN. Recently, studies have reported an early (170-290 ms) anterior positivity (EAP), to stimuli that were task-irrelevant but were high in emotional arousal in the (Asmaro, Carolan, & Liotti, 2014; Carolan, Jaspers-Fayer, Asmaro, Douglas, & Liotti, 2014; Taake, Jaspers-Fayer, & Liotti, 2009). A more common ERP variant of emotion modulation is the early posterior negativity (EPN) which is similar in latency to the EAP but with a posterior scalp topography (Schupp, Flaisch, et al., 2006; Schupp et al., 2003). Both components are larger following emotional stimuli, and neither have been shown to habituate after stimulus repetition.

LPP. A late positivity (LPP) peaking 300-700 ms over posterior scalp is the most common and robust emotionally modulated ERP component reported in the literature. The LPP is most responsive to task-relevant arousing images (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001; Olofsson, Nordin, Sequeira, & Polich, 2008). The magnetic equivalent of the LPP demonstrates both facilitation of perception and post-perceptual control by the central executive explained through reciprocal activity between prefrontal and occipital-parietal cortices (Moratti, Saugar, & Strange, 2011).

1.3.3. Oscillatory Dynamics

While ERPs are valuable for understanding task-dependent changes in activity they are a broad summation of underlying oscillations which are themselves separable in terms of frequency (faster – gamma, slower – delta) and range (local and global). A detailed knowledge of oscillatory dynamics is key for understanding the processes that governing human cognition, consciousness, and affective processing. As an example, the study of oscillatory function in combination with animal research and neuroanatomy has resulted in findings implicating gamma-band thalamocortical activity as requisite for consciousness, the integration of information from disparate brain regions, and relay of the integrated information back to cortical areas (Ribary, Doesburg, & Ward, 2014).

Oscillations underlying more cognitive ERP effects have been studied longer than those for affective effects. For instance, correct responses on Go trials have been associated with increased theta (4-7Hz) and decreased alpha (8-12Hz) power (Moore, Gale, Morris, & Forrester, 2006). Both theta and delta have been associated with response inhibition; particularly, in-phase theta and delta during the P3 time window results in large effects, but anti-phase theta and delta during the N2 time window results in no measurable effects (Bernat, Nelson, Steele, Gehring, & Patrick, 2011). Theta activity generally represents a similar process across cognitive tasks while delta is sensitive to task manipulations (Harper, Malone, & Bernat, 2014).

Extending this method of signal processing to task dependent affective modulations should allow us to identify the timing, frequencies, and regions in which affective information is perceived, integrated and/or suppressed. For example, it is possible that one oscillatory dynamic may be responsible for all affect dependent ERP modulations. Alternatively, there may be a difference in dynamics for endogenous versus exogenous responses to emotional information, or for early versus late ERP components. Finally, it is also possible that brain activations may not be present in the ERP components but will be clear in the TF decompositions.

Affective neuroscience is at the beginning of a surge in research integrating knowledge of oscillatory dynamics with canonical affective phenomena. For instance, findings have shown alpha-band increases following affective stimuli over posterior and central scalp (Uusberg, Uibo, Kreegipuu, & Allik, 2013), along with increases in alpha-

band during a visual working memory task following mood induction (Zhang, Zhang, & Liu, 2017). The timing (300-600 ms) and scalp locations are compatible with the P3 and LPP ERP components suggesting that alpha-band oscillations may be a mechanism of inhibition of affective attention. Alternatively, theta-band activity over posterior and frontal scalp is increased in response to threat processing (DeLaRosa et al., 2014). Slower oscillations (<4 Hz) are not given as much attention in affective neuroscience via EEG methodology, though power increases in delta-band are visually present the published literature alongside alpha and theta changes. Delta has been tentatively linked to anxiety (Gennady G. Knyazev, Bocharov, Levin, Savostyanov, & Slobodskoj-Plusnin, 2008; Gennady G. Knyazev, Savostyanov, & Levin, 2005; Gennady G. Knyazev, Schutter, & van Honk, 2006), impulsivity (Gennady G. Knyazev, Levin, & Savostyanov, 2008), behavioral inhibition (Gennadij G. Knyazev & Slobodskaya, 2003) and domain-general homeostatic/motivational processes (Gennady G. Knyazev, 2012).

1.3.4. Electrophysiology of approach and avoidance

Initial electrophysiological research used resting frontal asymmetry to distinguish between approach and avoidance networks. Individuals high in approach tendencies have strong left frontal resting alpha power, while high avoidance tendencies are related to right frontal alpha activity (Coan & Allen, 2003; Amodio, Master, Yee, & Taylor, 2008). When ongoing EEG is filtered to isolate the alpha band during presentation of masked emotional faces, those with high approach behavior had more activation in the left hemisphere towards happy expressions; whereas, participants high in avoidance generated more right lateralized activity to negative expressions of fear, disgust, anger, and surprise (Balconi & Mazza, 2009). Delta, theta, and gamma band activity show a similar hemispheric effect, though with more nuanced dynamics. Left anterior delta power is positively correlated with approach when viewing highly arousing (negative or positive) stimuli, while right delta power is negatively correlated with avoidance in response to arousing positive images (Balconi, Brambilla, & Falbo, 2009b). Alternatively, while approach effects are mirrored in the theta frequency, avoidance effects show an opposite pattern with right theta band activity positively correlating to avoidance in response to negative images (Balconi, Brambilla, et al., 2009b). Additionally, theta power is stronger in response to the presentation of false feedback for individuals high in

avoidance tendencies, most likely because false performance feedback is interpreted as a threat (Balconi & Crivelli, 2010b).

For ERP components, the P3b has been related to approach, particularly to reward responsiveness (Balconi & Crivelli, 2010a). On the other hand, high avoidance tendency has been associated with a morphing of the P3b to a more anterior distribution, presumably due to alpha-driven increases in right prefrontal cortex (Wacker, Chavanon, Leue, & Stemmler, 2010). Both fERN and No-Go N2 amplitude increase as trait avoidance increases (Amodio et al., 2008; Balconi & Crivelli, 2010a; Leue, Chavanon, Wacker, & Stemmler, 2009). It is important to note that the N2 results have been restricted to the Go/No-Go paradigm, which suggests the N2 and fERN pattern of results may depend on conflict monitoring, not response inhibition.

1.4. Research Goals

Functional oscillatory connectivity dynamics have advanced knowledge of cognition and consciousness in the human brain. However, to date, few studies have improved our understanding of the role of emotional experience in the five dimensions of oscillatory networks: three-dimensional brain space, frequency, and time. My Master's work demonstrated theta (6-8Hz) and delta (2-4Hz) frequency bands to be the underlying cause of emotional modulation of event-related potentials (ERPs). A recent study reported coupled gamma increases and alpha decreases, particularly in prefrontal regions, to underlie top-down emotion regulation (Popov, Steffen, Weisz, Miller, & Rockstroh, 2012). Another study demonstrated increases in theta and alpha in orbitofrontal and dorsolateral prefrontal cortex to be responsible for fast (250-550ms post-stimulus) processing of emotionally salient stimuli (Todd et al., 2014).

While new methods have allowed for great progress understanding the effects of exogenous emotional information, less is known about the modulation of affective state on cognitive neural networks. To understand when, where, and how electrophysiology is influenced by endogenous affect necessitates knowledge of the underlying cortical oscillatory dynamics. To understand the independence and interdependence of affect and cognitive function the results should be interpreted as the product of continuous regulation of affect and action. There are three pillars to my doctoral work:

1. The effect of endogenous and exogenous affect manipulation and their relationship with approach and avoidance.
2. The dynamics and impact of ongoing emotional experience.
3. The 5-dimensional role of oscillatory changes in response to endogenous affective manipulation.

Chapter 2. Experiment 1: Emotional Stop-Signal Task (EMO-SS)

2.1. Experiment overview

A canonical paradigm well suited to manipulate the dynamics between affective and cognitive networks is the Stop-Signal Task (SST). In this paradigm serially presented stimuli are evaluated by participants who must make or withhold responses on a trial-by-trial basis. Unlike the Go/No-Go paradigm in which participants discriminate between stimuli to determine whether or not to respond, every stimulus in the SST is a go-cue. Rather than responding immediately to target characteristics participants must withhold this prepotent reaction and remain vigilant for the possibility of a subsequent stop-signal stimulus that is presented on only a subset of trials. The advantage of the SST is that it allows researchers to dissociate between stimulus evaluation processes and the inhibitory mechanisms responsible for action regulation. This is particularly true in neuroimaging and electrophysiological studies, in which reactions to stimuli can be indexed even in the absence of overt behavioral responses.

The SST is proposed in terms of a horse-race inhibition model, in which an ongoing “go-horse” is infrequently and unpredictably met with a “stop-horse” opponent that must overtake it for action to be suppressed (Logan & Cowan, 1984). The task is thought to recruit controlled (i.e. top-down) inhibitory processes (Verbruggen & Logan, 2008). To perform well during a SST requires the rapid integration of exogenous (e.g. visual or auditory stimuli) and endogenous (e.g. response preparation, vigilance) information in addition to mental flexibility to cancel a response set when signaled to do so. Trial-by-trial effects show that task-irrelevant arousing exogenous information interferes with stop and go response processes by diverting cognitive resources to affective processing (Verbruggen & De Houwer, 2007).

Within the SST framework this study will manipulate exogenous emotional information through the presentation of faces with emotional expressions in combination with a manipulation of endogenous affect through an A-B-C block design. Blocks A and C are “fair” with equal gains/losses for right and wrong answers, whereas Block B is frustrating as points gained remained unchanged but an incorrect response results in the loss of every point gained so far (i.e. bankruptcy). Previous research using this design in

combination with a Go/No-Go task has shown it to be a robust manipulation (Lewis, Lamm, Segalowitz, Stieben, & Zelazo, 2006; Moadab, Gilbert, Dishion, & Tucker, 2010)

For the evocative stop-signal task (EMO-SS), the following predictions were made:

VPP amplitude will vary by emotional expression. Further, the affective modulation of the VPP will be largest in Block B, the punishing block. N170 amplitude will decrease across blocks both due to the repetition of the facial set and the increases in task demands across blocks. The N2 in response to the stop-signal will be more negative for successful versus failed inhibitions across blocks and the most negative for successful inhibitions during the unfair punishment block.

In terms of behavioral indices, reaction time on valid Go trials should be sensitive to the emotional facial expression with the longest reaction time to angry faces. The probability of inhibition should be poorest during the unfair punishment block along with increased signal-response reaction times.

Continuous self-reported frustration is expected to increase across blocks and be particularly high in the unfair punishment condition. On the other hand, motivation scores are expected to be lowest during unfair punishments but raise again in the baseline-change block when punishments are once again equal to rewards and participants can regain the points they've lost. Frustration and motivation scores are expected to be correlated throughout the experiment.

Those high in Drive will likely have the highest motivation scores and these scores should relate to reaction time and accuracy. Alternatively, those high in BIS are likely to have the greatest frustration scores, both of which should be related to N2 amplitude for successful inhibitions.

In line with the suggestion that delta oscillations are involved in motivational processes, increases in slow frequencies over frontal scalp will relate to subjective scores on motivation and Drive. Further, as the unfair punishment condition is intended to induce frustration, and by extension dysfunction in neural networks, if delta activity is indeed a mechanism of homeostasis, then power in the delta-band should be particularly sensitive to the block manipulation (Gennady G. Knyazev, 2012). Lastly, the delta effect should be temporally diffuse. While the focus of this analysis is on delta-band activity,

early (<300ms) theta increases are expected to be induced following successful inhibitions (Harper et al., 2014) and are expected to be positively correlated with BIS. Alpha activity will be sensitive to the endogenous affective manipulation and will relate to approach and avoidance variables (Balconi, Brambilla, et al., 2009b; Balconi, Falbo, & Brambilla, 2009; Balconi & Mazza, 2009; Coan & Allen, 2003)

Lastly, it is expected that beamforming analysis will produce source estimates of delta activity to be strongest in areas corresponding the salience network (Barrett & Satpute, 2013; Seeley et al., 2007)

2.2. Participants and Procedure

This study was approved by the Simon Fraser University Office of Research Ethics. Participants were 45 undergraduate university students recruited from the Research Participation System at Simon Fraser University. Each gave informed consent before participating in a 2-hour ERP session in exchange for course credits. Participants completed a brief self-report medical and demographics questionnaire, and the Behavioral Activation System/Behavioral Inhibition System scale. They then performed the 40-minute EMO-SS task during which EEGs were recorded.

The EMO-SS task (Figure 1) was developed and run using E-Prime 2.0.8.22 professional (Psychological Software Tools, Pittsburgh, PA). Stimuli were a series of faces taken from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Happy, angry and neutral expressions of five unique male, and five unique female faces were selected, grey-scaled, and placed in oval frames to remove jaw and hairlines. On each trial a single randomly chosen face, featuring one of the three randomly chosen expressions was displayed for 300 ms at the center of a black background, with a superimposed, central grey fixation cross. Participants responded using a Logitech game pad and were instructed to identify the gender of the face by pressing one of two buttons after the face had left the screen (go-condition). Responses could be made up for up to 1000 ms after face stimulus offset. However, on 33% of trials a stop-signal consisting of a grey hexagon with a centered white "S" and a white border appeared 200, 300, 400, 500, or 600 ms following stimulus presentation, and was displayed for 100 ms. Participants were instructed to withhold their response on these

trials (stop-condition). After each trial, a feedback slide displaying either “\$” or “X” indicated a correct or incorrect response.

Experimental Task

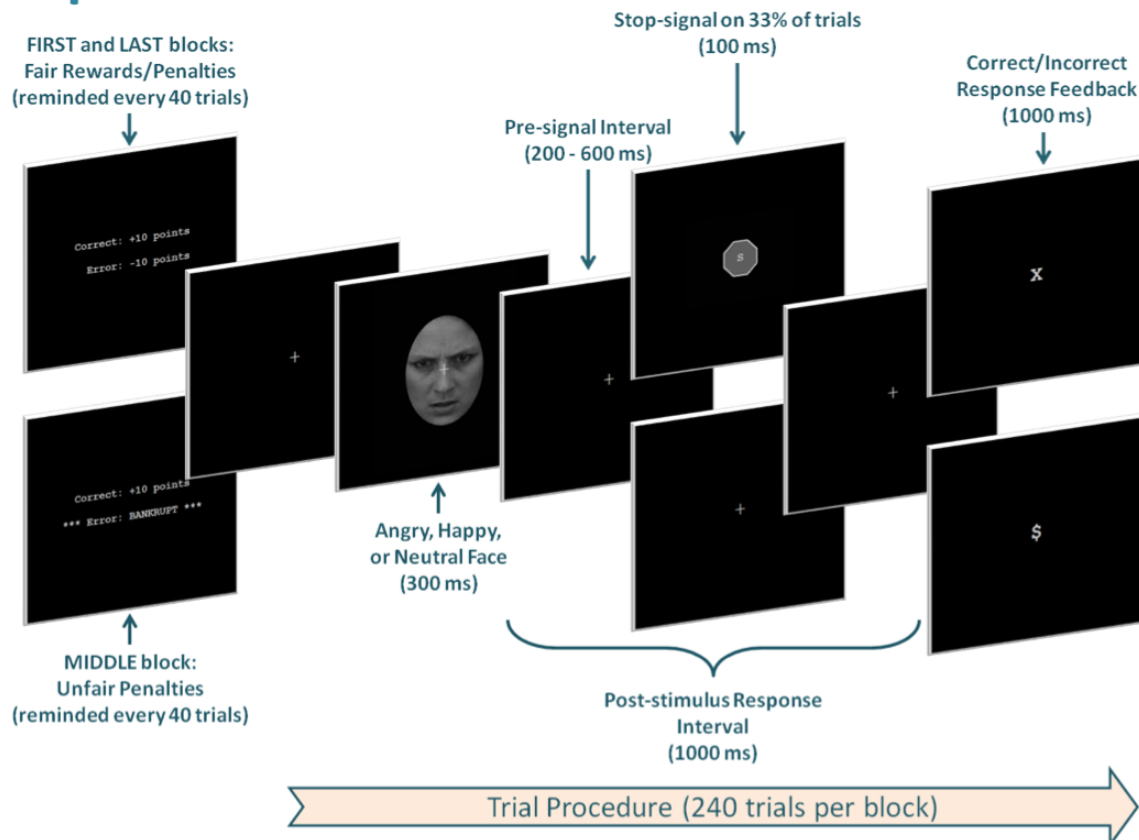


Figure 1. EMO-SS Task

Continuous measurement of emotional experience was collected every “mini-block,” i.e. every 40 trials (Goldin et al., 2008). Participants rated their level of Motivation and Frustration from 1 (“Not at all”) to 5 (“Extremely”) using a 5-point Likert scale, and were then given a 20 second break. At this time, if the average response time for an individual participant had been longer than 800 ms from stimulus offset (i.e. beyond the maximum possible time a stop-signal could occur), the minimum and maximum stop-signal delays were increased by 100 ms to prevent them from achieving 100% accuracy.

The experiment followed an A-B-C block design, with 6 mini-blocks per block (240 trials each). Blocks A and C were “fair” (equal point gains/losses for right and wrong answers), whereas block B was highly frustrating and punishing (point gains remained unchanged, but all points were lost each time an incorrect response was made). Based on previous Go/No-Go studies using this design (Lewis et al., 2006; Moadab et al., 2010) behavioral performance and physiological reactivity index cognitive and affective network activity in Block A, high stress-response during Block B, and stress-recovery in Block C. Total amount of points gained was displayed at the end of each mini-block, before Motivation and Frustration were assessed. Participants were reminded of the current rule set at the start of each mini-block, and alerted when the rules changed at the start of Blocks B and C.

2.3. Electrophysiological Scoring and Analysis

EEG activity was recorded using a 64-channel Ag/AgCl electrode cap at standard 10-10 sites (Biosemi Active Two, Amsterdam), plus electrodes over left and right mastoids, external canthi (for horizontal eye movements), and below each eye (for vertical eye movements and blinks). Voltages were recorded against a common mode sense (CMS) active electrode. Data were sampled at a rate of 512 Hz. Offline, EEG was digitally filtered (0.01 Hz highpass, 30 Hz lowpass), and re-referenced to average mastoid using FieldTrip (Oostenveld, Fries, Maris, & Schoffelen, 2010). Semiautomatic artifact rejection and visual inspection of the EEG removed trials contaminated by blinks and eye movements. For each block (A, B, and C) individual subject ERPs were time-locked to with a 200 ms baseline until 700 ms following stimuli presentation. Single subject averages were generated to the face (3 levels, Angry, Happy, Neutral), the stop-signal (2 levels, Successful and Failed inhibitions).

A broader time window (-1000 to 2000 ms) was used for the time-frequency (TF) analysis, particularly due to the interest in delta-band activity. The data were decomposed using a hanning taper method from .5 to 100 Hz in steps of .5, and a time resolution of 25 ms. An average mastoid reference was used and ocular artifacts were identified and surgically rejected using a semi-automatic algorithm and visual inspection.

2.4. Results

Repeated measures analysis of variance (rANOVA), Pearson Product Moment Correlations, and step-wise regression were used to analyze the data. Post-hoc comparisons were performed with Bonferroni correction where appropriate.

2.4.1. Manipulation Check

rANOVA with Block (A, B, C) and Emotional Experience (Frustration, Motivation) resulted in a main effect of Emotional Experience ($F(1,50)=6.18, p=.016, \eta_p^2=.11$) and an interaction between Block and Emotional Experience ($F(2,100)=23.36, p<.001, \eta_p^2=.318$). This interaction was characterized by a sharp increase in Frustration between Block A and B ($p<.000$) that continued into Block C. Motivation showed the opposite

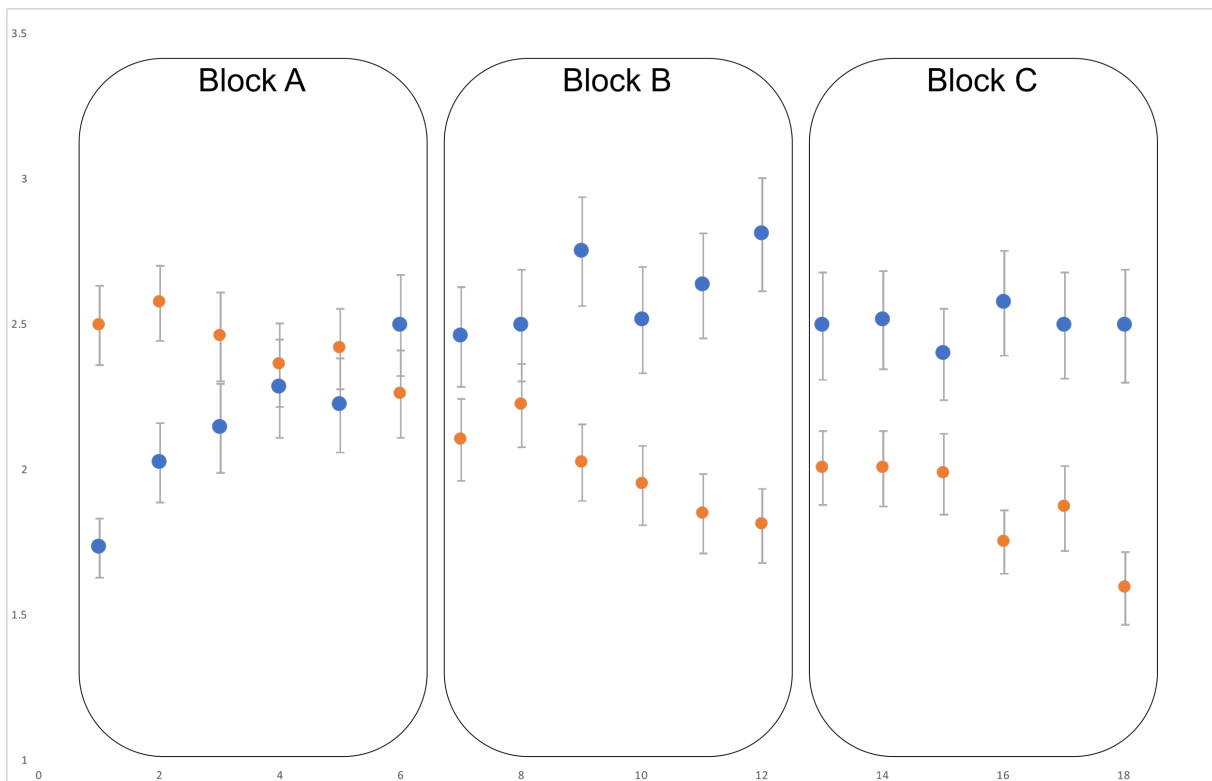


Figure 2 Frustration and Motivation Scores Experiment 1 (EMO-SS)

pattern of effects with a sharp decrease in Motivation between Block A and B ($p<.001$) continuing into Block C. While the overall group pattern was in line with the experimental hypothesis and demonstrates that the unfair punishment manipulation had the desired

effect there was a large amount of individual variation on the pattern of change between blocks. The correlation between Frustration and Motivation scores was strong in Block A ($r=.68$, $p<.00$), and Block C ($r=.43$, $p<.00$), though this relationship was lost in Block B.

	Block	Mean	SE
Frustration	A	2.14	.13
	B	2.60	.17
	C	2.49	.16
Motivation	A	2.42	.12
	B	1.98	.11
	C	1.86	.10
Go RT Angry Faces	A	1013.93	14.03
	B	1005.65	12.82
	C	968.32	17.92
Go RT Happy Faces	A	1005.96	14.96
	B	994.73	12.96
	C	970.27	16.39
Go RT Neutral Faces	A	1001.58	14.06
	B	995.41	12.93
	C	959.20	17.53
Signal-Respond RT	A	926.50	16.55
	B	932.12	16.51
	C	898.03	19.67
SSRT	A	281.29	22.52
	B	258.91	22.64
	C	258.10	24.29
plnh	A	.49	.14
	B	.48	.13
	C	.44	.13

Table 1 Behavioral Descriptive Statistics for the Experiment 1 (EMO-SS)

2.4.2. Behavioral Results

Go Reaction Time. The reaction time on valid Go trials showed a main effect of Block ($F(2, 98) = 7.03, p < .00, \eta_p^2 = .125$) and Valence ($F(2, 98) = 4.89, p = .01, \eta_p^2 = .09$). Reaction times were slower during Block C than both A ($p = .018$) and B ($p = .011$) while reaction times to Angry faces were slower than Neutral faces ($p = .018$). Both Drive and Motivation were correlated to reaction time following Happy ($r = -.31, p = .03; r = .33, p = .02$), Angry ($r = -.35, p = .01; r = .29, p = .03$) and Neutral ($r = -.35, p = .01; r = -.30, p = .03$) faces in Block A. Drive was also correlated to reaction time to Angry faces in Block B ($r = -.31, p = .02$) while Motivation in Block A and reaction time to Happy faces in Block B were correlated ($r = .34, p = .01$). Averaging across Valence in Block A yields a strong correlation to Drive ($r = -.47, p < .00$). Note that high Drive scores were related to faster reaction times while higher Motivation scores were related to slower reaction times with two caveats: the relationships were stable mostly in Block A, and Drive and Motivation scores did not share a relationship with each other.

Block Effects for Stop Trials. There was a main effect of Block for Signal-Respond reaction times ($F(2, 72) = 3.71, p < .03, \eta_p^2 = .09$), with reaction times significantly faster in Block C than B ($p = .006$). Probability of inhibition (pInh) was also sensitive to the Block manipulation ($F(2, 72) = 3.77, p < .03, \eta_p^2 = .09$), with the pInh for Block C significantly lower than Block A ($p = .045$). SSRT was remarkably stable across Blocks ($p = .5$) suggesting that if the response inhibition processes are engaged they may behave the same way within the individual regardless of other situational factors. As with go reaction time, Drive was negatively correlated to Signal-Respond reaction time ($r = -.48, p < .00$) and SSRT ($r = -.45, p < .00$) for Block A only.

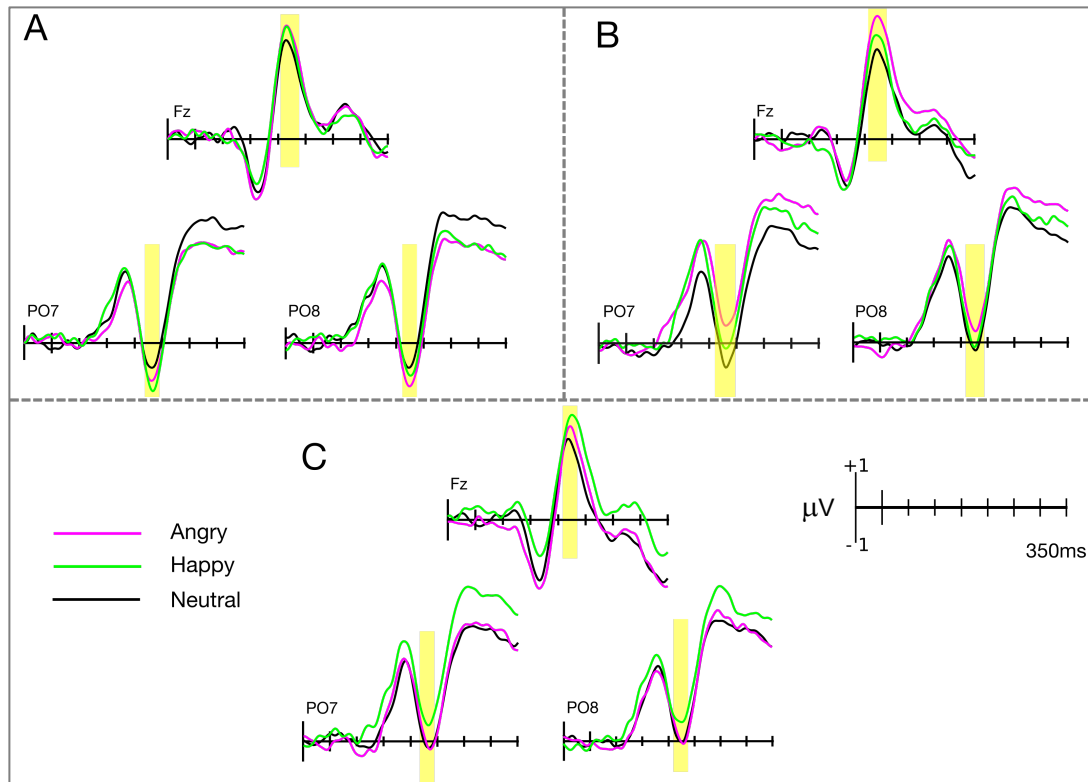


Figure 3 VPP/N170 amplitudes for statistical testing

The VPP (Fz) and N170 (PO7/PO8) are displayed for Angry, Happy, and Neutral faces for Block A, B, and C.

2.4.3. Electrophysiological responses to face stimuli

N170/VPP ERP Effects. N170 amplitude was not sensitive to Valence ($F=.7$) but did vary across Blocks ($F(2, 66) = 16.72, p<.000, \eta_p^2=.34$) with an initial reduced negativity between Block A and B ($p<.00$) which continued without changing into Block C (A-C $p<.00$; B-C $p=.8$). The VPP was sensitive to both Block ($F(2, 70) = 4.41, p<.016, \eta_p^2=.112$) and Valence ($F(2, 66) = 5.37, p<.00, \eta_p^2=.13$), without the two factors interacting. The VPP during Block C had a greater amplitude than Block A ($p=.03$) and was more positive for Angry faces than Neutral ($p<.00$) faces. The VPP following Angry faces in Block B was correlated to Fun-Seeking ($r=.36, p=.03$) and Reward Responsiveness ($r=.39, p=.02$).

Posterior LPP effects (P08, 300-600). There was an interaction between Block and Valence ($F(4, 136) = 2.8, p<.03, \eta_p^2=.076$) characterized by a Valence effect in Block B ($F(2, 70) = 5.6, p<.00, \eta_p^2=.14$), but not A or C. In Block B, LPP amplitude to Angry faces

was more positive compared to Neutral ($p=.011$). The amplitude to Angry faces in Block B was correlated to BIS ($r=.52, p<.00$) while LPP amplitude to Neutral faces in Block B was related to Frustration in Block B ($r=-.4, p<.01$).

Anterior LPP effects (AFz, 300-600ms). While the LPP is traditionally a posterior component the current data showed a similar, if not stronger effect over more anterior scalp locations. Indeed, the anterior manifestation of this ERP complex was even more sensitive to the Block manipulation ($F(2, 70) = 11.13, p<.00, \eta_p^2=.25$), with an overall negative shift in amplitude between Block A and C ($p<.00$). At this anterior location there was neither an effect of Valence nor an interaction of Block and Valence.

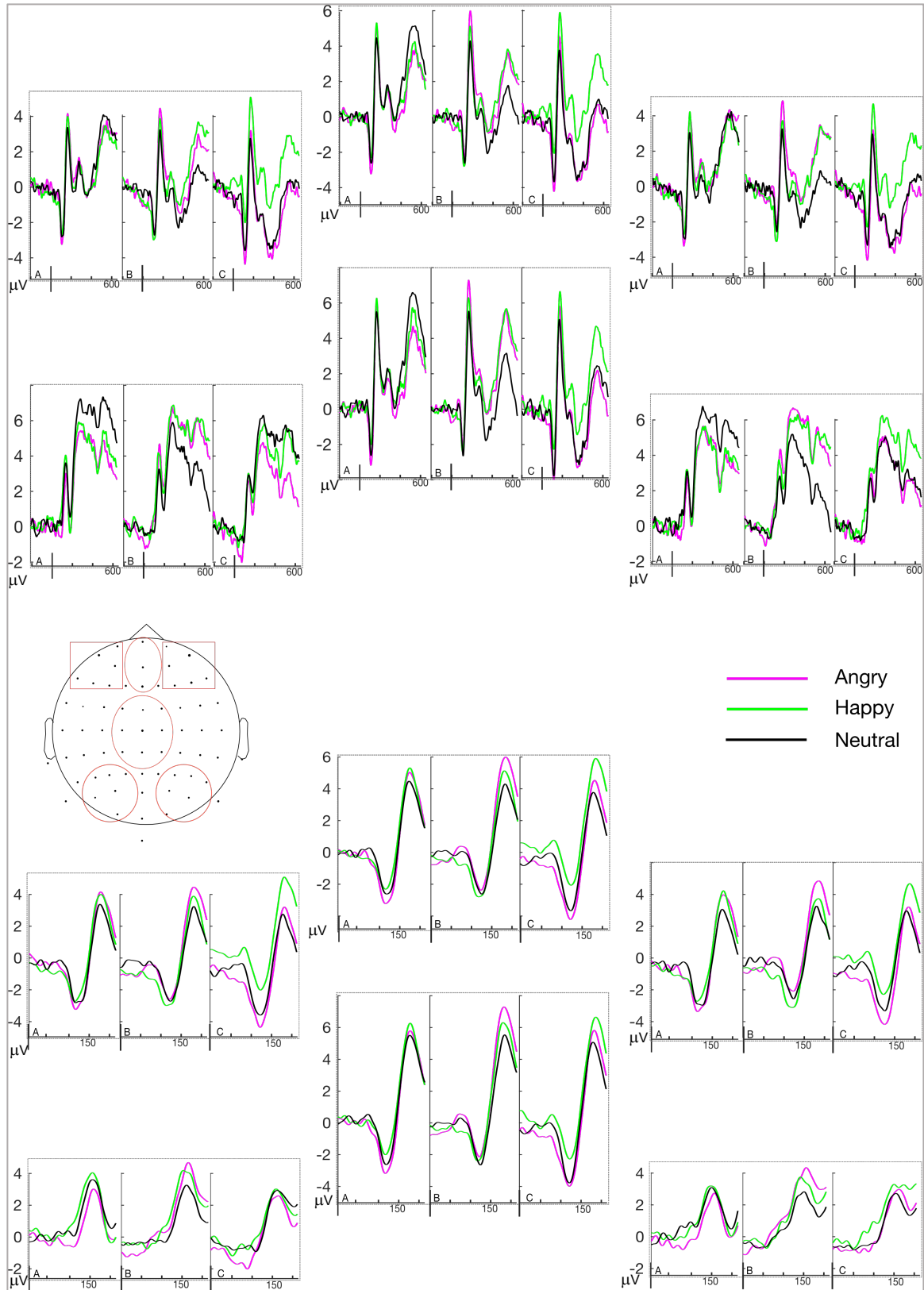


Figure 4 ERP Scalp Topography to Face Presentation (EMO-SS)

Top: Full ERP epoch, from 200 before stimuli presentation to 600ms after. Bottom: Zoomed in time region, from the onset of the face to 200ms after in order to show P1/N170/VPP amplitude effects by Valence and Block.

Oscillatory Dynamics to Face Stimuli. To better understand the N170 and VPP results Figure 5 displays the TF-decompositions by rows of Valence (Angry, Neutral, Happy) and columns of Block (A, B, C), for six regions of interest across the scalp. Throughout all scalp regions, Valences and Blocks there is a distinct decrease in power across multiple bandwidths, 10-20 Hz (alpha/beta ranges) coinciding with the offset of the stimuli and extending the duration of the epoch. The latency, topography, and duration of this strong inhibition of 10-20 Hz activity suggests it is task-dependent and related to the simultaneous target identification and response inhibition which is unique to the Stop-Signal paradigm. To demonstrate the consistency across Valence topographic F -maps were computed between Valence for each Block (Figure 5, bottom left) which showed no difference in the effect between Valence for any Block. On the other hand, there is a large difference in the effect between Block within each Valence (Figure 5, bottom right) starting early (before 150ms) and continuing. This difference between Blocks is due to an increase in the strength of the inhibition after transitioning from Block A to B, and continuing into Block C (Figure 5, bottom middle). The difference between Blocks is quite dramatic when the topographical maps are scaled to the maximum negative value, $-30 \mu V^2$, compared to the scale used for overall effects in the top portion of Figure 5 in which the negative extreme is only $-5 \mu V^2$.

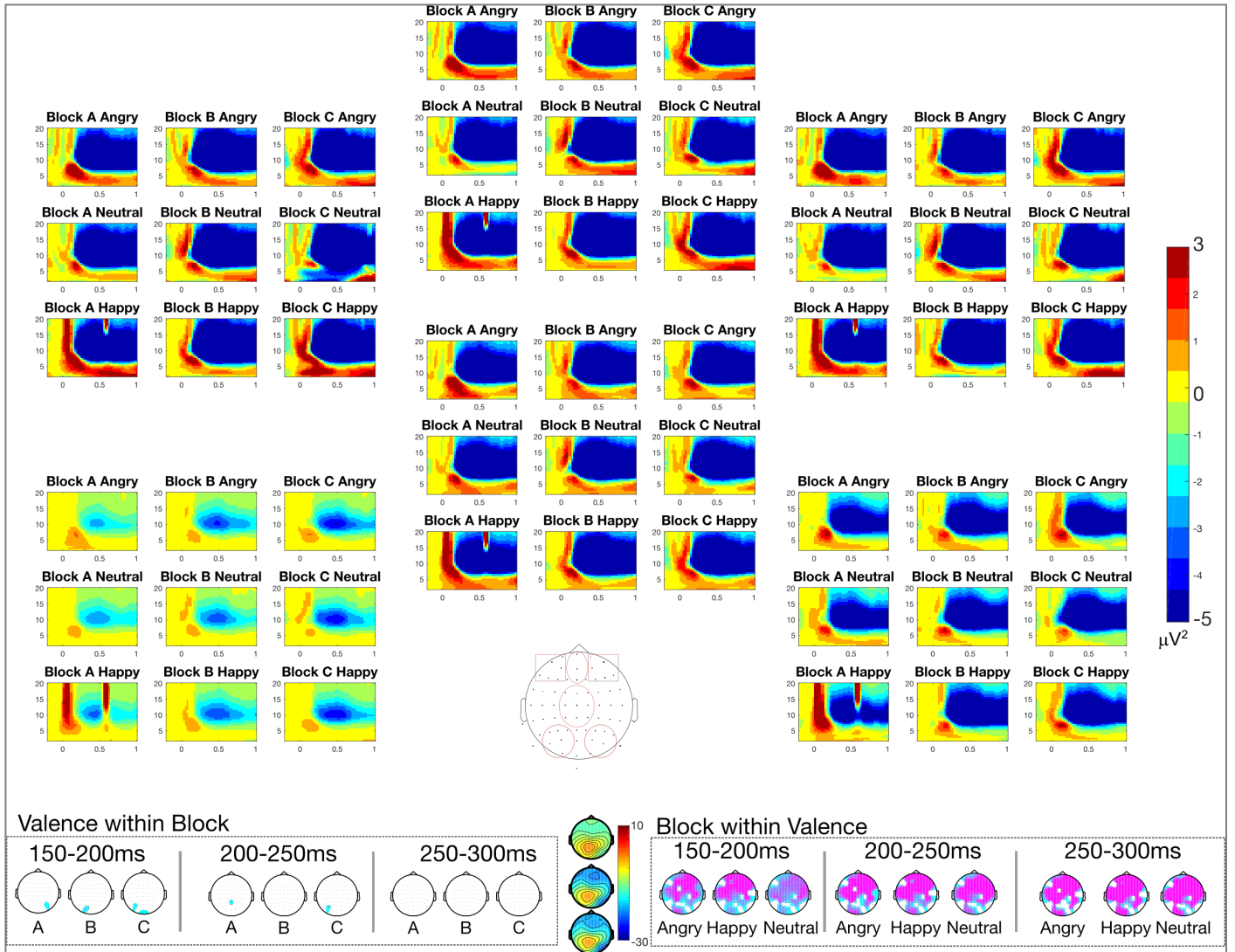


Figure 5 TF Face Stimuli

TF-decompositions by rows of Valence (Angry, Neutral, Happy) and columns of Block (A, B, C), for six regions of interest across the scalp.

2.4.4. Electrophysiological responses on Stop Trials

N2 Effects. N2 amplitude varied by Block ($F(2, 80) = 5.9, p < .00, \eta_p^2 = .128$) and between Successful (SI) versus Failed (FI) Inhibitions ($F(2, 80) = 7.57, p < .00, \eta_p^2 = .159$). N2 amplitude was more negative for SIs and was particularly negative for Block B compared to C ($p = .003$), in which N2 amplitude was notably reduced (Figure 6), but not A ($p = .55$). Stepwise regression was used to model N2 amplitude by BIS, Drive, Fun-Seeking, and

Reward-Responsiveness, as well as Frustration and Motivation. Only the N2 amplitude for SIs in Block B was accurately modeled, with both approach and avoidance variables predicting N2 amplitude in Block B. The stepwise regression produced a model of N2-SI amplitude for Block B ($R=.577$, $F(3,32)=4.8$, $p=.008$) which retained BIS ($\beta=.482$, $t=2.93$, $p<.00$), Drive ($\beta=.572$, $t=3.00$, $p<.00$), and Reward-Responsiveness ($\beta=-.458$, $t=2.56$, $p=.016$) as significant predictors.

P3 Effects (Cz). The P3 was sensitive to Block ($F(2, 80) = 5.28$, $p<.00$, $\eta_p^2=.12$), but did not vary between successful and failed inhibitions ($F(2, 80) = .6$). This difference was characterized by a decrease in amplitude between Block A and B ($p=.02$). P3 amplitude increased again in Block C, but did not reach the same magnitude as Block A.

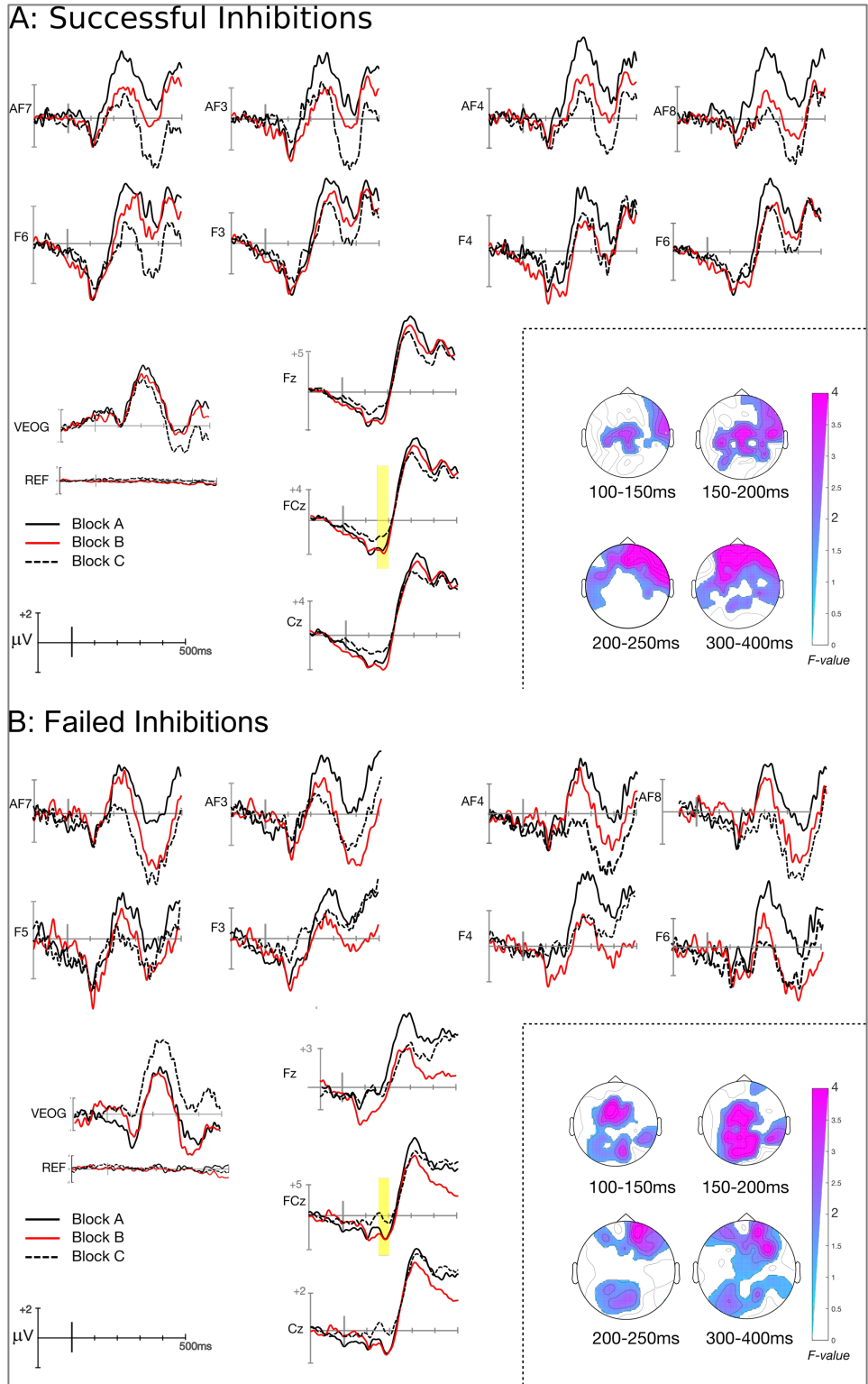


Figure 6 Stop-Signal N2 to Successful and Failed Inhibitions

The ERP in response to the onset of the stop-signal are displayed for Successful (Panel A) and Failed (Panel B) Inhibitions. The bottom right of each panel shows topographical F-maps for Block within each response type.

Oscillatory Dynamics on Stop Trials. To better understand the N2 results Figure 7 displays the TF-decompositions by columns for Trials Type (SI, FI) and rows by Block (A, B, C), for six regions of interest across the scalp. The anterior regions show stronger theta/alpha (>4Hz) activity for failed compared to successful inhibitions, and an overall decrease in this activity between Blocks for both failed and successful inhibitions. At the central region there is early (<200ms) delta activity unique to successful inhibitions which decreases in Block C. Successful inhibitions also have a sharp increase in theta between 200-400ms. For failed inhibitions at the central region there is strong activity more diffuse in time and frequency when compared with successful inhibitions, also decreasing in strength in Block C. Finally, in the posterior regions, both right and left, there is a general trend of slower frequencies (<5Hz) for successful inhibitions, and higher (>5Hz) frequency activations for failed inhibitions, with a gradual difference between Blocks than the anterior regions.

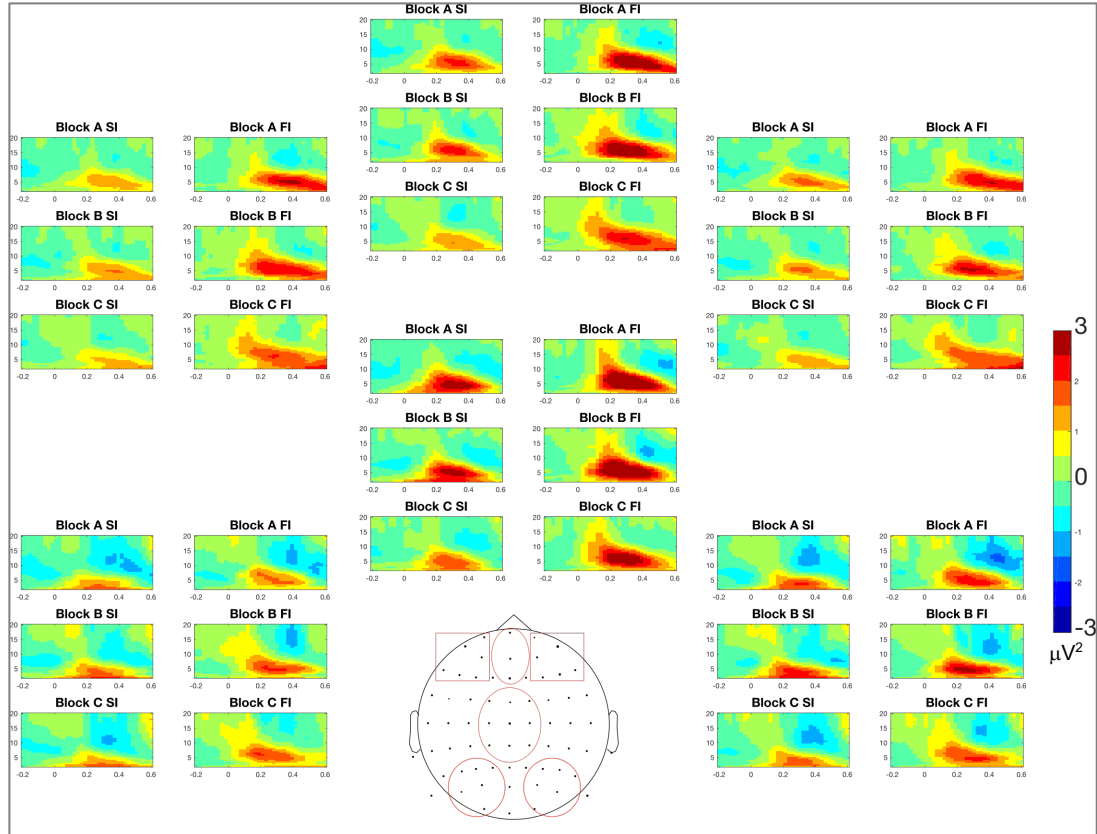


Figure 7 TF Stop-Signal (EMO-SS)

TF-decompositions by columns for Trials Type (SI, FI) and rows by Block (A, B, C), for six regions of interest across the scalp

Oscillatory Dynamics in the Delta bandwidth (1-3.5 Hz). The activity attributable to slower frequencies was isolated for both successful and failed inhibitions (Figure 8). There are two regions of delta activity, one fronto-polar and other fronto-central/central-posterior. A striking difference in the fronto-polar activity is the intensity of the activity for failed inhibitions in Block A, which is even stronger in Block C and relatively diffuse in time (300-700ms) and is not present for successful inhibitions. On the other hand, successful inhibitions have a relatively broad pattern of delta activity in terms of time (100-400ms) and space (central-parietal), which is less intense in Block C though just as dispersed. Failed inhibitions have a sharper pattern of activity over fronto-central scalp in Block A which disperses and loses intensity across Block B and C. To clarify these differences *F-maps* were calculated for the effect of Block separately for successful and failed inhibitions (Figure 8 – bottom). This technique was used as an exploratory data analysis method not as a parametric statistical test, similar to plotting difference maps.

These maps show no consistent change between Blocks at any time for failed inhibitions. Successful inhibitions show a difference between blocks at left posterior (100-300ms), fronto-central (100-400ms), and fronto-polar (100-400ms) locations.

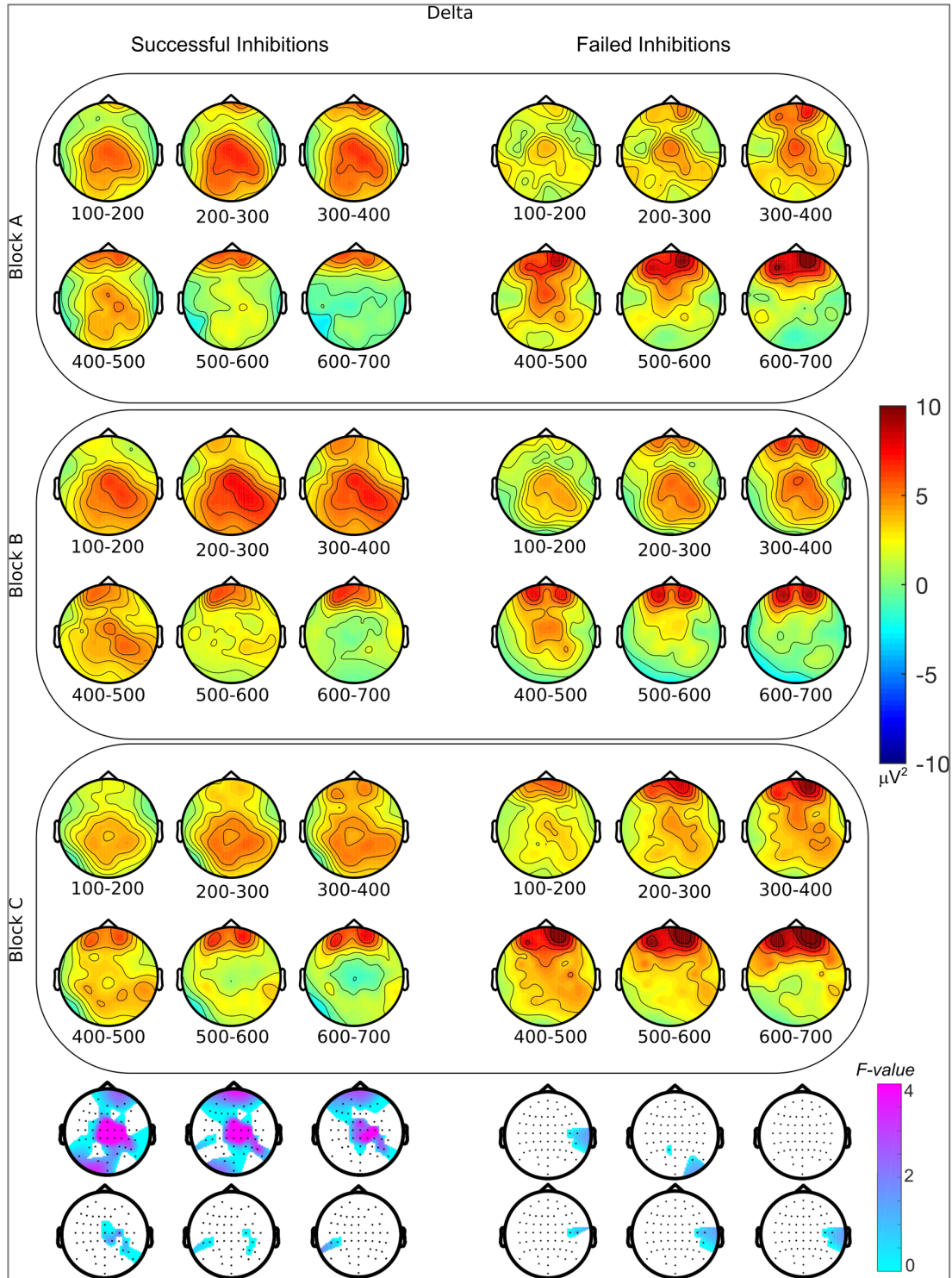


Figure 8 Delta Figure (EMO-SS)

Time frequency decompositions for Delta (1-3.5Hz) activity for successful inhibitions (left), failed inhibitions (right) with F-map both comparisons (bottom).

Oscillatory Dynamics in the Theta (4-7.5Hz) bandwidth. Both successful and failed inhibition trials have a clear theta-driven fronto-central N2 peaking 200-300ms across all Blocks, with greater intensity for failed inhibitions which may be due to error or feedback related processing (Figure 9). Both successful and failed inhibitions show a fronto-central scalp difference between Blocks, though this effect is broader and more consistent across time for successful inhibitions.

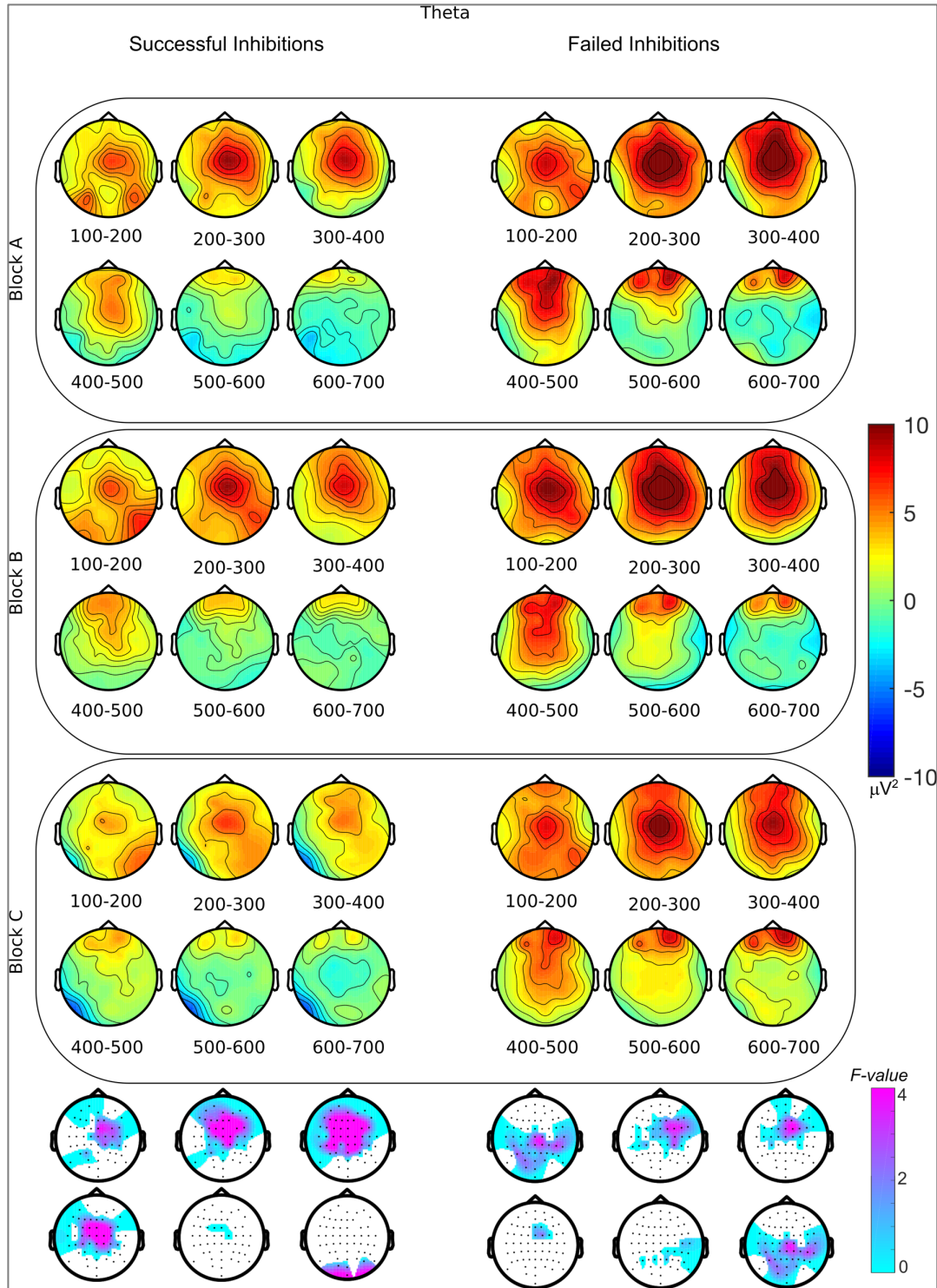


Figure 9 Theta Figure (EMO-SS)

Time frequency decompositions for Theta (4-7.5Hz) activity for successful inhibitions (left), failed inhibitions (right) with F-map both comparisons (bottom).

Oscillatory Dynamics in the Alpha (8-15Hz) bandwidth. Similar to the pattern of results seen in the theta bandwidth, the alpha activity shows an early (100-300ms) fronto-central activation for failed trials (Figure 10). However, in the case of alpha activity this is followed by an even stronger suppression of alpha over posterior scalp which is also stronger for in failed inhibitions. Despite this initial pattern of similarity, the difference between Blocks for successful inhibitions is across anterior scalp (Figure 10, bottom) from 200-300ms, while failed inhibitions have a left-frontal difference between Blocks which occurs intermittently first from 100-200ms then again 600-700ms.

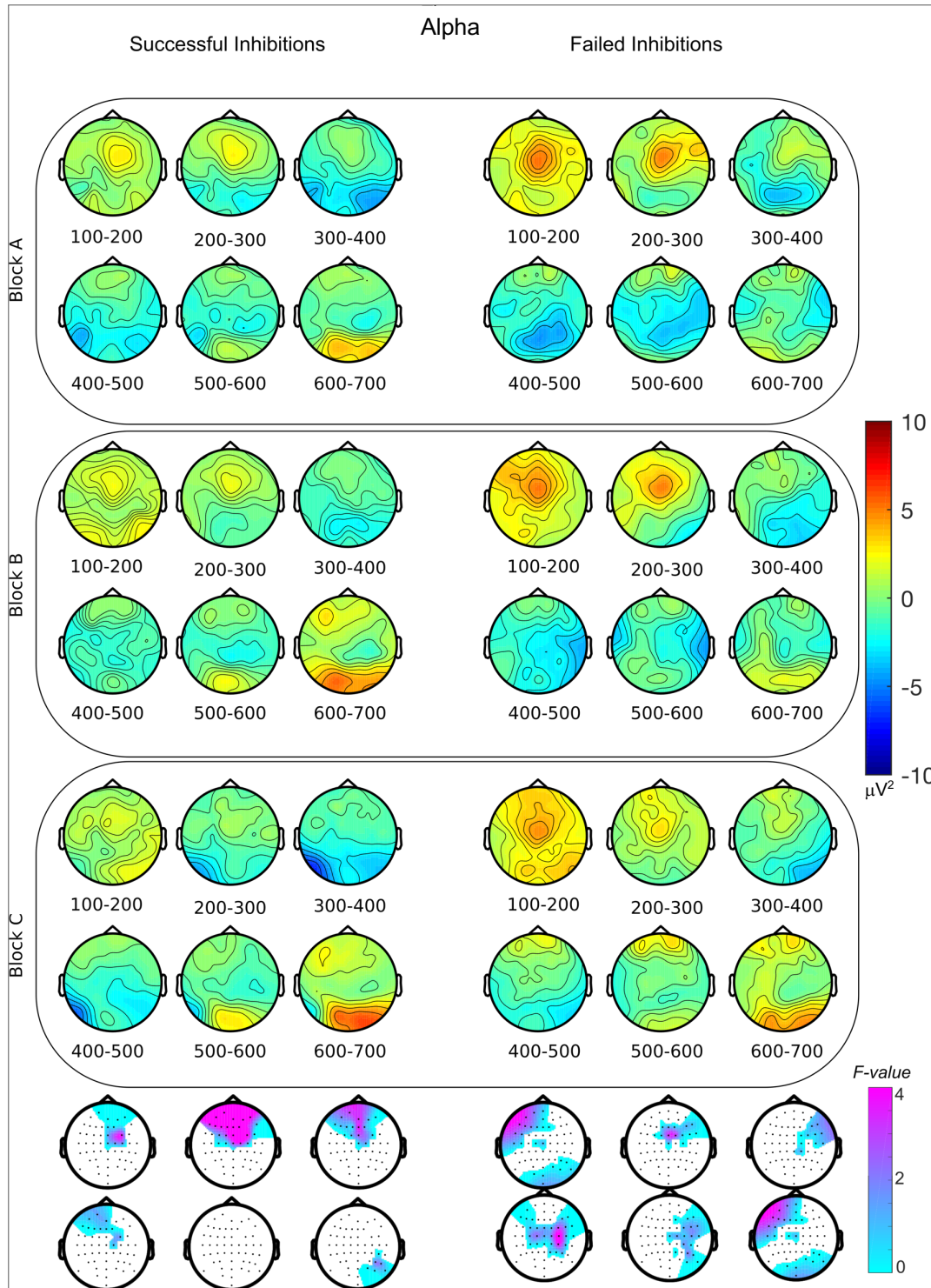


Figure 10 Alpha Figure (EMO-SS)

Time frequency decompositions for Alpha (8-15Hz) activity for successful inhibitions (left), failed inhibitions (right) with F-map both comparisons (bottom).

2.4.5. Beamforming source estimation to Successful Inhibitions

The purpose of the oscillatory exploratory data analysis (Figures 8-10) was to target the condition(s) and latency to concentrate on for beamforming source estimation in order to compare the Block effect for delta, theta, and alpha. The 200-300ms time window for successful inhibitions was selected for this deeper analysis. To validate this selection, the activity of each frequency group in Block A was correlated to approach and avoidance variables as well as Frustration and Motivation scores. This was done for Block A as it would provide the association between variables before the activity becomes dysregulated. The delta activity was correlated to approach ($r=.52, p<.00$) but not avoidance, while theta was negatively correlated to Frustration ($r= -.36, p=.03$), B ($r= -.54, p<.00$) and C ($r= -.49, p<.00$) and was unrelated to Motivation while alpha was positively correlated with avoidance ($r= .4, p=.02$) and negatively correlated with approach ($r= -.4, p=.02$).

Frequency	Index	MNI	Talairach	Talairach Client	Brodmann
Delta	D1	37 ,-1, 21	35,-1,22	Right Cerebrum, Frontal Lobe, Sub-Gyral, Insula	-
Delta	D2	40, 9, 21	38,8,22	Right Cerebrum, Frontal Lobe, Inferior Frontal Gyrus, Gray Matter	BA44/9
Delta	D3	35, -1, 21	34, -1, 21	Right Cerebrum, Sub-lobar, Insular	-
Delta	D4	-40,-62, -26	-39, -63, -18	Left Cerebellum, Posterior Lobe, Declive	-
Theta	T1	59,-50,-20	57, -51, -12	Right Cerebrum, Temporal Lobe, Inferior Temporal Gyrus	BA37/20
Theta	T2	-18,26,16	-17,24,16	Left Cerebrum, Frontal Lobe, Sub-Gyral	(44,45,46,9, 8,10)
Theta	T3	-20,22,27	-19, 21, 25	Left Cerebrum, Frontal Lobe, Sub-Gyral	-
Alpha	A1	-37,19,-7	-36, 15, -3	Left Cerebrum, Sub-lobar, Insula	BA 47/13, left insula
Alpha	A2	-14,35,45	-14, 36, 41	Left Cerebrum, Frontal Lobe, Superior Frontal Gyrus	BA8

Table 2 Source Estimation Voxel Talairach and Brodmann Conversions

Dynamic imaging of coherent sources (DICS) was used to compute the cross-spectral density matrices for the scalp activity for reference free amplitudes (Gross et al., 2001). The Boundary Element Method volume conduction model available in FieldTrip

(Oostenveld, Stegeman, Praamstra, & van Oosterom, 2003) and the standard MNI Colin Holmes MRI (Holmes et al., 1998) were used to compute and visualize the headmodel. Three-dimensional electrode locations for the 10-10 system were aligned to the same coordinates of the headmodel and the leadfield matrix was computed with a 1 cm resolution. The DICS regularization parameter was set to 5%. Beamforming analysis was done for each Block (A, B, C) and Frequency (Delta, Theta, Alpha) for successful inhibition trials. To isolate the source estimation differences between Blocks a dependent-samples univariate Monte Carlo permutation analysis with 10,000 randomizations was calculated separately for Delta, Theta, and Alpha. The pseudo *F*-values were then plotted in MNI-space. The single-point x,y,z coordinates for the midpoint of each coherent region were extracted and input into the MNI2TAL application from the Yale Bioimage Suite Package which converts MNI to Talairach coordinates (Lacadie, Fulbright, Rajeevan, Constable, & Papademetris, 2008) and estimates the corresponding Brodmann areas (Lacadie, Fulbright, Arora, Constable, & Papademetris, 2008). The Talairach Daemon (Lancaster et al., 1997, 2000) was used to retrieve the brain labels, according to the Talairach Atlas, and to cross-validate the Brodmann Area estimations from the MNI2TAL application (Table 2). For an unbiased comparison with fMRI studies the MNI coordinates were also input into Neurosynth, a platform for large-scale automated synthesis of fMRI data (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). Neurosynth works in two ways, first a keyword search can be used for a metanalysis of fMRI studies using that keyword, second the coordinates can be used so that all the fMRI studies reporting that coordinate will be included in the metanalysis. In this case the latter approach was used.

For Delta (Figure 11) there were four potential regions of interest, largely in the right hemisphere. The first (D1, Table 2) was a right medial frontal region extending down into the insula, falling outside defined Brodmann areas. Neurosynth associates this area with fMRI studies ranging from pain (effects on cognitive load and real versus imagined pain), familiar face perception, to more cognitive mechanisms such as the effects of concurrent processing on attentional resources and the effects of gains and losses on source memory encoding.

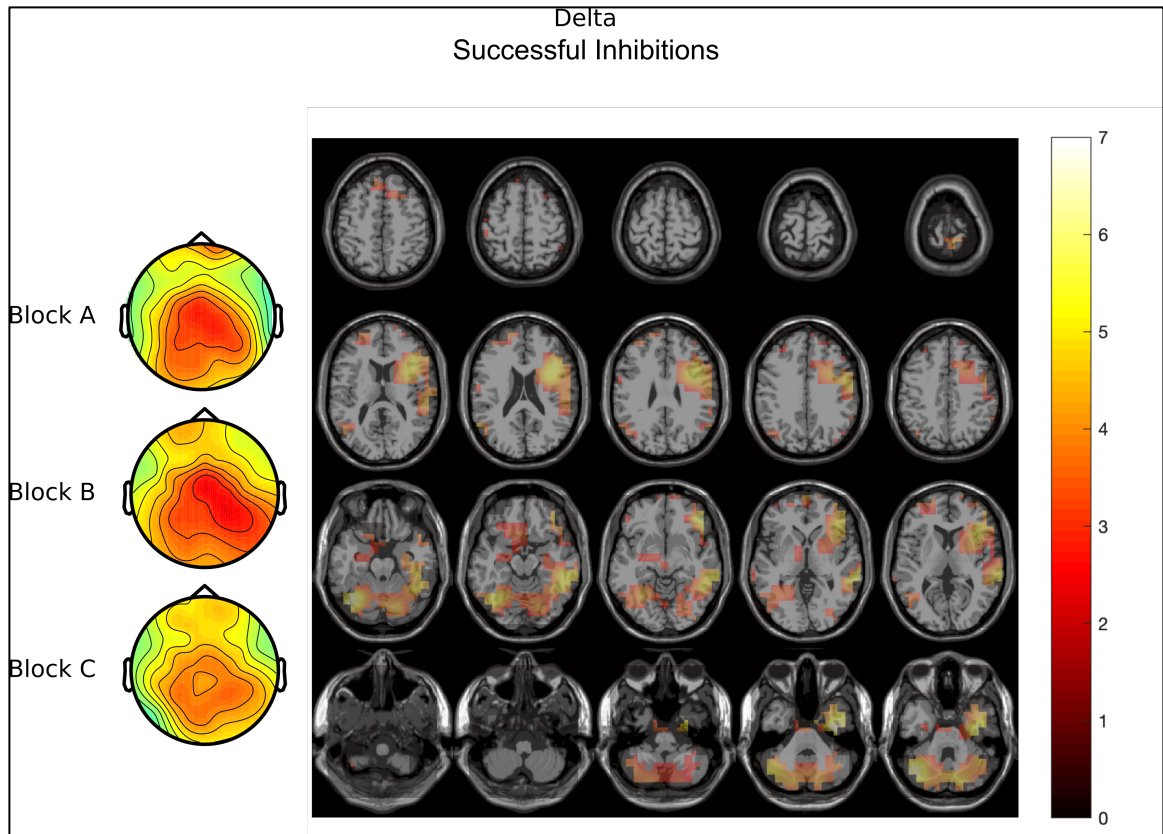


Figure 11 Delta Source Figure (EMO-SS)

The next Delta region (D2, Table 2) was also in the right frontal lobe but is more dorsal and anterior than D1 falling in the Brodmann 44 area, related to selective response suppression (Forstmann, van den Wildenberg, & Ridderinkhof, 2008), and Brodmann 9, which is associated with a very broad range of cognitive and affective processes. A Neurosynth meta-analysis also relates D2 with a range of variables including working memory, emotional-cognitive interaction, pleasant and unpleasant emotion induction, insula-cingulate network, cognitive reappraisal in major depressive disorder, and gambling tasks.

The next delta region (D3, Table 2) was in the right parahippocampal, sub-lobar insula region, falling outside defined Brodmann regions. The Neurosynth analysis of this region relates this spatial area to studies on face processing (general and emotional), learned helplessness, emotional memory, and loss of the inhibitory influence of the cingulate. The final region (D4, Table 2), is the only delta region in the left hemisphere, and is more inferior than the others spanning the fusiform and the cerebellum. The most common activity this region is related to is face processing, though it is also reported in

fMRI conditioning studies related to aversive stimuli and emotional decision making in anxiety.

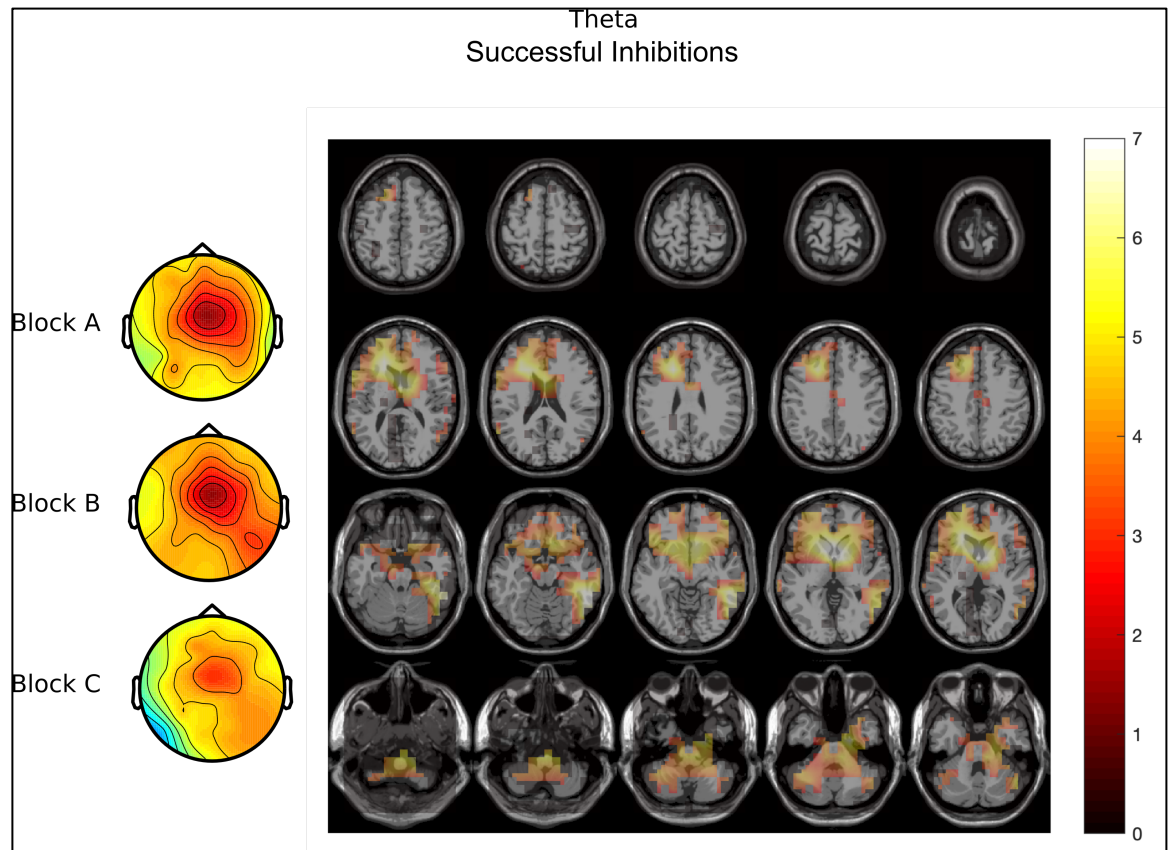


Figure 12 Theta Source Figure (EMO-SS)

The Theta frequency has two potential regions of interest, one in the right hemisphere (T1, Table 2). T1 is in the inferior right temporal lobe, falling in the Brodmann 37 fusiform face area. The next region (T2, Table 2) is in the left medial prefrontal cortex at a junction of several Brodmann Areas (44, 45, 46, 8, 9, 10), which taken together involve processes for planning complex movement, uncertainty, high-level executive functions including stimulus-representation retrieval, strategy, and decision making. Similarly, a Neurosynth search associates this area with response conflict and inhibition, reward anticipation, emotional learning and reappraisal and social cooperation.

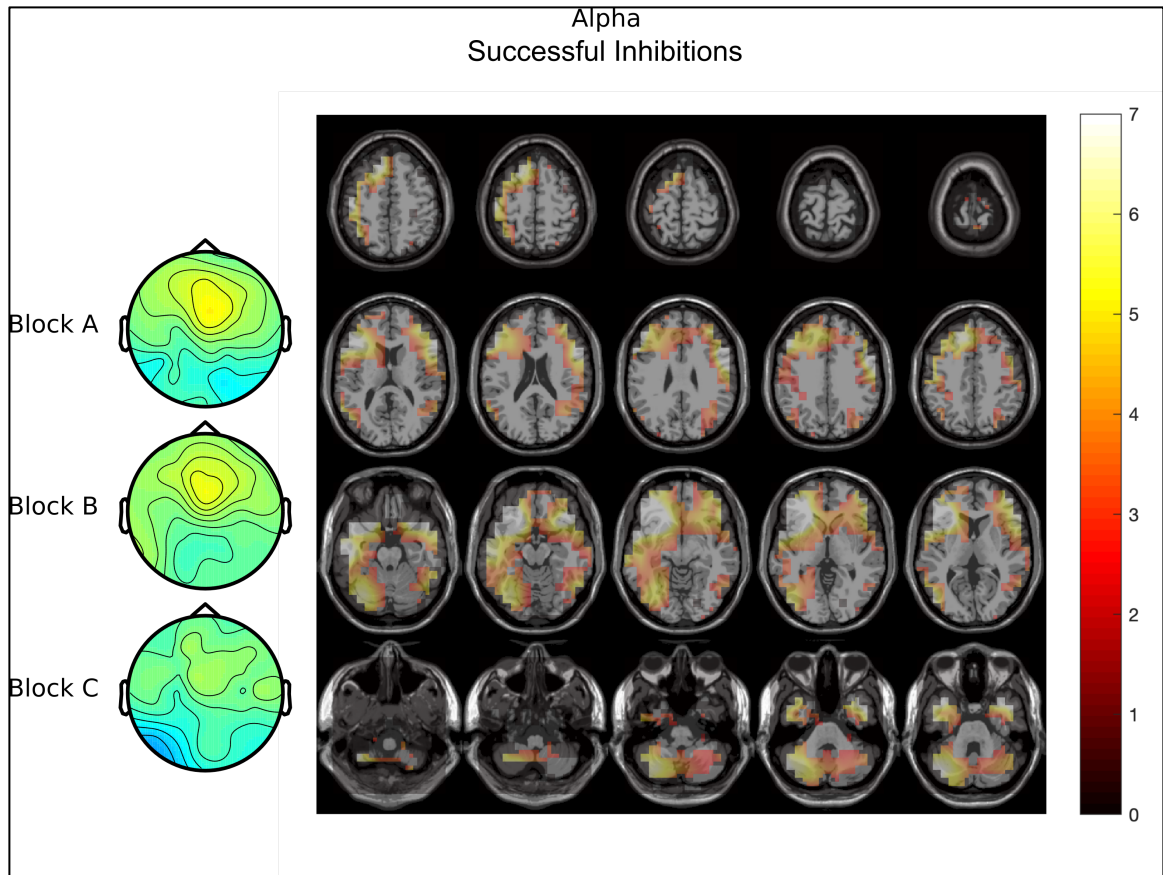


Figure 13 Alpha Source Figure (EMO-SS)

The Alpha frequency had two main regions of interest, both of which appear bilateral though with greater intensity in the left hemisphere. The first (A1, Table 2) was in the anterior insular cortex, or Brodmann Area 13, a region which is increasingly associated with subjective emotional experience particularly during emotional tasks with cognitive demand (Phan, Wager, Taylor, & Liberzon, 2002b). More traditionally in fMRI studies the A1 region is associated with stop-signal tasks, response inhibition, fear, strategy and errors. Finally, the second alpha region (A2, Table 2) falls squarely into the left frontal lobe, in Brodmann Area 8, an area involved in the management of uncertainty. A Neurosynth search associates this region with fMRI studies on the interaction between cognition and emotion during response inhibition and dopaminergic circuits in reward processing.

2.5. EMO-SS Discussion

The prediction that reaction time on valid go trials would be sensitive to exogenous (Valence) affective manipulation was supported, with slower reaction times to Angry faces. Go reaction time was also sensitive to the manipulation of endogenous (Block) affect, with Block C having the slowest reaction time.

While probability of inhibition was sensitive to the Block manipulation, as predicted, it was lowest in Block C, not Block B. Similarly, signal-respond (error) reaction time was fastest in Block C, not Block B. Contrary to predictions, Stop-Signal Reaction time was very robust across Blocks, suggesting a stability to the speed of response inhibition processes once they are engaged.

Emotional experience did change across Blocks, with continuous self-reported Frustration scores spiking in Block B, as predicted. However, there was an increase in Frustration, on average, which continued into Block C instead of decreasing once gains/losses were again of equal magnitude. Motivation scores had an inverse pattern where there was a sharp decrease between the baseline and unfair punishment blocks which continued into the baseline-change block. There was a strong relationship between Frustration and Motivation in the baseline and baseline-change blocks, with increases in one corresponding to increases in the other. However, in the unfair punishment block this relationship was lost, while a negative correlation was expected. While this does not support the hypothesis that Frustration and Motivation would be related to each other across blocks it does make sense in light of evidence from the data that neither Frustration nor Motivation returned to baseline values in the baseline-change block. This suggests that the emotional experience of some participants may have hit a ceiling in the unfair punishment blocks which caused a disengagement from the task.

Contrary to predictions there was no relationship between Drive and Motivation overall or at the block level, nor was there a relationship between avoidance and Frustration. However, both Drive and Motivation related to reaction time with high scores in Drive associated with faster reaction times for go (valid), signal-response (error) reaction times and stop-signal reaction time (baseline block only).

In the electrophysiological response to task manipulations there were similar but almost perfectly inversed effects between posterior and anterior scalp locations and

early versus late latencies. For instance, the amplitude of the vertex positive potential was sensitive to the exogenous affective stimuli, with an overall greater amplitude following angry faces, which was particularly pronounced in the punishment block and was related to behavioral approach variables (Fun-Seeking and Reward). The same pattern of results was apparent over posterior scalp locations at a later latency where amplitude was also positively shifted in the punishment block following Angry faces compared to Neutral. This difference was related to avoidance for Angry faces (with those higher in avoidance having more positive amplitudes) while the amplitude following Neutral faces was related to Frustration levels in the punishment block (with greater frustration corresponding to less positive amplitudes). Alternatively, if the latencies and spatial locations are flipped there is a different pattern of results. In this case there is a strong effect of the block manipulation for both early and late ERP components with posterior (N170) amplitude shifting positively in amplitude and anterior (frontal LPP) amplitude shifting negatively in amplitude. For both the N170 and the LPP there was an absence of an exogenous emotion effect and an absence of any relationship with approach, avoidance, or emotional experience scores. Based off of the timing, scalp topography, and sensitivity to the punishing block it is likely that this “anterior LPP” effect may actually be a fronto-polar ERP (Fp450), which previous literature has linked to punishment associations and the effect of punishment on cognitive control (Wang, Kleffner, Carolan, & Liotti, 2018; Schmajuk, Liotti, Busse, & Woldorff, 2006; West, Bailey, Tiernan, Boonsuk, & Gilbert, 2012; West & Travers, 2007; Bergström, Williams, Bhula, & Sharma, 2016).

The prediction that N2 amplitude would be more negative for successful than failed inhibitions was supported by the data, as was the prediction that N2 amplitude would be most negative for successful inhibitions in the punishment block. However, the difference between blocks was characterized by a reduction in N2 amplitude in the baseline-change block rather than an increase in negativity for the punishment block. While behavioral avoidance and Frustration scores were predicted to relate to N2 amplitude a regression analysis produced avoidance and approach (Drive, Reward-Responsiveness) variables as significant variables while Frustration did not correspond to N2 amplitude.

Increases in slow (delta) frequencies over frontal scalp were related to motivational processes at the trait (approach variables) but not the state level, and only

in the baseline block. This supports the interpretation that delta oscillations are involved in motivation as the relationship is seen prior to endogenous affective dysregulation and not at all after. Power in the delta-band was sensitive to the block manipulation with differences between blocks occurring relatively early and extending several hundred milliseconds (100-400ms). However, this pattern of results was not unique to delta frequencies but is also present in theta (which is even more temporally diffuse) and alpha (more temporally restricted, with a more anterior distribution). Two further hypotheses about theta, that it would be stronger for successful inhibitions and be related to avoidance variables, were not supported by the data. On the contrary, theta was stronger (and more stable) for failed inhibitions and was related not to trait avoidance but to emotional experience. Baseline-block theta activity was related to Frustration scores with lower levels of theta power in the baseline block corresponding to higher frustration scores. As predicted, alpha was related to both approach and avoidance variables. Alpha power in the baseline-block had an inverse relationship with approach and avoidance such that increases in alpha were associated with increases in avoidance while increases in alpha were associated with decreases in approach.

Due to the unexpected complexity of the results at the emotional experience, behavioral, and scalp levels, it was not surprising that the results of the source estimation analysis were similarly complex. As predicted, delta-driven differences between blocks were localized to brain regions corresponding to the saliency network, in particular insular and temporal pole areas (Seeley et al., 2007) with a more dorso-lateral right prefrontal cortical region corresponding to: 1) an area of the affect network associated with anticipation-induced emotion, attentionally distracting secondary tasks and effortful emotion decreasing (Ochsner & Gross, 2005) and 2) the ventral attention system, a component of the central executive network which is sensitive to saliency and uncertainty (Fox et al., 2006). The inferior cerebellar regions cannot be linked with the saliency, affect, or central executive network. Instead this area is reported in very slow (<.1Hz) eyes open default mode network activity in a negative correlation with the precuneus, a combination which has been interpreted to reflect an introspectively oriented mode (Fransson, 2005). Taken together, sensitivity to the block manipulation, the strong link with behavioral approach, the estimated anatomical consistencies with the saliency, central executive, affective, and default mode networks along with the functions found in the same regions in fMRI studies (attentional resources, gain/losses in

gambling, source memory, pleasant and unpleasant emotions, emotional-cognitive interaction, mood induction, and conditioning) support the hypothesis that delta activity may indeed act as a mechanism of homeostasis in controlling endogenous affect while performing a task.

Neither hypothesis about theta power, that it would be stronger for successful inhibitions and related to behavioral avoidance was supported. Instead, for stop-trials, successful inhibitions were weaker in theta power compared to failed inhibitions but were sensitive to the block manipulation and power in the baseline block was negatively related to Frustration. The source estimations of the block-based theta difference correspond somewhat to the central executive network (anterior left and posterior right) but more so to the medial prefrontal cortex. Low theta power in the baseline corresponding to higher scores in frustration and prefrontal cortical differences across blocks combine together to suggest differential recruitment of cognitive control processing (in particular those based on stimulus representations and decision making) due to the endogenous affect manipulation (e.g. greater frustration, lower theta, differences in pre-frontal cortex activity). A striking difference between the role of alpha and delta is their opposite relationship with behavioral approach, supporting the interpretation that it is delta-based activity, not alpha-based, which relates to the generation of motivational drive and approach behavior, whereas the role of alpha activity may be better explained by avoidance behavior.

In the baseline block, increases in alpha power relate to higher avoidance and lower approach scores. The brain regions related to alpha correspond well to the central executive network, though with stronger differences in the left hemisphere, and the saliency network (anterior insula). This suggests the alpha-based processing is also related to the management of cognition-emotion interactions, response inhibition, subjective emotional experience, and reward processing.

Another unforeseen role of alpha, though more broad range (10-20Hz) occurred to the visual stimuli and changed dramatically across blocks (Figure 5). Namely, there was a strong decrease in activity which began quite early (~150ms) and continued through the rest of the epoch. While the topography of this effect was spatially dispersed, the peak effect was over anterior scalp locations, across all valences, and strongest for the punishment block. The continuation of the effect into the baseline-

change block suggests it cannot be explained only by the change in penalties the perceived difficulty of the task, but rather may reflect the effect of the change in endogenous affect on electrophysiology. A similar explanation that relates back to the ERP results is that the inhibition of 10-20Hz activity may be the underlying cause of the Fp450. The latency, topography, and origin of both effects in the punishment blocks supports this interpretation and suggests that the presentation of the stimuli as an external cue of a new trial triggered punishment association as the participant had a great deal of uncertainty in whether the stimuli would be followed by a stop cue (high likelihood of guessing incorrectly).

The overall pattern of results showing a drop-off in performance and brain activity in the baseline-change block suggests that although participants were able to successfully marshal the resources needed to suppress their own endogenously generated affect and maintain performance under stressful and unfair conditions, there was an associated cost after completion of the difficult and punishing block in which participants were unable to match their baseline performance during the “recovery” block. These results underscore the interdependence of cognitive and affective networks and the limitations in their shared resources. The interpretation that the right fronto-insular cortex allocates resources to task-relevant processes by initiating engagement of the central executive is also supported by the results of this study (Sridharan, Levitin, & Menon, 2008). Further, delta activity is implicated to drive the right insular activity, which may then trigger engagement of cognitive control processes via theta and alpha activity.

Chapter 3. Experiment EMO-GNG

3.1. Experiment Overview

By implementing a Go/No-Go paradigm instead of the Stop-Signal paradigm the endogenous and exogenous emotional manipulation effects can be measured independent of task difficulty. Without the interaction of an increasingly difficult task and unfair/frustrating punishments participants are less likely to reach a breaking point of high levels of frustration and low levels of motivation. The Go/No-Go task also eliminates the element of uncertainty characteristic of a Stop-Signal task as the stimulus can always be immediately followed by the response without the possibility of a potential “stop” appearing.

In terms of behavioral effects of the endogenous affective manipulation, Frustration scores are likely to be highest in the punishment block followed by a decrease in the baseline-change block. Both false alarm rate and reaction time are predicted to be sensitive to the exogenous affective manipulation with a greater rate of false alarms following No-Go Angry faces (compared to No-Go Happy and No-Go Neutral) and slower reactions time following Go-Happy and Angry faces (compared to Go-Neutral). Overall, electrophysiological effects for the task predict a more negative N2 for No-Go and related to behavioral avoidance. A slow-wave EAP effect is expected for Neutral compared to Angry No-Go stimuli and will be related to behavioral approach. While the EMO-GNG has a large number of variables, as did the EMO-SS, the approach to understanding the impact of the diverse variables in this experiment was through data reductions techniques (component analyses). For this analysis the data remain on the scalp as event-related potentials.

3.2. Participants and Procedure

This study was approved by the Simon Fraser University Office of Research Ethics. Participants were 21 undergraduate university students recruited from the Research Participation System at Simon Fraser University. Each gave informed consent before participating in a 2-hour ERP session in exchange for course credits. Participants completed a brief self-report medical and demographics questionnaire, and the

Behavioral Activation System/Behavioral Inhibition System scale. They then performed the 40-minute Go/No-Go task (EMO-GNG), during which electroencephalograms (EEGs) were recorded. The EMO-GNG task was based off of the EMO-SS Task from Experiment 1 (Figure 1) with two significant changes which were the lack of a rare stop-signal and the absence of adaptive performance based off of a computer algorithm. Stimuli were a series of faces taken from the Karolinska Directed Emotional Faces database (Lundqvist et al., 1998). Happy, angry and neutral expressions of five unique male, and five unique female faces were selected, grey-scaled, and placed in oval frames to remove jaw- and hairlines. On each trial a single randomly chosen face, featuring one of the three randomly chosen expressions (angry, happy, neutral) was displayed for 300 ms at the center of a black background, with a superimposed, central grey fixation cross. Participants responded using a Logitech game pad and were instructed to press one a button after the faces of the Go gender had left the screen (Go-gender counterbalanced across participants). Responses could be made up for up to 1000 ms after face stimulus offset. Continuous measurement of emotional experience was collected every “mini-block,” i.e. every 40 trials (Goldin et al., 2008). Participants rated their level of motivation and frustration from 1 (“Not at all”) to 5 (“Extremely”) using a 5-point Likert scale, and were then given a 20 second break. Similar to the previous experiment EMO-GNG followed an A-B-C block design, with 6 mini-blocks per block (240 trials). Blocks A and C were “fair” (equal point gains/losses for right and wrong answers), whereas block B was “unfair” (point gains remained unchanged, but all points were lost each time an incorrect response was made). Total amount of points gained was displayed at the end of each mini-block, before motivation and frustration were assessed. Participants were reminded of the point gains and losses at the start of each mini-block, and alerted when the amount of points lost for incorrect responses were altered at the start of Blocks B and C.

3.3. Results

EEG activity was recorded using a 64-channel Ag/AgCl electrode cap at standard 10-10 sites (Biosemi Active Two, Amsterdam), plus electrodes over left and right mastoids, external canthi (for horizontal eye movements), and below each eye (for vertical eye movements and blinks). Voltages were recorded against a common mode sense (CMS) active electrode. Data were sampled at a rate of 512 Hz. Offline, EEG was

digitally filtered (0.01 Hz highpass, 30 Hz lowpass), and re-referenced to average mastoid using FieldTrip (Oostenveld, Fries, Maris, & Schoffelen, 2010). Semiautomatic artifact rejection and visual inspection of the EEG removed trials contaminated by blinks and eye movements. For each block (A, B, and C) individual subject ERPs were time-locked to with a 200 ms baseline until 700 ms following stimuli presentation. Single subject averages were generated to the face (3 levels, Angry, Happy, Neutral), and trial type (2 levels, Go, No-Go).

A multiblock partial least squares (PLS) analysis was used to assesses scalp ERP effects for the EMO-GNG experiment. PLS is a multivariate technique which extracts latent variables (LVs) through singular value decomposition to capture the maximum covariance between the experimental design, scalp activity, and psychometric/behavioral effects (McIntosh & Lobaugh, 2004). rANOVA was used to test for emotion by block difference in accuracy, reaction time, and frustration and motivation scores.

3.3.1. Manipulation Check

Frustration and Motivation scores differed significantly across Blocks ($F(2, 40) = 8.83$, $p < .001$, $\eta_p^2 = .306$). Block B had the highest Frustration and Motivation scores compared to both Block A ($p = .013$) and Block C ($p = .002$) while Block A and C did not differ ($p = 1$). The mean pattern of Frustration and Motivation scores for each mini-block shows that Frustration scores start low and rise quickly, peaking midway through Block B, then fall in Block C though not to baseline levels (Figure 14). On the other hand, Motivation scores begin at a moderate level in Block A, rising and peaking during Block B just as the Frustration score do, however Motivation scores then drop to below-baseline levels. Accuracy for both Go and No-Go trials was high across all blocks (mean accuracy $> .9$), supporting the intention that cognitive demands for the Go/No-Go experiment would be less demanding than the EMO-SS task in Experiment 1.

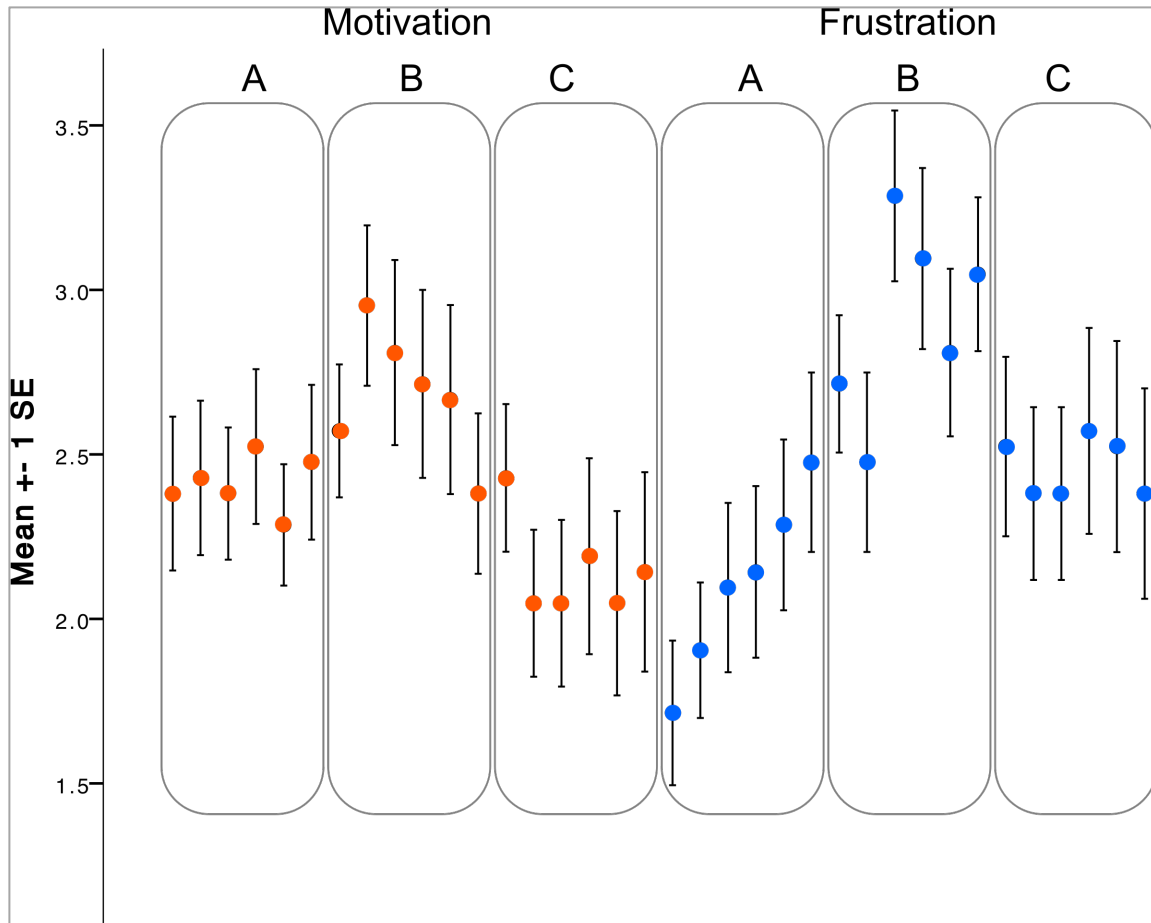


Figure 14 Frustration and Motivation Scores Experiment 2 (EMO-GNG)

3.3.2. Behavioral Results

Reaction Time. Reaction time was sensitive to Block (A,B,C) $F=3.91, p=.028, \eta_p^2=.164$, and Emotional Expression, or Valence (Angry, Happy, Neutral) $F=11.09, p=.001, \eta_p^2=.357$, in the absence of a Block by Valence interaction, $F=1.47, p=.07$. Reaction times to Angry expressions were significantly slower than Happy ($p=.004$) and Neutral expressions ($p=.005$) but did not differ between Happy and Neutral faces ($p=.5$). While there was an overall speeding in reaction time across Blocks pairwise comparisons did not reveal a between-Block difference (all $ps > .05$). This characteristic slowing of reaction times to Angry-Go stimuli supports the original hypothesis. However, this characteristic was most stable in Block A and B and was negligible in Block C (~4 ms mean difference between Angry faces compared to Happy and Neutral in Block C). Once again there is a demonstration of performance maintenance in Block B followed by

a break in Block C which could be due to demotivating effects of maintaining performance during unfair punishments in Block B. Even though the task was less cognitively demanding than the EMO-SS task, the errors in the EMO-GNG are true errors, actual keystroke mistakes, which could have impacted the block effect and facilitated the global speeding of responses to all Go stimuli in Block C.

	Block	Mean	SE
Frustration	A	2.10	.20
	B	2.90	.18
	C	2.46	.26
Motivation	A	2.41	.18
	B	2.68	.21
	C	2.15	.21
Go RT Angry Faces	A	320.15	18.74
	B	303.35	17.51
	C	286.65	16.73
Go RT Happy Faces	A	301.99	19.78
	B	291.02	17.89
	C	282.23	15.70
Go RT Neutral Faces	A	302.36	18.83
	B	299.41	17.15
	C	282.05	16.55

Table 3 Behavioral Descriptive Statistics for Experiment 2 (EMO-GNG)

3.3.3. Scalp PLS Effects

A multiblock partial least squares (PLS) analysis was used to assess design, psychometric, and behavioral effects. The single-subject averages for each participant by Trial Type (Go, No-Go), Block (A,B,C) and Valence (Angry, Happy Neutral) were combined into a data matrix, resulting in a Design matrix of 18 conditions per subject each of the 64 EEG channels. The psychometric and behavioral information was comprised of BIS-Total, BAS-Total, Drive, Fun-Seeking, Reward Responsiveness, Frustration (Blocks A, B, C), Motivation (Blocks A, B, C). The PLS analysis captured the maximum covariance of scalp activity between the Design and Behavioral matrices across the 64 EEG channels through singular value decomposition which produced

orthogonal latent variables (LVs). The number of latent variables produced is equal to the number of conditions plus the product of the number of conditions (18) and behavioral/psychometric measures (7), in this case producing 144 LVs. Permutation tests were used to determine the statistical significance of each LV (McIntosh & Lobaugh, 2004). The strength of an LV is a single value representing the covariance of the design scores and the scalp scores (across electrodes and latencies) for that LV. If, from random permutations, there are no other values equal to or greater than this single LV score 95% of the time ($p < .05$) the LV is considered to be statistically significant. In addition to the permutation test for statistical significance bootstrap resampling was also performed to assess reliability of the effect. The purpose of the bootstrap procedure is to identify the portions of the LV (in space and time) that show reliable experimental effects. If the strength of the LV depends on which observations (i.e. participants) are in the sample, then the effect is not reliable and will have a low bootstrap ratio.

	Singular Value	Percent Covariance	p
LV1	5.77	21.55%	.000
LV2	3.58	8.37%	.007
LV3	3.29	7.08%	.000
LV4	2.76	4.97%	.002

Table 4 PLS Singular Values and Percent Covariance

Latent Variable 1 (LV1)

The EMO-GNG PLS resulted in four significant latent variables (Table 3). The task PLS design scores demonstrate the weight of each condition for each latent variable. The four significant LVs have differential condition weights. Task design scores represent the effect of that LV across all scalp locations and latencies.

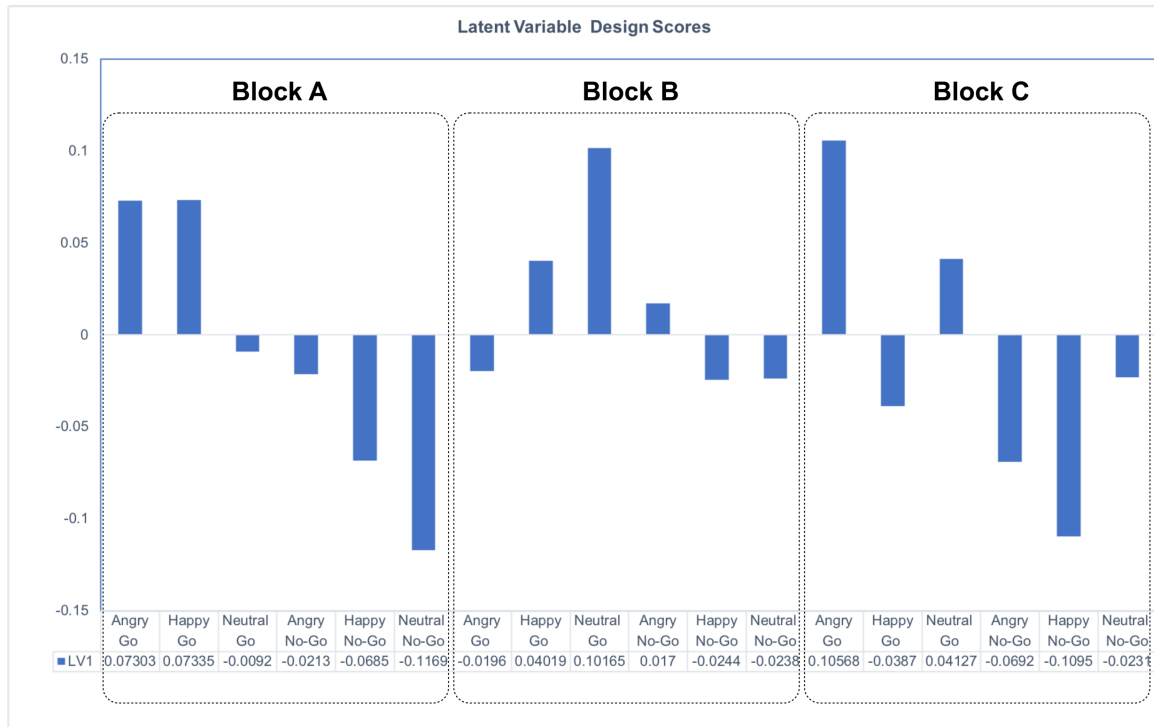


Figure 15 EMO-GNG PLS Design Scores LV1

Design score differences in LV1 are a complex interaction of Block, Valence, and Task (Figure 15). For Block A the largest differences are between Angry/Happy Go stimuli and Happy/Neutral No-Go stimuli. For Block B the biggest difference is between Neutral-Go and Neutral No-Go stimuli whereas in Block C there is a low impact of Neutral stimuli but a high contrast between Angry-Go stimuli and Angry/Happy No-Go stimuli. This complex configuration of results is clarified by the scalp scores for LV1 (Figure 16). The central-parietal topography which extends laterally on both hemi-scalps is consistent with both EAP/MFN and P3/LPP. In addition, the latency of the bootstrap stability (~400-600ms) matches P3 and LPP latencies (Figure 16, C4, CP1), with earlier (~280ms) bootstrap stability at more anterior and lateral electrode locations (Figure 8, F5). The conjunction of these two ERP components into one latent variable explains the effects of Task and Valence. The lateralization of the scalp effects suggests the early latency effects (~280) to be more related to EAP modulations, rather than N2 modulations.

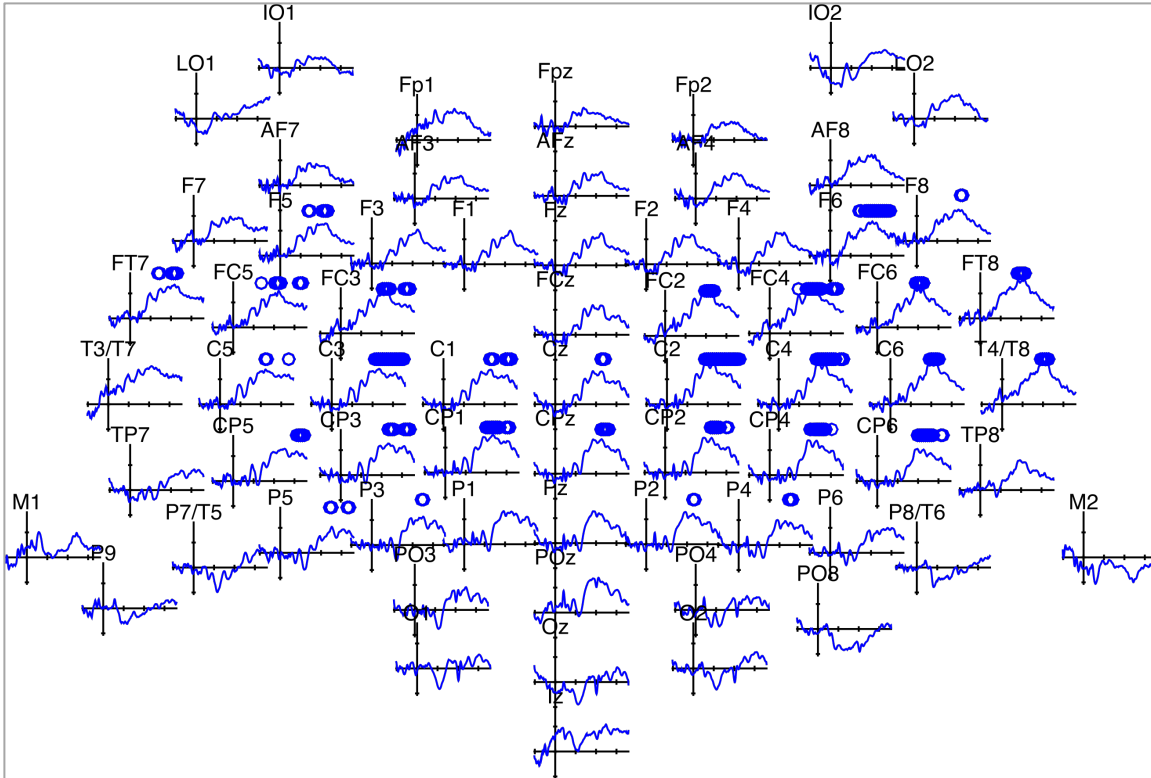


Figure 16 Scalp Scores LV1, y-axis is in PLS Score units

In addition to design effects the PLS analysis also estimates the effects due to psychometric and behavioral information. Brain scores are estimated for each subject and each latent variable and the correlation between brains scores and other measurements is produced simultaneously with the latent variable analysis. In this way the behavioral scores can be interpreted at behavioral weights on the latent variable. For LV1 Behavioral approach (BAST), and in particular Drive and Fun-Seeking, were strongly related to No-Go stimuli, particularly in Block A, such that negative saliences related to greater scores in the psychometrics scales while positive saliences were related to lower scores on the psychometric measures (Figure 18).

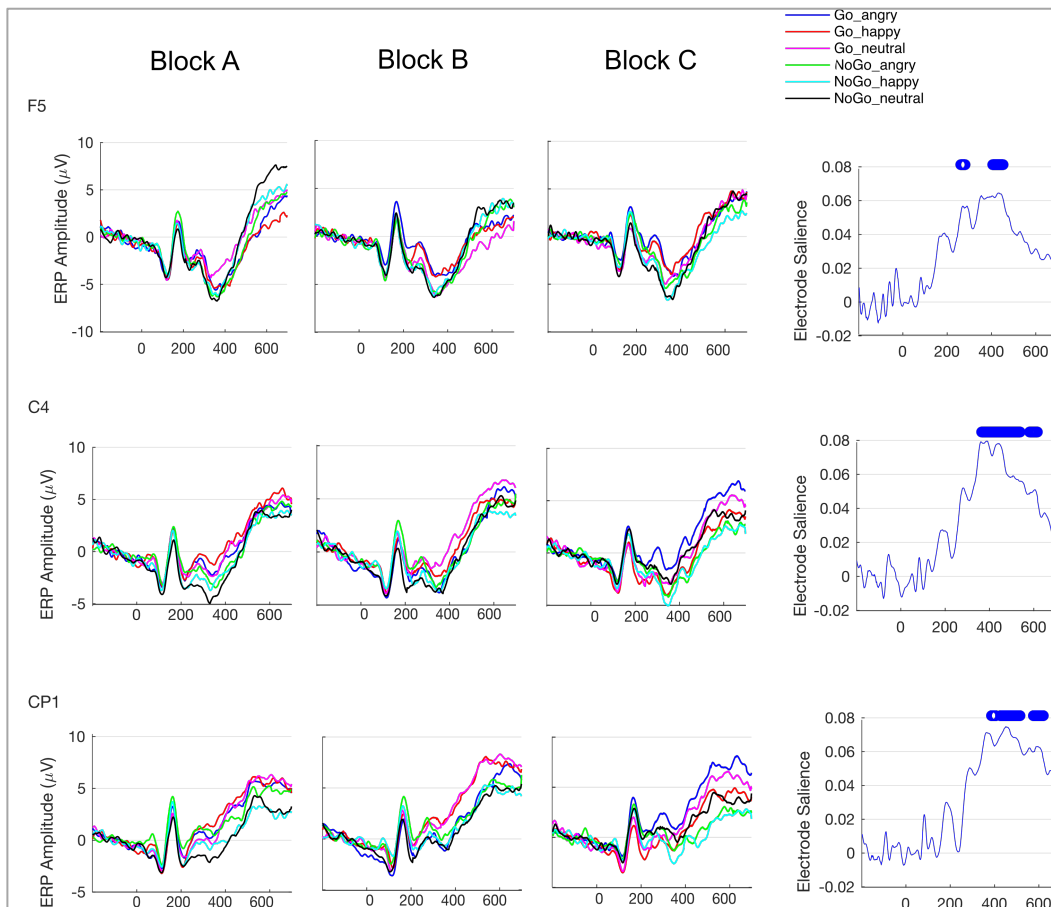


Figure 17 ERP and Scalp Scores for LV1

The behavioral scores have a complex background of correlations (Table 5). In Block A brain scores in the Angry-Go condition were negatively correlated with avoidance (BIS; $r = -.46$). Brain scores in the Neutral-Go condition have relationships with Frustration ($r = -.43$), Drive ($r = -.46$), Fun-Seeking ($r = -.50$), and BAST ($r = -.51$). In Block A the Angry/No-Go condition brain scores were negatively correlated with Drive ($r = -.45$), Fun-Seeking ($r = -.45$), and BAST ($r = -.50$). Brain Scores in the Happy/No-Go condition were negatively correlated with Fun-Seeking ($r = -.44$) and BAST ($r = -.42$). Lastly, Neutral/No-Go brain scores were negatively correlated with Frustration ($r = -.48$), Drive ($r = -.44$), Fun-Seeking ($r = -.40$), Reward-Responsiveness ($r = -.51$), and BAST ($r = -.55$).

In Block B brain scores in the Neutral-Go condition were related to avoidance (BIS; $r = -.44$). Brain scores in the Angry/No-Go condition were related to Reward-Responsiveness ($r = -.46$) and BAST ($r = -.44$). For the Happy-go condition brain scores were related to Drive ($r = -.61$), Fun-Seeking ($r = -.42$), and BAST ($r = -.54$).

Brain scores in Block C were correlated with Drive for Angry-Go ($r = -.43$), Neutral-Go ($r = -.45$) and Angry/No-Go ($r = -.51$) conditions. Angry/No-Go brain scores were also correlated with Frustration ($r = -.45$) and BAST ($r = -.51$).

In sum, LV1, the latent variable representing P3/LPP complexes (and perhaps the EAP/N2) was sensitive differences between Block, Task and Valence. Approach variables had strong scores for LV1 particularly Fun-Seeking, Drive, and BAST. Given the directionality of the relationship higher scores on approach variables were related to more negative brain scores. Frustration and behavioral avoidance had more intermittent effects characterized by Angry-Go stimuli in Block A and Neutral-Go stimuli in Block B related to avoidance with Neutral/No-Go stimuli in Block B and Angry/No-Go stimuli in Block C related to Frustration. In other words, high scores in behavioral avoidance and Frustration were related to reduced amplitudes in the P3/LPP.

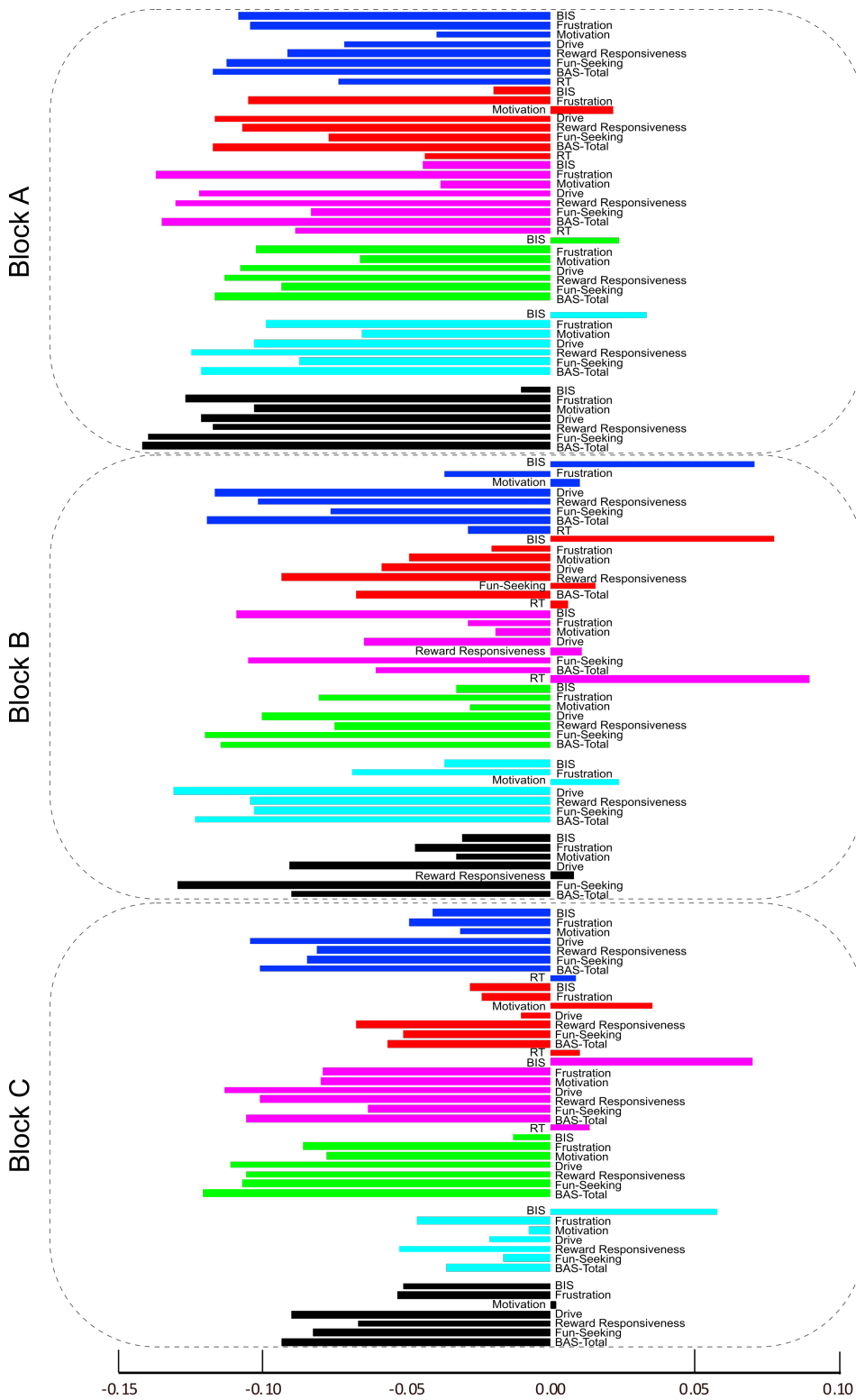


Figure 18 Behavioral PLS Scores LV1, y-axis is in PLS Score units

Latent Variable 2 (LV2).

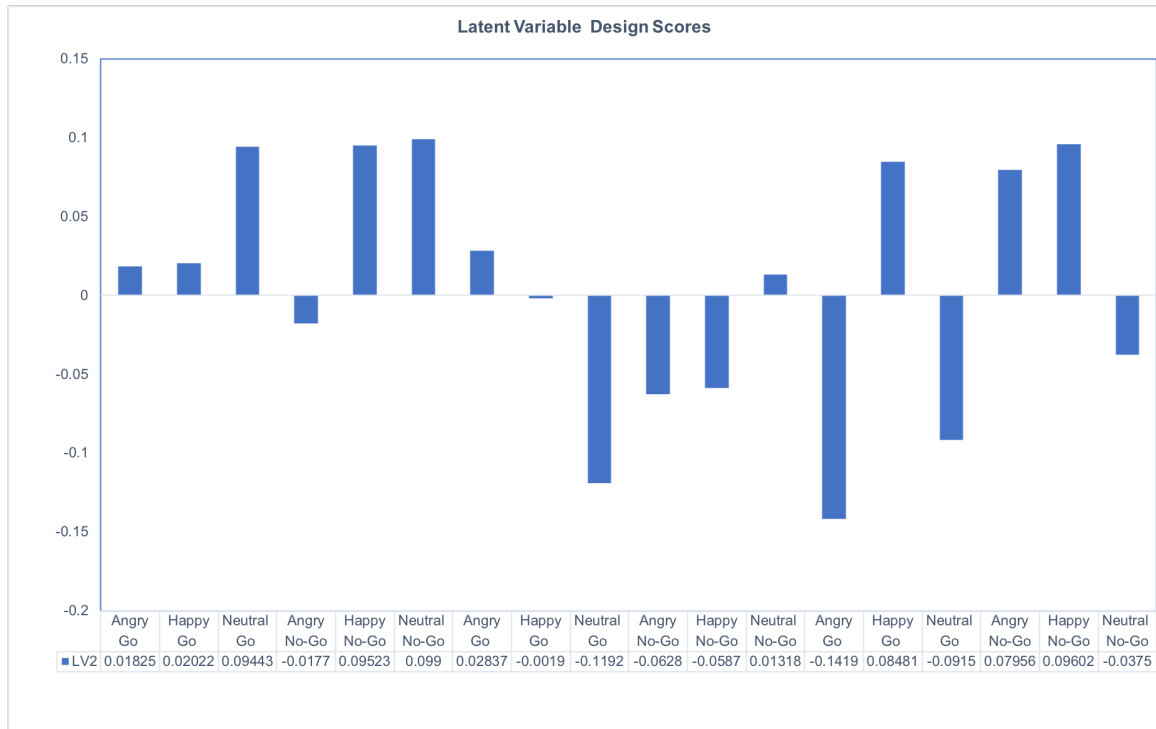


Figure 19 PLS Scores LV2

The design scores for LV2 show a difference between Blocks. The LV2 scores in Block A are strongest for the Neutral-Go stimuli, and the Happy/Neutral No-Go. The design scores then invert in Block A and are strongest for Neutral-Go and Happy/Angry No-Go stimuli. Lastly, in Block C there is a mixture of positive and negative scores with Angry/Neutral-Go having a strong negative design score and Happy-Go as well as Angry/Happy No-Go having strong positive scores.

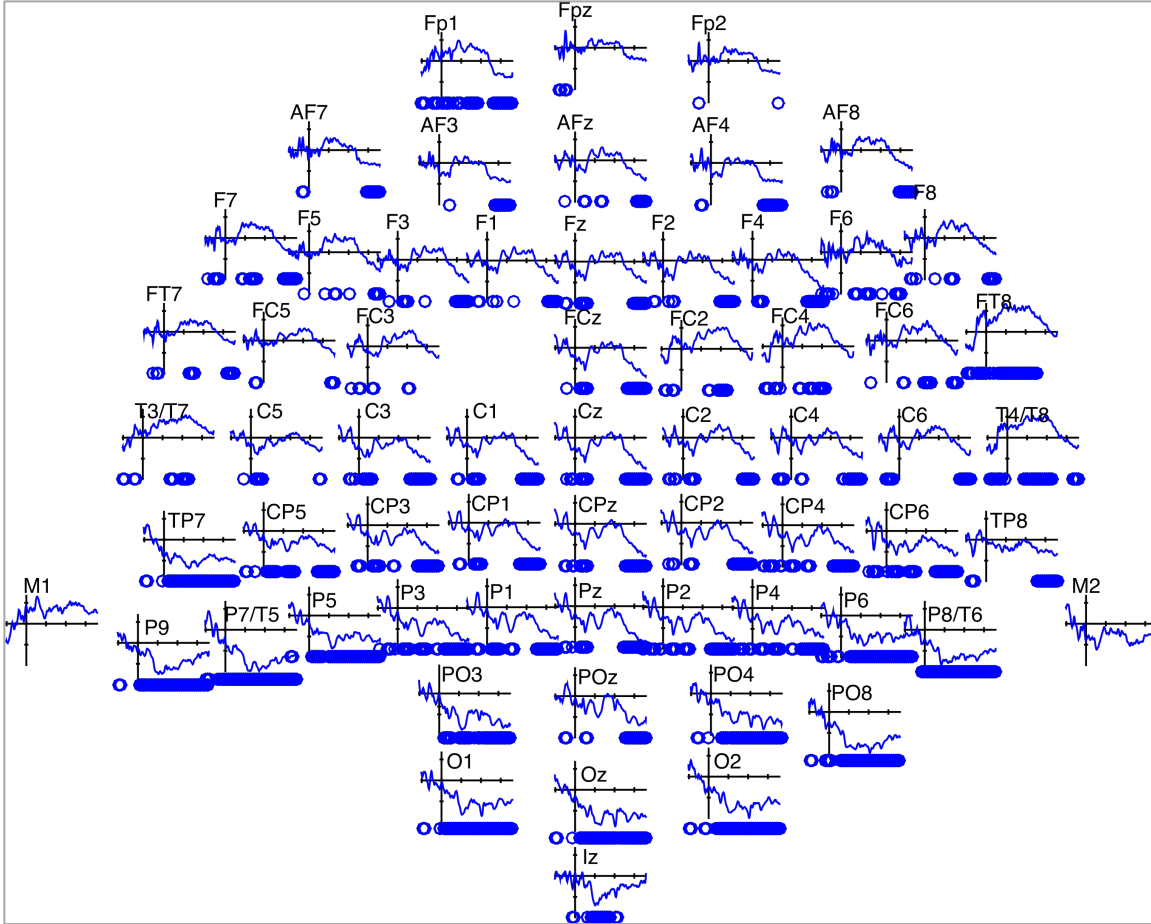


Figure 20 LV 2 Scalp Score Topo, y-axis is in PLS Score units

The scalp scores for LV2 are widely distributed across scalp locations and ERP latencies. For scalp locations along the midline or at anterior locations there are two distinct bootstrap-reliable moments, an early effect between 0-200ms and a later effect beginning at 500ms and extending to the end of the ERP components. Over posterior scalp locations the latent variable effects are throughout the ERP from ~100ms extending the entire length of the epoch.

Three regions of interest from the scalp scores that capture the midline anterior and posterior lateral effects were selected to compare to the ERP grand averages: Cz, PO3, PO4 (Figure 21). Once the grand averages and the scalp scores are placed side-by-side the pattern of effects becomes clear. The early anterior/midline effect maps onto the VPP component, which in Block A is relatively similar across Valences and Task, with No-Go Angry the most positive and No-Go Neutral the least positive, a difference which decreases across Block B and C. Another effect in that same time window and

location is a negative trend of the ERP in this early latency unique to Block B. At the Cz location during the later effect is a noticeably minimal difference in the LPP component for Block A followed by a noticeable divergence of LPP amplitudes in Block B and C. In Block B the LPP amplitude for Go stimuli is more positive overall than No-Go, likely combining with the P3 Go/No-Go effects, showing a marginal difference in Task, but not Valence. For Block C within the No-Go condition Happy and Angry ERPs are attenuated compared to Neutral, while in the Go condition Angry/Neutral stimuli are more positive than Happy. What this pattern of results may suggest is that while Frustration and Motivation are high in Block B, the LPP is more positive across conditions, but particularly for Go stimuli, while in Block C when Motivation is at its lowest there is the greatest divergence between conditions suggesting dysregulation caused by reactivity to the frustration manipulation. In the more posterior electrode locations (PO4/PO3) where LPP effects are strongest there is an even clearer pattern of dysregulation of the frustration manipulation characterized by greater dispersion between amplitudes across Blocks. Specifically, the greatest dispersion is in Block C, where there is an overall Task differences when Go amplitudes are more positive than No-Go as well as a Valence effect where Go-Angry/Neutral are more positive than all other conditions (i.e. in the Go condition, the largest amplitude difference is between Angry and Happy Go stimuli).

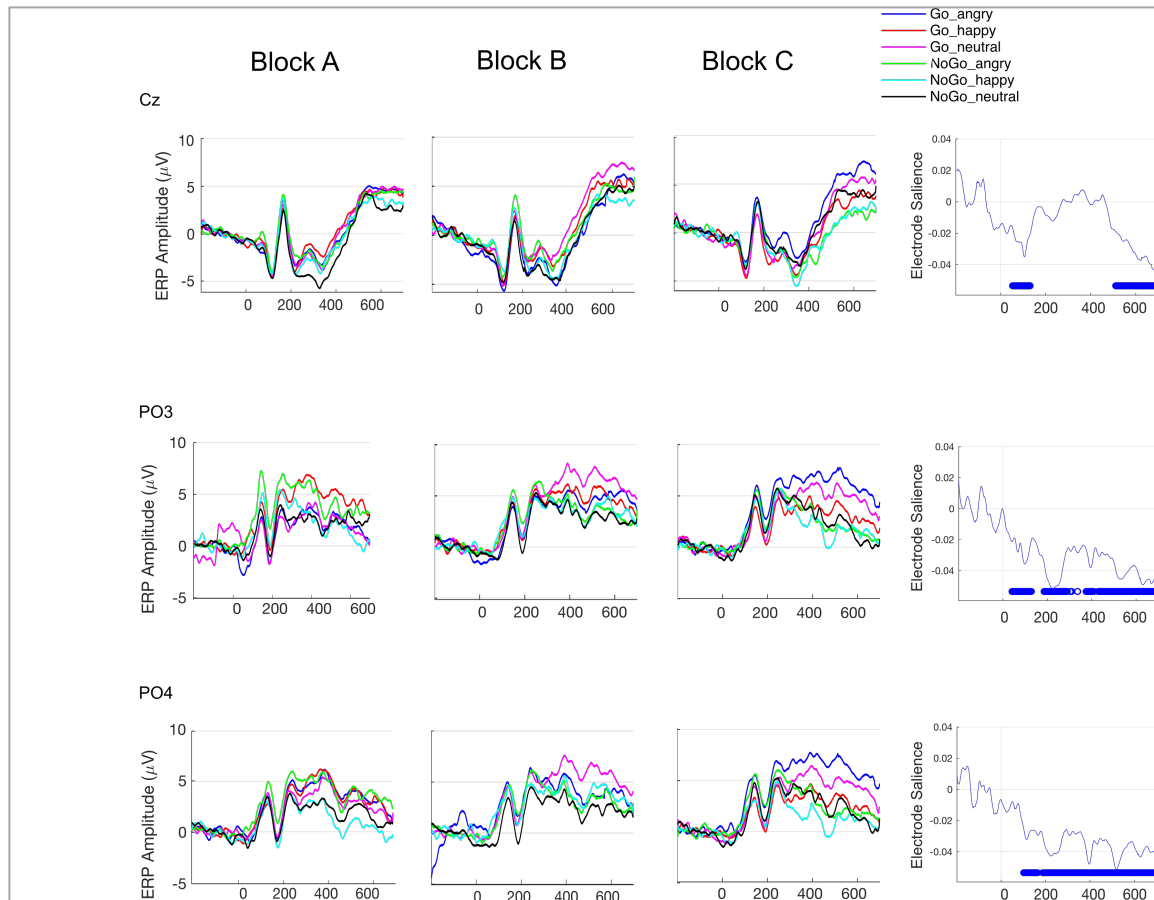


Figure 21 ERP and Brain Scores LV2

Going deeper into LV2 to incorporate the behavioral variables (Figure 22) there are major differences in behavioral weightings across Task, Block, and Valences. In Block A one effect that stands out from the others is a strong weighting for avoidance scores (BIS) unique to the Angry-Go condition which is supported by an underlying correlation of $r=.53$ indicating that as behavioral avoidance increased the overall LV2 score, the LV representing VPP/LPP, also increased, meaning that the more avoidant an individual is temperamentally the less positive their P3/LPP (and perhaps VPP) amplitude (Table 5).

A notable Block difference in behavioral weights during Block B is an overall increase in the strength of the weightings across Tasks and Valences, particularly a reversal of the Angry-Go/avoidance effects ($r= -.4$) and Neutral-Go stimuli which has high weightings across variables and strong underlying correlations with Frustration ($r= -.47$), and Fun-Seeking ($r= -.42$). Hence in Block B, as task demands changed, the

relationship between Angry-Go stimuli and behavioral avoidance changes such that increases in avoidance are now associated with decreases in LV2, which indicates more positive VPP/LPP amplitude. At the same time there is a similar pattern for Neutral-Go stimuli such that increases in Frustration and Fun-Seeking are also associated with more positive P3/LPP potentials (more negative LV2 scores). The relationship patterns change again in Block C, first noticeable in the absence of the relationship between Angry-Go and behavioral avoidance, though now both Angry-Go and Neutral-Go scores are negatively correlated with frustration ($r = -.44$, $r = -.4$) as in Block B, meaning in those conditional high scores of Frustration are associated with larger P3/LPP (and/or VPP). Additionally, Angry-Go brain Scores were positively correlated with reaction time, meaning that in Block C, longer RTs are related to more positive LV2 brain scores, and less positive P3/LPP (and/or VPP) amplitudes. In Block C as well there are strong weights for the No-Go task. In particular there was a strong weight for Motivation in the Angry/No-Go condition, supported by an underlying positive correlation between Motivation and brain scores, corresponding to reduced positivity in the ERP ($r = .61$), a pattern which is also present with Drive ($r = .45$). Lastly, for the No-Go condition in Block C, Happy/No-Go and Neutral No-Go stimuli both have strong negative behavioral weights with Frustration scores, and underlying correlations for both Happy/No-Go ($r = -.47$) and Neutral/No-Go ($r = -.38$).

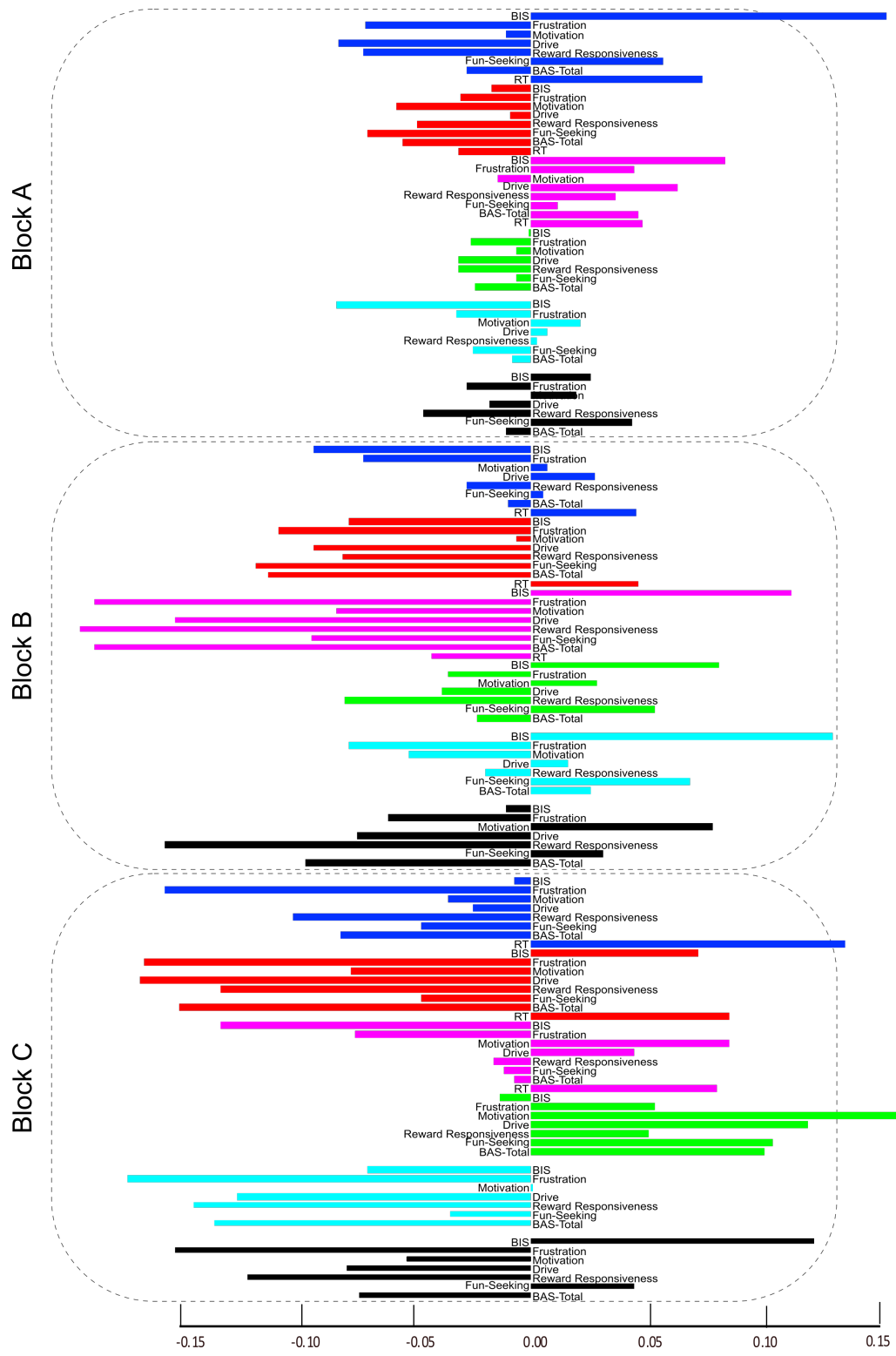


Figure 22 Behavioral Scores LV2, y-axis is in PLS Score units

Latent Variable 3 (LV3)

The third latent variable (LV3) has strong negative loadings across Go stimuli in Block A, and generally positive loadings for that same Block (Figure 23). In Block B there are positive loadings for stimuli except Happy-Go, with a particularly high loading for Neutral/No-Go stimuli. This pattern of results completely reverses in Block C, where all stimuli have weak and/or negative loadings.

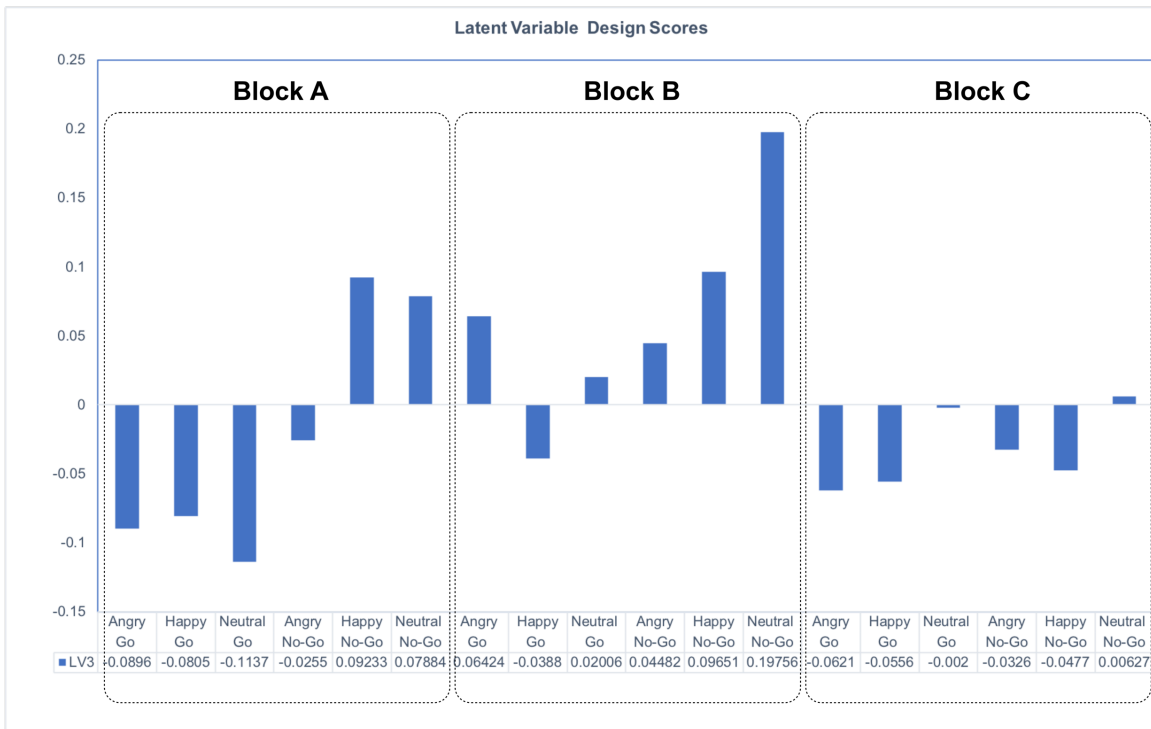


Figure 23 PLS Scores LV3

The scalp topography for LV3 scores (Figure 24) shows a nexus around the vertex that begins quite early and continues on to around 350ms across anterior, posterior and lateral scalp locations. Along the most inferior coronal line and in central-anterior electrode locations there is also a later (~600 ms) effect.

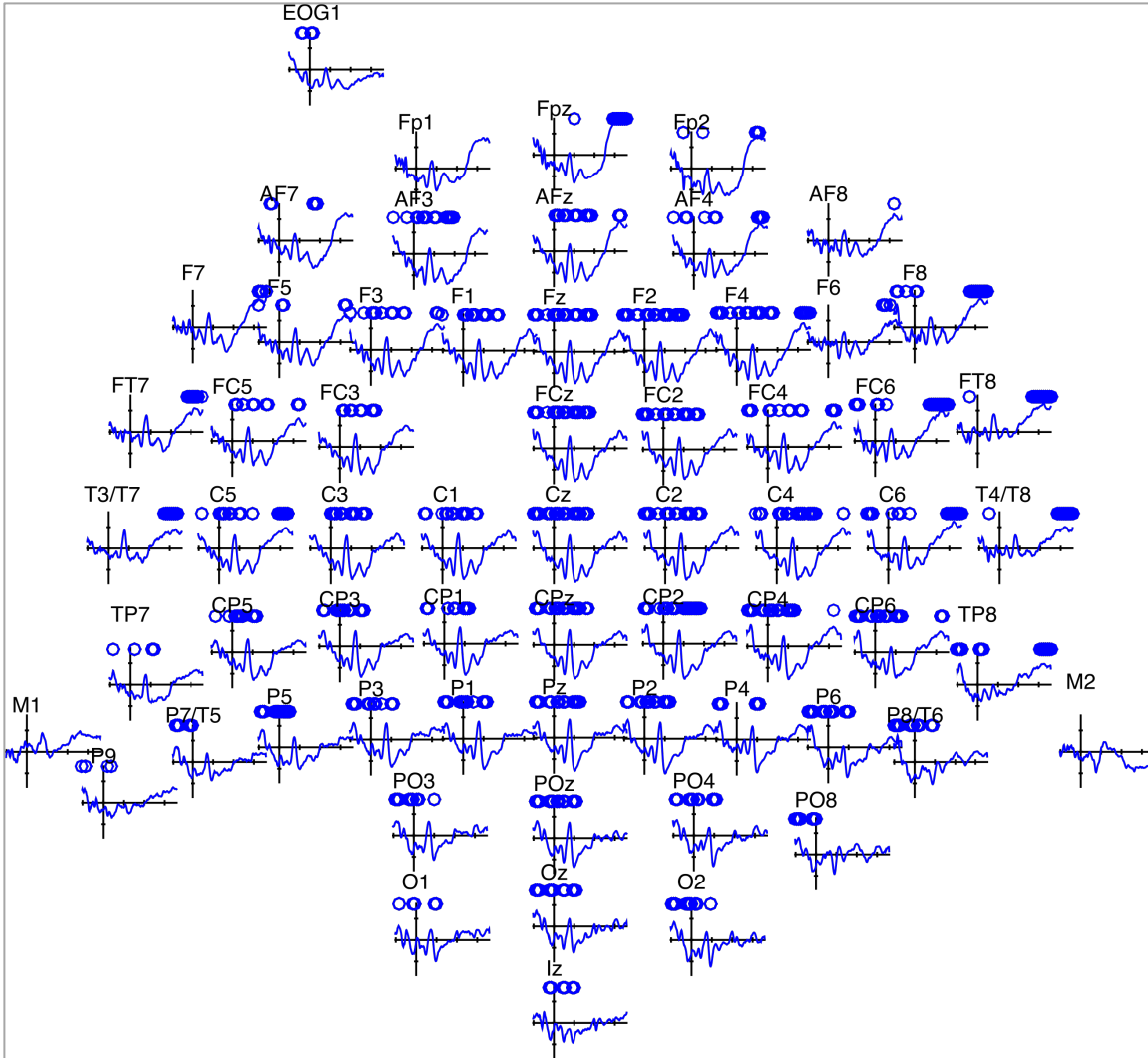


Figure 24 LV3 Topo Scalp Scores, y-axis is in PLS Score units

Three regions of interest were selected to capture the scalp effects and compare them to the ERP condition grand averages: Fpz, FT8, Pz (Figure 25). The early effect, as it appears at Fpz, is the beginning of a Go/No-Go N2 (Fpz Block A, starting at 200ms) which peaks around 400 ms and is clearly differentiated between Task conditions, with a stronger more negative N2 for the No-Go condition (green, cyan, and black lines). The later effect could be a P3, but due to the timing (> 500ms) and the topography (anterior and inferior) it could also be the late ERP component related to response inhibition, particularly in the contexts of reward and punishment, the FN, or Fp450 (Wang et al., 2018), or the anterior LPP unique to EMO-SS and EMO-GNG. The preference for No-Go stimuli, as well as an increase in amplitudes across Blocks and Task conditions such that both Go and No-Go stimuli have greater positive amplitudes in Block C, may reflect

implicit activation in the form of punishment associations, first for trials not requiring an overt categorization or selection or and execution of a motor response (No-Go) and then for all trials in Block C due to the punishment manipulation. For the lateral electrode, FT8, the spatiotemporal LV3 effects coincide with a portion of the ERP which in Block A distinguished between Task (No-Go more negative) and Valence (No-Go Neutral more negative than No-Go Happy/Angry and Go-Neutral more negative than Go-Happy/Angry). This could be the effect of the EAP seen more independently than at midline locations due to less of a temporal overlap with the N2. This pattern becomes less ordered in Block B, when the ERPs to Happy-Go and Happy/No-Go faces are more negative than the other conditions. In Block C the differentiation is largest between Angry stimuli (Go and No-Go) which has the most positive amplitude, and Happy/No-Go stimuli which have the most negative amplitude. The Pz electrode location's effect is at a later latency (~600ms) with an initial differentiation between Go and No-Go in Block A which continues throughout all three blocks then by Block C there is an additional effect of Valence were Angry-Go stimuli have the most positive amplitudes while Happy/No-Go stimuli have the most negative. Given the location, timing, and pattern of results the Pz effect is likely due to the P3 ERP effect.

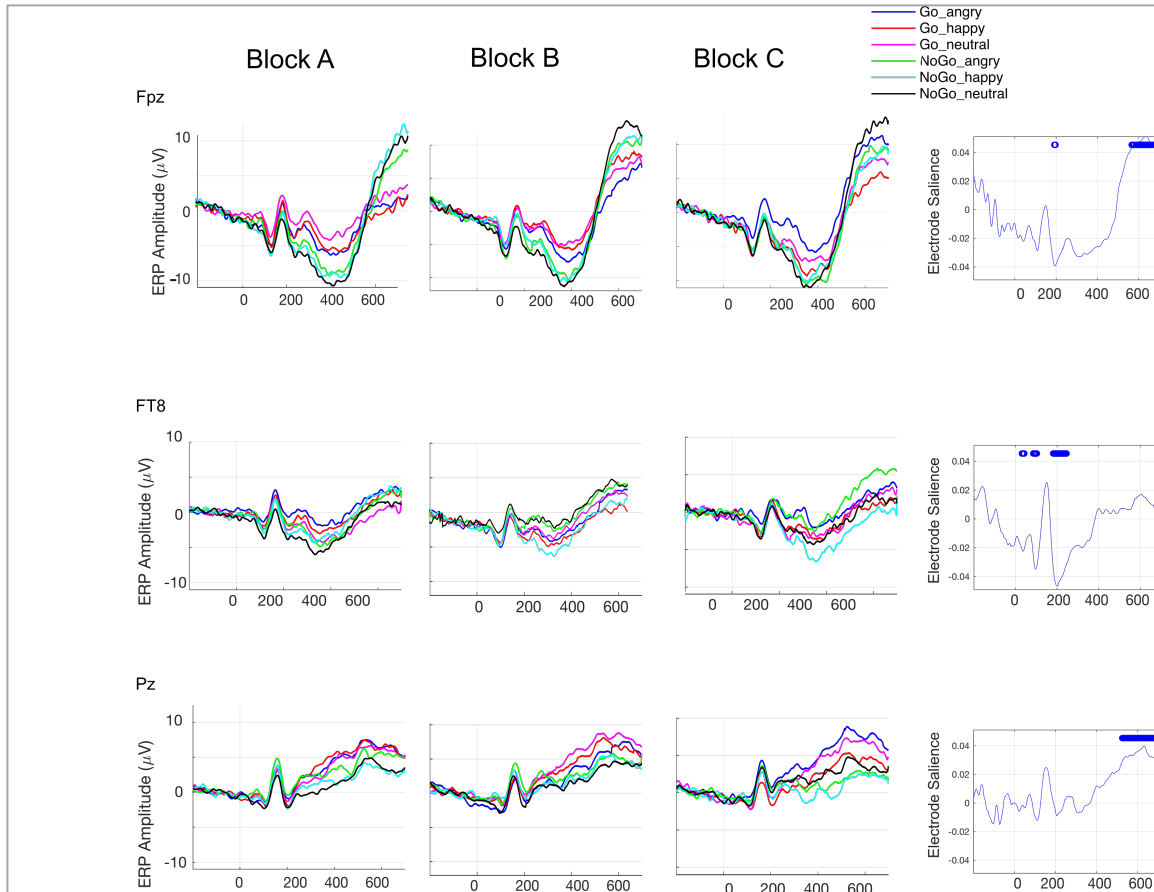


Figure 25 LV3 ERP Scalp Scores

Looking at the impact of behavioral variables there is a clear extreme of behavioral weights in Block C (Figure 26). This is particularly true of the avoidance variable (BIS) for Angry-Go, Happy-Go, Angry/No-Go and Happy/No-Go variables in Block C. In the opposite direction there is also a strong negative weight for reaction time (RT) across all Valences in the Go condition in Block C. These weights are supported with strong underlying correlations (Table 6) in the Go condition for Angry ($r = .51$) and Happy ($r = .50$) valences than in the No-Go condition where the correlations are still present but weaker for both Angry ($r = .41$) and Happy ($r = .43$) stimuli. For Angry/No-Go stimuli there was also a strong correlation with Frustration ($r = .45$). LV3 brain scores correlated in the opposite direction with RT for Angry ($r = -.43$), Happy ($r = -.42$) and Neutral ($r = -.45$) stimuli.

For Blocks A and B there was only one condition that had a correlation with brain scores greater than .4, and that was Happy-Go stimuli in Block A ($r = .41$). Overall,

these results lead to the interpretation that LV3, which represents EAP/FN/P3 is sensitive to the Block, Task, and Valence effects, with the behavioral avoidance variable (BIS) showing a particular relationship with LV3 such that those higher in avoidance had more positive brain scores (whole epoch amplitudes) for Angry-Go and Happy/No-Go stimuli, while longer RTs were associated with more negative brain scores.

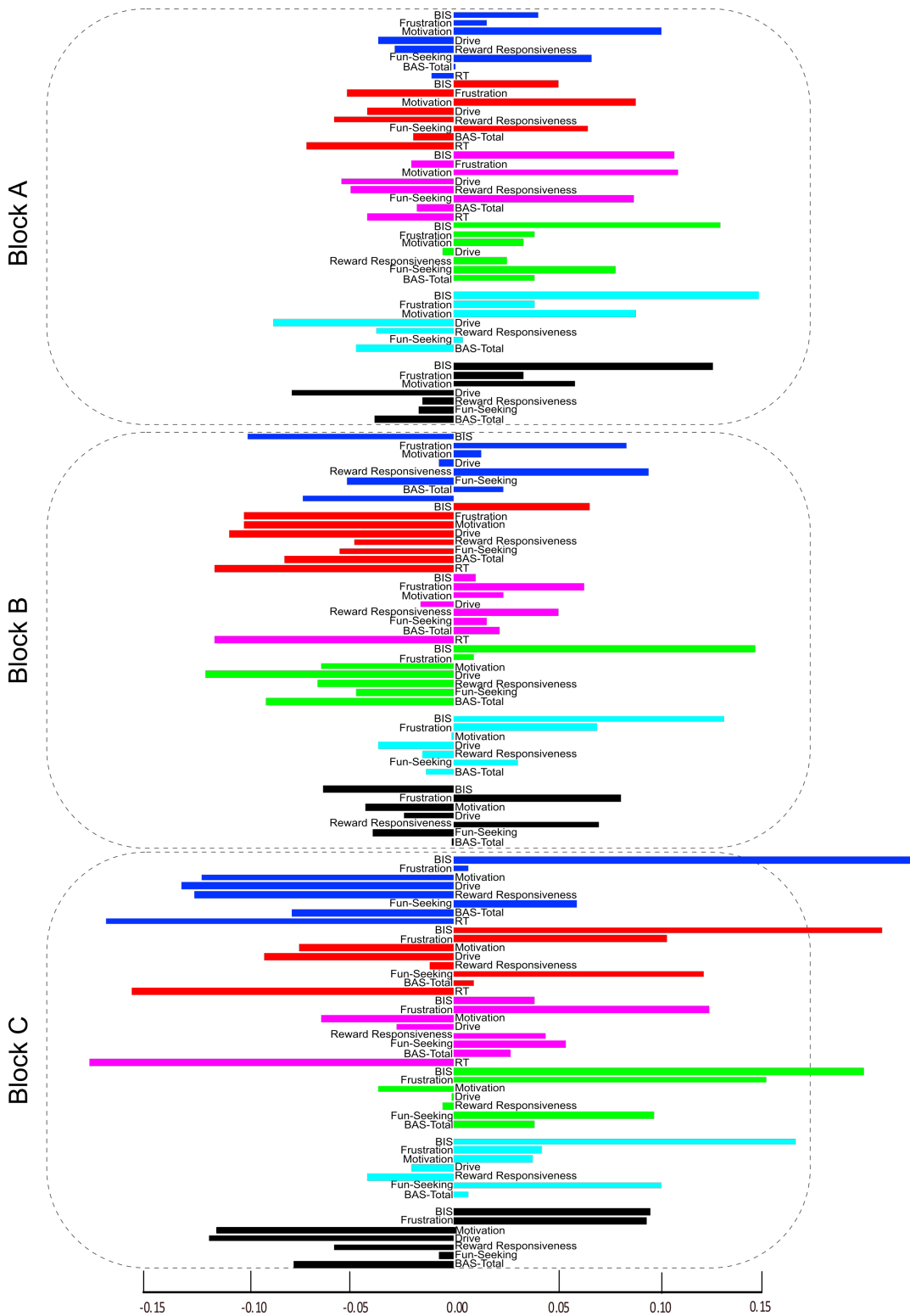


Figure 26 LV3 Behavioral Scores, y-axis is in PLS Score units

Latent Variable 4 (LV4)

The fourth latent variable (LV4) is strongly weighted to Go stimuli in Block A (Figure 27). The design scores for Blocks B and C are in the opposite direction with Angry/Happy-Go and Angry/Neutral/No-Go showing the strongest weights in Block B, while in Block C the weights are overall reduced with Neutral-Go/Neutral/No-Go conditions having the largest values within that Block.

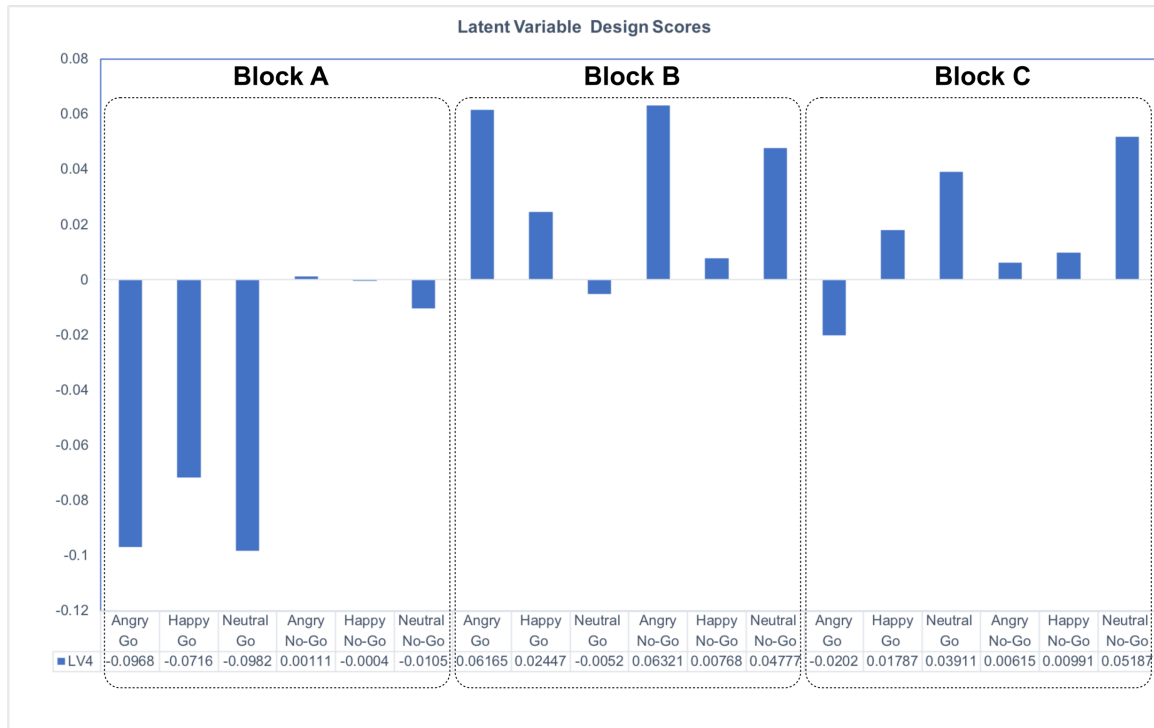


Figure 27 PLS Scores LV4

Interestingly, LV4 differs from the previous LVs in that the most reliable effect happens during the pre-stimulus baseline period and continues into the first half of the epoch (<200ms). This could indicate an overall change in network activity starting at Block B and continuing into Block C combined with a sensitivity for Angry/No-Go faces in Block B which is likely the VPP (Figure 28). In Block B there is a noticeable negative downward trend in the ERP particularly at inferior electrode locations (FT7).

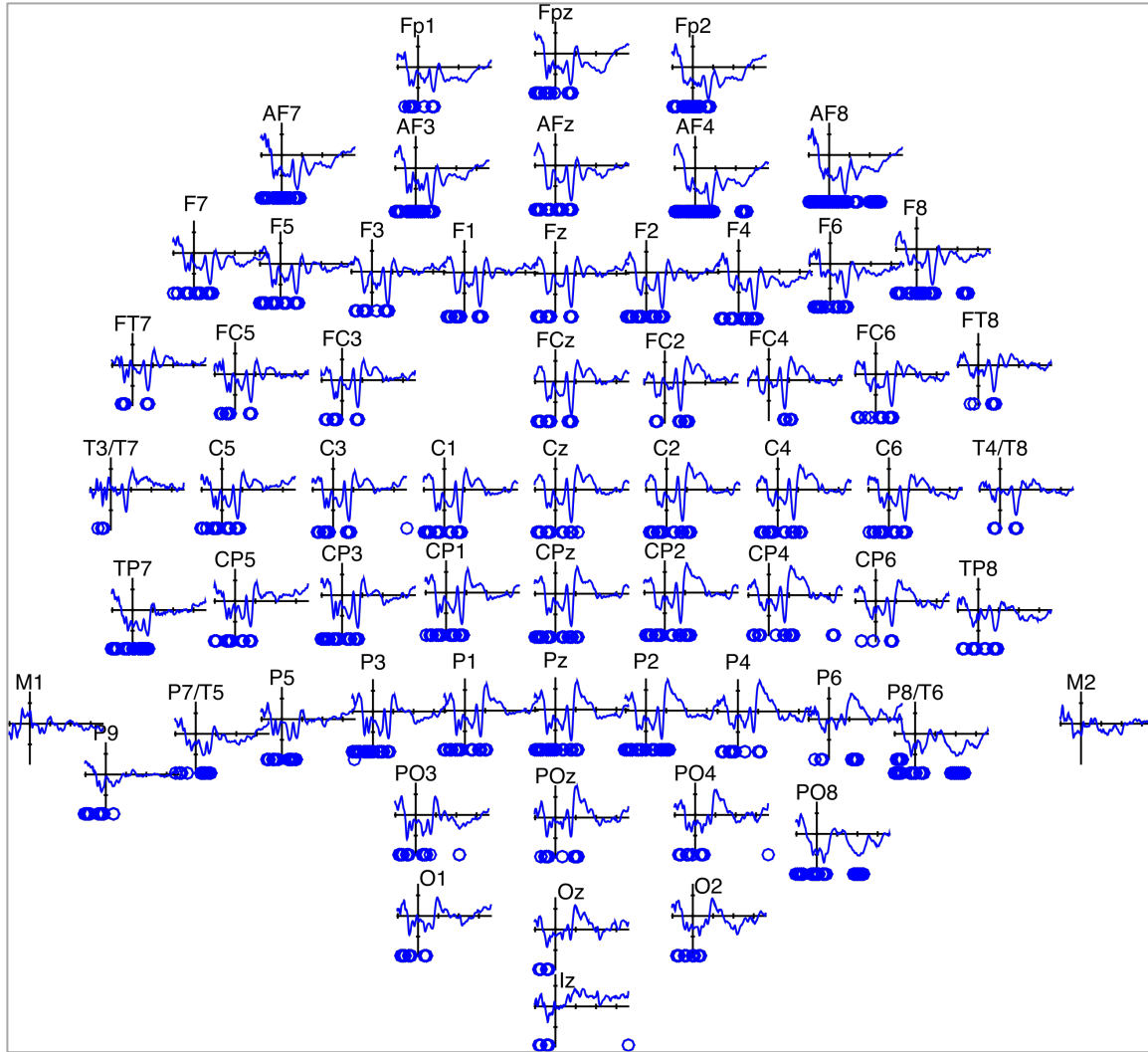


Figure 28 LV4 Topo Scalp Scores, y-axis is in PLS Score units

The behavioral effects for LV4 in Block A show strong weightings for Happy-Go and Neutral-Go and RT, along with Angry/No-Go weightings across several variables (Figure 30). The underlying RT correlations (Table 6) support these weightings for Happy-Go ($r = .35$), Neutral-Go ($r = .41$) as well as a negative correlation between Happy-Go and Motivation ($r = -.39$). For the Angry/No-Go condition in Block A there is a strong positive correlation between Drive ($r = .4$) and Fun-Seeking ($r = .45$).

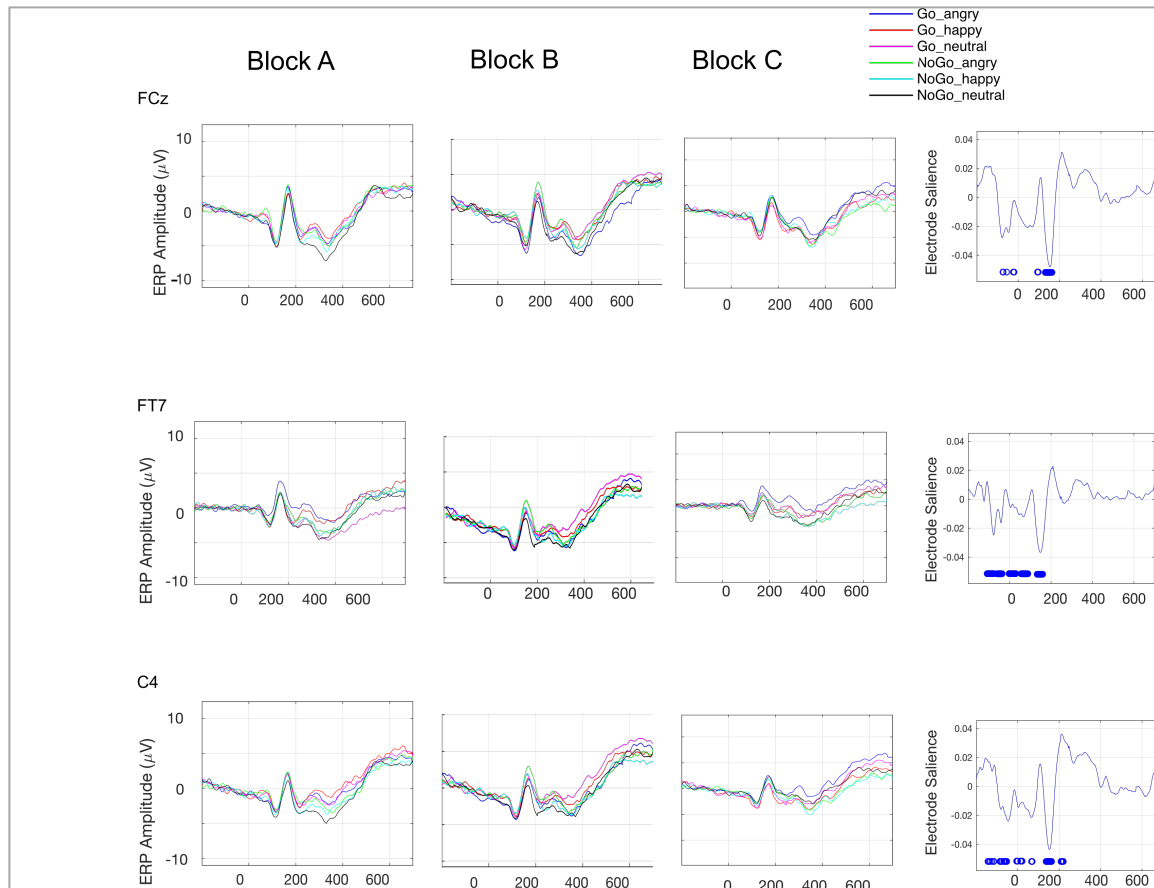


Figure 29 ERPs and Scalp Scores LV4

In Block B the behavioral weights are strong for avoidance (BIS) in the Angry-Go and Neutral/No-Go conditions and for Motivation for across all conditions. The behavioral weights are supported with strong negative correlations with avoidance and brain scores for Angry-Go ($r = -.55$), Angry/No-Go ($r = -.43$), and Neutral/No-Go ($r = -.46$). Motivation is negatively correlated with brain scores for Neutral-Go ($r = -.55$), Angry/No-Go ($r = -.48$), Happy/No-Go ($r = -.49$) and Neutral/No-Go ($r = -.55$).

Behavioral scores in Block C for LV4 have strong weights for Motivation in the Happy-Go condition and for avoidance (BIS), Motivation, and Fun-Seeking in the Neutral/No-Go condition. These correspond to brain score correlations with Motivation in Happy-Go ($r = -.49$), avoidance in Neutral/No-Go ($r = -.44$), Motivation in Neutral/No-Go ($r = -.42$), and Fun-Seeking in Neutral/No-Go ($r = -.41$).

Taken together, LV4 is interpreted as a combination of an overall change in network activity due to the punishment manipulation along with a sensitivity in the

perception of Angry No-Go faces in the punishment Block B. This particular latent variable was sensitive to Motivation such that high scores in Motivation in the punishment block were correlated with more negative brain scores, which in the ERP grandaverages corresponds to an overall negative downward trend of the ERP beginning the pre-stimulus baseline interval.

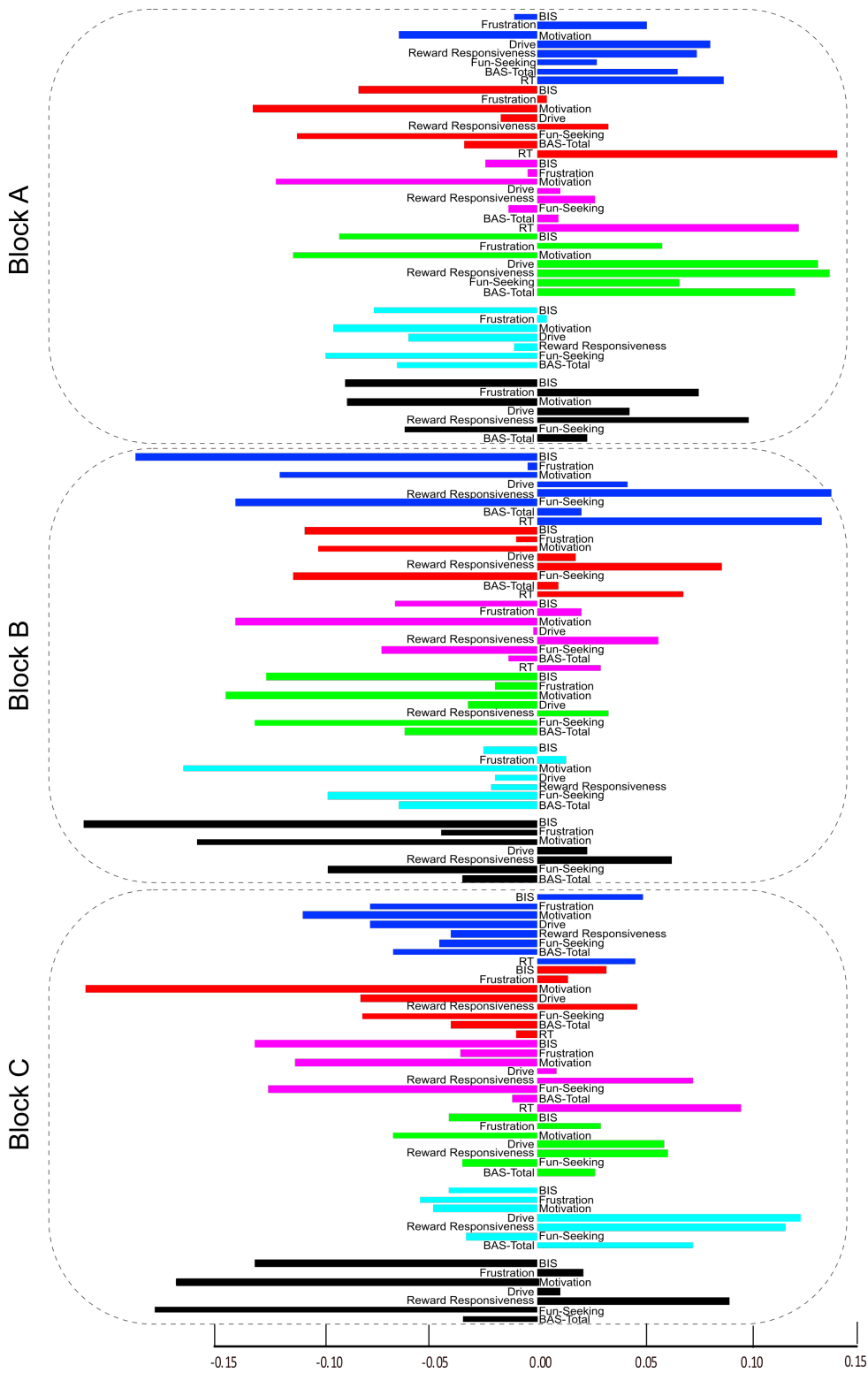


Figure 30 Behavioral Scores LV4, y-axis is in PLS Score units

3.4. EMO-GNG Discussion

An emotional Go/No-Go task was embedded within an A-B-C block design in which Block B deployed unfair punishments for errors in performance. It was hypothesized that continuously measured frustration and motivation scores would vary across blocks, with the highest frustration scores in the unfair punishment block. False alarm rates were expected to be sensitive to the presentation of Angry facial expressions (exogenous affective manipulation) and reaction times were expected to be slower. These behavioral hypotheses were supported by the results of Experiment 2.

To test to complexity of the Block by Task by Valence effects on an electrophysiological level a partial least squares analysis was performed. From this analysis four latent variables were extracted. The first accounted for over 20% of the covariance in the experimental variables and was likely the component representing the P3/LPP effect. This component was particularly related to behavioral approach variables as well as behavioral avoidance for Go stimuli (Angry and Neural) and Frustration for No-Go stimuli (Angry and Neutral).

The second latent variable explained over 8% of the experimental covariance and is representative of the VPP/LPP effects. This LV was related to behavioral avoidance, Frustration, and reaction time in Blocks A and B and C, while approach, and Motivation variables were related only to brain scores in Block C. The directionality of the scores and the correlations suggest that high levels of behavioral avoidance and frustration were related to high scores on the component representing the VPP/LPP while Motivation and approach variables were related to less positive scores for this latent variable.

The third latent variable accounted for ~7% of the experimental covariance and is likely related to the N2 task effects, and perhaps the P3 or a frontopolar negativity as well. While the design scores for Block C were the lowest, the behavioral weights for behavioral avoidance and reaction time were strongest for this Block, with an additional relationship between brain scores in Angry/No-Go and Frustration.

The fourth latent variable accounted for less than 5% of the experimental covariance. This extracted component seems to account for an overall change brain network activity as well as a perceptual sensitivity to Angry/No-go stimuli in the

punishment Block. Interestingly, this latent variable was related to reaction time, Motivation and approach variables.

Behavioral avoidance had a particular role in scores for Angry-Go faces and other Go stimuli, though not to the complete exclusion of No-Go stimuli for components representing P3/LPP/VPP/N2. Behavioral approach variables were particularly attuned to No-Go conditions (not to the complete exclusion of Go conditions) for components representing the P3/LPP and overall network and perceptual components (VPP). Motivation had the strongest impact on the component related to overall changes in network activity (LV4), though Motivation also had a strong relationship with the Angry/No-Go condition in Block C for the VPP/LPP component, and a weaker relationship with Happy-Go condition in Block A for the N2 component (LV3). Frustration scores were related to a wide variety of conditions in the latent variables representing the P3/LPP/VPP, particularly for Angry and Neutral conditions. The overall divergence of behavioral avoidance variables and approach variables to independent components supports the hypothesis that approach and avoidance tendencies interact with how the task is experienced. The results also support the hypothesis that behavioral approach and avoidance have independent, though not orthogonal, impacts on electrophysiology.

				BIS	Frust	Moti	Drive	FS	RR	BAST	RT
LV1	Block A	Go	Angry	-0.46	-0.28	-0.07	-0.19	-0.26	-0.33	-0.35	-0.22
			Happy	-0.07	-0.33	0.06	-0.36	-0.32	-0.20	-0.35	-0.11
			Neutral	-0.11	-0.43	-0.08	-0.46	-0.50	-0.22	-0.51	-0.25
		NoGo	Angry	0.11	-0.32	-0.17	-0.45	-0.45	-0.33	-0.50	-
			Happy	0.10	-0.29	-0.17	-0.35	-0.44	-0.23	-0.42	-
			Neutral	-0.04	-0.48	-0.33	-0.44	-0.40	-0.51	-0.55	-
	Block B	Go	Angry	0.34	-0.11	0.05	-0.33	-0.31	-0.17	-0.31	-0.08
			Happy	0.22	-0.09	-0.18	-0.22	-0.36	0.04	-0.24	0.03
			Neutral	-0.44	-0.08	-0.06	-0.17	0.07	-0.34	-0.15	0.29
		NoGo	Angry	-0.07	-0.24	-0.10	-0.39	-0.27	-0.46	-0.44	-
			Happy	-0.14	-0.31	0.10	-0.61	-0.42	-0.38	-0.54	-
			Neutral	-0.04	-0.10	-0.07	-0.27	0.02	-0.51	-0.25	-
	Block C	Go	Angry	-0.17	-0.17	-0.10	-0.43	-0.27	-0.30	-0.37	0.02
			Happy	-0.11	-0.07	0.13	-0.02	-0.18	-0.13	-0.15	0.04
			Neutral	0.30	-0.32	-0.32	-0.45	-0.36	-0.19	-0.37	0.04
	NoGo	Angry	-0.03	-0.45	-0.37	-0.51	-0.38	-0.42	-0.51	-	
		Happy	0.21	-0.14	0.00	-0.06	-0.15	-0.03	-0.09	-	
		Neutral	-0.20	-0.15	0.04	-0.36	-0.22	-0.28	-0.32	-	
LV2	Block A	Go	Angry	0.53	-0.13	-0.03	-0.16	-0.16	0.16	-0.04	0.17
			Happy	0.01	-0.03	-0.17	-0.01	-0.12	-0.19	-0.15	-0.05
			Neutral	0.18	0.22	-0.05	0.29	0.21	0.02	0.23	0.16
		NoGo	Angry	-0.02	-0.22	-0.03	-0.28	-0.30	-0.12	-0.27	-
			Happy	-0.24	-0.12	0.03	0.04	0.00	-0.04	-0.01	-
			Neutral	-0.01	-0.12	0.04	-0.01	-0.13	0.14	-0.01	-
	Block B	Go	Angry	-0.40	-0.23	0.00	0.08	-0.09	-0.01	-0.04	0.14
			Happy	-0.27	-0.26	0.06	-0.23	-0.26	-0.24	-0.30	0.16
			Neutral	0.37	-0.47	-0.19	-0.27	-0.42	-0.16	-0.36	-0.10
		NoGo	Angry	0.12	-0.14	0.19	-0.05	-0.19	0.19	-0.02	-
			Happy	0.28	-0.27	-0.09	0.10	-0.04	0.18	0.10	-
			Neutral	-0.01	-0.16	0.24	-0.11	-0.36	0.16	-0.16	-
	Block C	Go	Angry	0.02	-0.44	0.00	0.04	-0.22	-0.03	-0.13	0.41
			Happy	0.14	-0.38	-0.13	-0.29	-0.24	-0.06	-0.25	0.20
			Neutral	-0.35	-0.40	0.35	0.20	-0.13	0.07	0.00	0.24
	NoGo	Angry	-0.23	0.17	0.61	0.45	0.20	0.24	0.34	-	
		Happy	-0.26	-0.47	-0.02	-0.27	-0.26	-0.11	-0.27	-	
		Neutral	0.32	-0.38	-0.02	-0.09	-0.22	0.14	-0.09	-	

Table 5 Correlations between LV Scores and Psychometrics (LV1 and LV2)

				BIS	Frust	Moti	Drive	FS	RR	BAST	RT
LV3	Block A	Go	Angry	0.06	0.10	0.31	-0.13	-0.10	0.17	-0.03	-0.13
			Happy	0.18	-0.15	0.41	-0.06	-0.14	0.37	0.06	-0.33
			Neutral	0.23	-0.10	0.30	-0.32	-0.28	0.16	-0.18	-0.25
	NoGo	Angry	0.34	0.16	0.08	-0.11	0.04	0.10	0.03	-	
		Happy	0.32	0.12	0.12	-0.16	-0.04	0.01	-0.07	-	
		Neutral	0.27	0.12	0.11	-0.21	-0.01	-0.08	-0.10	-	
	Block B	Go	Angry	-0.20	0.17	-0.02	-0.02	0.19	-0.06	0.06	-0.19
			Happy	0.27	-0.22	-0.33	-0.28	-0.13	-0.02	-0.16	-0.29
			Neutral	-0.03	0.25	0.04	0.02	0.24	0.07	0.14	-0.28
	NoGo	Angry	0.37	0.04	-0.21	-0.26	-0.12	-0.06	-0.18	-	
		Happy	0.29	0.16	-0.07	-0.13	-0.03	0.04	-0.06	-	
		Neutral	0.05	0.23	-0.18	-0.05	0.17	-0.08	0.03	-	
	Block C	Go	Angry	0.51	0.14	-0.30	-0.29	-0.19	0.10	-0.14	-0.43
			Happy	0.50	0.28	-0.15	-0.15	-0.01	0.22	0.04	-0.42
			Neutral	0.38	0.34	-0.23	-0.15	0.00	0.12	0.00	-0.45
NoGo	Angry	0.41	0.45	-0.19	-0.07	-0.01	0.18	0.06	-		
	Happy	0.43	0.24	-0.01	-0.05	-0.05	0.17	0.02	-		
	Neutral	0.30	0.29	-0.26	-0.23	-0.10	0.05	-0.11	-		
LV4	Block A	Go	Angry	-0.11	0.17	-0.32	0.23	0.26	-0.03	0.17	0.33
			Happy	-0.21	0.16	-0.39	0.11	0.25	-0.26	0.04	0.35
			Neutral	-0.19	0.14	-0.35	0.17	0.29	-0.11	0.14	0.41
	NoGo	Angry	-0.38	0.20	-0.25	0.40	0.45	0.05	0.35	-	
		Happy	-0.18	0.09	-0.24	-0.10	0.07	-0.23	-0.12	-	
		Neutral	-0.12	0.24	-0.26	0.15	0.31	-0.18	0.10	-	
	Block B	Go	Angry	-0.55	-0.01	-0.32	0.05	0.27	-0.32	0.00	0.30
			Happy	-0.22	0.02	-0.35	0.06	0.33	-0.23	0.08	0.22
			Neutral	-0.19	0.15	-0.55	0.05	0.19	-0.15	0.03	0.10
	NoGo	Angry	-0.43	-0.02	-0.48	0.01	0.16	-0.36	-0.11	-	
		Happy	-0.13	0.12	-0.49	0.00	0.01	-0.29	-0.17	-	
		Neutral	-0.46	0.01	-0.55	0.13	0.18	-0.20	0.01	-	
	Block C	Go	Angry	-0.15	-0.09	-0.35	-0.14	0.09	-0.27	-0.13	0.19
			Happy	-0.17	0.06	-0.49	-0.08	0.20	-0.27	-0.05	0.03
			Neutral	-0.39	-0.03	-0.24	-0.03	0.17	-0.28	-0.07	0.29
NoGo	Angry	-0.07	0.12	-0.27	0.25	0.22	-0.05	0.14	-		
	Happy	-0.23	-0.02	-0.27	0.35	0.36	-0.18	0.19	-		
	Neutral	-0.44	0.10	-0.42	0.07	0.26	-0.41	-0.04	-		

Table 6 Correlations between LV Scores and Psychometrics (LV1 and LV2)

Chapter 4. Experiment 3 Balloon Analogue Risk Task

4.1. Experiment Overview

In the balloon analogue risk task (BART) participants have the opportunity to gain money based on their performance. Participants earn money by inflating a balloon, each time a key is pressed earns more money so the bigger the balloon is pumped the more money earned. If the balloon pops then no money is earned from that balloon. The probability of the balloon popping incrementally changes so that participants continually guess how many pumps until the balloon bursts. How large a balloon is pumped is interpreted as the amount of risk a participant is willing to take in order to potentially gain more money (Lejuez et al., 2002).

The BART task produces large fERNs following the bursting of a balloon which signals monetary loss (Y. Chen & Wallraven, 2017; Fein & Chang, 2008; Kessler, Hewig, Weichold, Silbereisen, & Miltner, 2017) and has shown sensitivity to anxiety (Takács et al., 2015) and impulsivity (Cheng & Lee, 2016). The fERN during the BART is likely produced by fronto-central theta oscillations (Crowley et al., 2014) with increases in theta synchrony following balloon bursts. This study aims to use EEG power to assess differences in power spectra associated with the likelihood of risk-taking (more balloon pumps) or risk aversion (fewer balloon pumps).

A notable difference between the BART and the EMOSS and Go/No-Go was that the BART does not introduce exogenous emotional information, nor was endogenous emotional state be purposefully manipulated. Additionally, frustration scores were expected to be low-medium while motivation scores were expected to be high given the monetary-gain component. The benefit of this design is that it allows the relationship between approach/avoidance and delta activity to be identified in terms of reward motivations and salencies rather than dysregulations induced by affective manipulations. This way it is easier to isolate the role of approach variables, in particular Reward-Responsiveness and Fun-Seeking. In light of current understanding, lower delta power is linked to risk-taking (Shufman et al., 1996) while higher delta power is expected to be linked to risk avoidance (Gennady G. Knyazev et al., 2005). Approach, in general, and Reward Responsiveness, in particular, is expected to relate to gain trials (delta/theta

increase compared to baseline). Avoidance is more likely to relate to losses (delta increase compared to baseline).

4.2. Participants and Procedure

This study was approved by the Simon Fraser University Office of Research Ethics. Participants were 20 undergraduate university students recruited from the Research Participation System at Simon Fraser University. Each gave informed consent before participating in a 1-hour ERP session in exchange for course credits. Participants completed a brief self-report medical and demographics questionnaire, and the Behavioral Activation System/Behavioral Inhibition System scale. After being seated in a sound-attenuated chamber resting EEG was recorded for 2 minutes eyes open and two minutes eyes closed. Participants then performed the 15-30-minute Balloon Analogue Risk Task (BART). The BART task contained 30 trials, i.e. 30 balloons, with a 3000ms inter-trial interval. Each time a balloon appeared on the screen the participant would press a button to make it larger and each button press was worth \$.05. If participants banked the money they have earned on that trial before the balloon popped, they would get to keep the money, but if the balloon popped, they would lose the money they earned on that trial. The maximum number of pumps before the balloon popped varied randomly each trial. Frustration and Motivation scores were measured before and after BART. If a participant chose to bank their money a ding! sounded, and if they popped the balloon a crashing sound would play.

After recording, the EEGs were epoched to the onset of the sound, were ICA cleaned for ocular artifacts, and were then decomposed using the Fast-Fourier Transformation (FFT) in the fieldtrip toolbox (Oostenveld, Fries, Maris, & Schoffelen, 2010). The same procedure was performed on clean 3000 ms epochs from the resting state baseline condition. For the PLS analysis only resting state data from the eyes open condition was used in consideration of the goal to compare the power spectrum from gain and loss trials, in which participants' eyes were open, to the baseline data

4.3. Results

EEG activity was recorded using a 64-channel Ag/AgCl electrode cap at standard 10-10 sites (Biosemi Active Two, Amsterdam), plus electrodes over left and right

mastoids, external canthi (for horizontal eye movements), and below each eye (for vertical eye movements and blinks). Voltages were recorded against a common mode sense (CMS) active electrode. Data were sampled at a rate of 512 Hz. Offline, EEG was digitally filtered (0.01 Hz highpass, 40 Hz lowpass), and re-referenced to average mastoid using FieldTrip (Oostenveld, Fries, Maris, & Schoffelen, 2010). Trial epochs were time-locked to 100 ms post-trial for a length of 3 seconds. Independent component analysis removed visual artifacts using the runica algorithm, with a maximum of 3 components out of 64 extracted. The single-subject FFT averages for each participant by Trial Type (Loss, Gain), were combined into a data matrix, resulting in a Design matrix of 2 conditions per subject each of the 64 EEG channels.

A multiblock partial least squares (PLS) analysis was used to assess design, psychometric, and behavioral effects. The psychometric and behavioral information was comprised of BIS-Total, BAS-Total, Drive, Fun-Seeking, Reward Responsiveness. The PLS analysis captured the maximum covariance of scalp activity between the Design and Behavioral matrices across the 64 EEG channels through singular value decomposition which produced orthogonal latent variables (LVs).

4.3.1. Behavioral Results

Frustration and Motivation scores before and after BART were very stable on average (Table 7). The average number of button presses per balloon was 67.32, with a minimum of 39 and a maximum of 108 presses for a single balloon. The total value of money earned at the end averaged \$36.66, with a minimum take home amount of \$29.35 and a maximum of \$45.25. Few button presses per trial, and a lower take-home amount are generally indicative of a participant who did not take many risks during the experiment, instead opting to bank their money early to avoid losses.

	Mean	SE	Minimum	Maximum
Drive	10.85	0.44	7	15
Fun-Seeking	11.3	0.43	8	15
Reward Responsiveness	16.95	0.41	14	20
BAS-Total	39.1	1.01	30	49
BIS	21.15	0.76	12	27
Monetary gain	36.66	1.11	29.35	45.25
Button presses (max)	67.32	4.06	39	108
Frustration-Pre	1.15	0.08	1	2
Frustration-Post	1.8	0.21	1	4
Motivation-Pre	3.15	0.23	1	5
Motivation-Post	3.2	0.18	1	5

Table 7 Descriptive Statistics for Experiment 3 (BART)

4.3.2. Electrophysiological BART Results

The PLS analysis produced one latent variable which explained 86% of the covariance in the experiment ($p = .01$). There were differences across all frequencies (1-40Hz) between the three conditions (baseline, gains, losses). Central (CPz/FCz) and lateral (C3/C4) regions of interest were selected from the scalp scores to compare to the power spectrum and the behavioral variables (Figure 31). The brain activity following a loss trial had greater broadband power compared to both baseline activity and gains; in the electrode salience window this corresponds to negative LV scores. For slower frequencies (<5.75 Hz) there is a difference between all three conditions (except for the more parietal CPz electrode), with the lowest power in the baseline, the greatest power in the loss condition, and gains in between. For most locations the power for baseline activity and gain trials converges around the theta/alpha frequency and the two maintain their power similarity through the high frequency ranges.

In terms of behavioral effects, the variables' scores (Figure 7, solid) varied slightly between conditions with stronger scores across behavioral variables in the loss condition. Interestingly, approach variable (Drive and Fun-Seeking) scores for gain trials were reduced compared to Reward-Responsiveness and avoidance (BIS) as well as in comparison to losses and baseline. The underlying correlations have a slightly different pattern of results with Drive and Fun-Seeking strongly correlated to brain scores for the

baseline condition, and avoidance strongly correlated to brain scores in the gain condition.

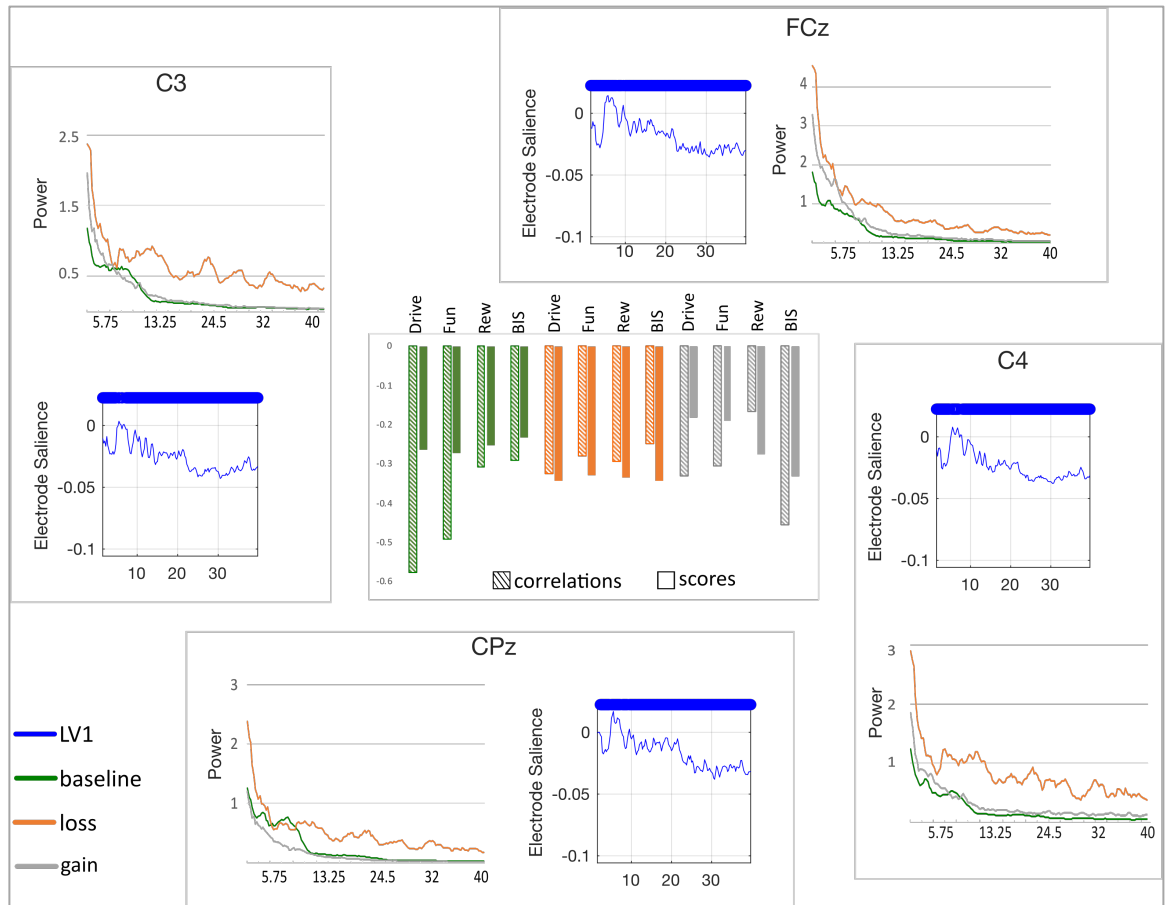


Figure 31 BART PLS and FFT

4.4. BART Discussion

Experiment 3, BART, was designed to test the relationship between approach variables, in particular Reward-Responsiveness and Fun-Seeking, on brain frequency dynamics. The BART paradigm was designed to be an engaging and positive experience, a hypothesis which was tested by measuring Frustration and Motivation before and after the BART; low ratings of Frustration and high ratings of Motivation support this hypothesis.

In terms of brain electrophysiological effects it was predicted that low delta power would be related to risk-taking behavior while higher delta power would relate to risk

aversion. While the participant's risk-taking was not assessed at a state level, high delta power following losses (orange line) and low delta power for gain trials supports the interpretation that delta power has a role in risk-taking behavior. However, there are two major caveats to this interpretation. First, this pattern of effects was not unique to the delta bandwidth, second there is no evidence of a direct change in risk-taking based off of the result of a current trial. In other words, banking money, a gain, could inspire the participant to earn more money on the next trial, but it could also make the participant develop a performance pattern where they pump the balloon to the same level (performance maintenance) rather than choose to pump the balloon even bigger on the next trial (risk-taking).

A particular role for Reward-Responsiveness in this paradigm was not found; not in behavioral scores, not in correlations, not for gains, or losses, or even baseline activity. While at first this result is surprising it can be explained in three ways. First, the experimental intention is that the monetary gain will be an implicit reward, but since the "reward" is gained by the (sometimes) careful decision to discontinue earning more the mixture of expectation, intentionality, and the potential loss of funds if they had taken more risk can lead to not subjectively experiencing the task as rewarding. Second, the well-known electrophysiological response to reward, the fERN, is traditionally isolated through the ERP averaging process. While there is evidence that the fERN is produced by theta activity (Crowley et al., 2014) it could be that decomposing the EEG using an FFT, thereby isolating theta power, cannot account for the electrophysiological complexities that converge together to produce the fERN. Lastly, since the data were analyzed using a PLS analysis the impact of Reward-Responsiveness may not be an important factor when the conditions, frequencies, and other psychometric variables are considered. In other words, the low scores for Reward-Responsiveness should be limited to the interpretation that for this latent variable with this particular design there were other factors that accounted for a larger percent of the covariance in the EEG power spectra.

Avoidance was hypothesized to relate to losses, however the results indicate equal behavioral scores for avoidance following both losses and gains, however with a high correlation of avoidance with brain scores following gains. This could be related to risk-avoidance following trials with monetary gain, whereas following a loss the to-be avoidance event has already occurred and is therefore not subjectively felt as something that can be currently avoided.

Two unexpected results were the strong correlations between baseline brain scores and approach variables (Drive and Fun-Seeking) and the broadband increase in power for the loss condition. The strong negative correlations suggest that more negative baseline brain scores (greater power in the EEG power spectra) are related to higher ratings of both Drive and Fun-Seeking. This supports the concept that behavioral approach, produced by appetitive motivational tendencies, and can be seen at the scalp level with increases in resting brain activity. The broadband power increases related to loss are more challenging to explain. It could be a global dysregulation due to a disruption in goal behavior caused by the very salient experience of hearing and seeing the balloon pop along with the earnings disappearing. Alternatively, it could be a recruitment of neural resources related to increased motivation to have a more successful trial and earn greater funds on the next balloon. Overall, behavioral approach and avoidance variables related to the latent variable, which differentiated between gains, losses, and baseline activity and accounted for 88% of the covariance in the grand averaged EEG power spectra.

Chapter 5. General Discussion

The backbone of this dissertation was centered around three main research categories:

4. The effect of endogenous and exogenous emotion manipulation and their relationship with approach and avoidance.
5. The dynamics and impact of ongoing emotional experience.
6. The 5-dimensional role of oscillatory changes in response to endogenous affective manipulation.

The endogenous manipulation of emotion was done through implementation of a task with a changing set of contexts, one in which the punishments for incorrect trials was intended to be unfair. To manipulate exogenous emotional information faces with various expressions (Angry, Happy, Neutral) were used. Approach and avoidance tendencies were measured using the BIS/BAS self-report psychometric scale. The endogenous manipulation was successful in both Experiment 1 (EMO-SS) and Experiment 2 (EMO-GNG). What was most interesting was that, while the *a priori* hypothesis predicted the unfair punishment block to be the most difficult, performance in that block, as well as brain activity, was relatively stable compared to the initial fair block. However, when the context changes from unfair punishments back to fair a breakdown in performance and brain activity occurs. This suggests that while participants were able to rally their resources to maintain performance under high levels of frustration and in an unfair context they were not able to sustain this effort once the task demands were reduced. Put another way, the switch back to equal rewards and punishments was intended to be a “recovery” block in which participants would be able to gain back the points they lost and perform well again. However, it actually appears that the intended “recovery” block became a “disengage” block where participants were more likely to withdraw from the task - evidenced by both behavior and brain electrophysiology. For example, in the baseline-change (“recovery”) block in Experiment 1/EMO-SS N2 amplitudes were most reduced, Go reaction times were slower, false alarm (erroneous) signal-respond reaction times were faster, sensitivity to the presentation of a face (VPP) was greater, N170 amplitude was reduced, anterior LPP was significantly negatively shifted, and there were increases in fronto-polar delta after failed inhibitions along with with increases in central-parietal delta. At the source level differences between the block

contexts was related to a relatively wide range of brain areas associated with the effect of pain on cognitive load, face perception, cognitive and executive control networks, emotional-cognitive network interaction, emotional induction, cognitive reappraisal, learned helplessness, uncertainty, retrieval, inhibition, and dopaminergic reward networks. The endogenous manipulation in Experiment 2/Go/No-Go was not as impactful on behavioral performance and brain activity as in Experiment 1, which was in part due to an intentional experimental change. In this experiment, reaction times varied across blocks, but the effect was weaker. Electrophysiological effects of the endogenous emotional manipulation were noticeable for latent variables related to N2/VPP/P3 and LPP ERPs. The exogenous manipulation of emotion was evidenced through differences in reaction time to angry faces during the EMO-SS and the EMO-GNG task; the VPP and LPP were also sensitive to angry faces, particularly during the punishment block. However, the effect of the endogenous emotional manipulation completely overshadowed the comparatively small effect of the exogenous emotional manipulation.

Approach and avoidance tendencies led to a better understanding of the pattern of effects across all three experiments. In terms of approach, the variable Drive was a significant predictor of N2 amplitude following successful inhibitions in the punishment block, had a strong weight to latent variables representing LPP/P3/EAP activity, and high Drive scores were related to faster reaction times (correct trials and false alarms), and increased resting state activity in the baseline period as measured by FFT decomposition. The approach variable, Fun-Seeking, also had a strong weight for the LPP/P3/EAP latent variable, was associated with increases in resting state activity in the baseline period as measured by FFT decomposition, and was positively correlated to VPP amplitude to Angry faces in Block B. The approach variable, Reward-Responsiveness was related to high VPP amplitude to Angry Faces in Block B, as well as No-Go conditions for the latent variable representing LPP/P3/EAP, and was a predictor of N2 amplitude for successful inhibitions in Block B such that increases in Reward-Responsiveness corresponded to more negative N2 amplitudes. Finally, the avoidance variable, BIS, was strongly correlated to greater LPP amplitude following Angry faces in the punishment block, was related to Angry faces across all four latent variables in Experiment 2, predicted N2 amplitude to successful inhibitions in Block B, and was related to increased activity following monetary gains as measured by FFT decomposition.

In the oscillatory domain, for N2 amplitude in EMO-SS, delta activity was related to approach while alpha activity was negatively related to approach and positively related to avoidance. Taken together, both approach and avoidance variables predicted N2 amplitude in the punishment Block; avoidance had a unique relationship to EEG following Angry faces across particularly for later stage processing (i.e. LPP), while approach variables were related to behavioral indices and VPP amplitudes mainly in the punishment block. Additionally, for resting state activity approach variables were related to baseline activity while avoidance was correlated to task-related activity following monetary gains. This pattern of results underscores the non-orthogonality of approach and avoidance variables as well as the complex dynamics of the action and affect loops. For instance, in the punishment block, where the affect loop is assumed to be providing input to the action loop, both Drive and avoidance (BIS) have a similar effect on the ERP, while Reward-Responsiveness has an opposite effect. While behavioral avoidance can relate to anxiousness, the pattern of results here suggests the relationship between N2 amplitude for successful inhibitions and BIS may be due to relief in response to accurate performance (i.e. successful avoiding loss all the banked points). On the other hand, the approach variables, which could be related to motivation and excitement, may actually be due to frustration or angry (negative affects related to approach) in the punishment block context.

The dynamics of the ongoing emotional experience (Frustration and Motivation) varied across the three experiments. In the most straightforward instance (BART) the task was made to be engaging, fun, and motivating, which corresponded to stable (low) Frustration and (high) Motivation scores, on average. For a more difficult task (EMO-GNG) Frustration and Motivation scores were both greatest in the punishment block then lowered to baseline levels whereas in the most demanding experiment (EMO-SS), Frustration continually increased and Motivation continually decreased. Frustration was negatively correlated to theta activity across blocks, but particularly for the punishment block as well as LPP amplitude in the punishment block. Motivation related to reaction time and had strong behavioral scores for the No-Go condition in the latent variable related to an overall change in brain activity due to the endogenous affective manipulation. The most salient interpretation from this pattern of results is the assumption of “recovery” after an extremely unpleasant experience. To be clear, in the punishment block for EMO-SS it is nearly impossible to avoid errors after accounting for

the intermittent stop-signal and the adaptive computer algorithm. Participants found this frustrating, which was predicted, but the rate of demotivation across blocks combined with increases in Frustration was not expected. This suggests that the immediate opportunity to “recover” by itself is not enough to counteract the endogenous emotional manipulation, there may also be a need for a completely off-task refractory period in which Frustration and Motivation return to baseline levels to facilitate “recovery.”

The 5-dimensional role of the endogenous affective manipulation (3-D brain space, frequency and time) was a main research question in the EMO-SS task. The goal was to isolate the delta, theta, and alpha frequencies for a time-of interest (based off of scalp time-frequency decomposition) and use beamforming source analysis techniques to define the regions in the brain that are sensitive to changes between blocks within each frequency band.

Delta activity resulted in four potential regions of interest the first of which related to areas which in fMRI are implicated in research on pain, familiar face perception, attentional resources and the effects of gains and losses on source memory encoding; the second region corresponded to fMRI research on working memory, emotional-cognitive interaction, pleasant and unpleasant emotion induction, insula-cingulate network, cognitive reappraisal in major depressive disorder, and gambling tasks; the third region corresponds to fMRI research on face processing (general and emotional), learned helplessness, emotional memory, and loss of the inhibitory influence of the cingulate; and the fourth region was related to face processing, emotional decision making, anxiety, and conditioning fMRI studies. Altogether, the source estimation for delta activity correspond to fMRI research which supports the endogenous emotion manipulation in the EMO-SS task, as well as the interpretation of the impact of the punishment block on the participant. Theta activity had two source regions of interest, the first region falls squarely in the fusiform face area; the second corresponds to fMRI research on complex movement, uncertainty, high executive function including stimulus-representation retrieval, strategy, and decision making. Overall, theta activity is related more so to changes in cognitive/task processing in EMO-SS (face processing, cognitive control, etc.) rather than the emotional repercussion of the punishment manipulation as is seen in the delta bandwidth. Lastly, the alpha bandwidth also had two main regions of interest. The first maps onto fMRI research on subjective emotional experience and cognitive demands, stop-signal tasks, fear, strategy and errors; the second region is

implicated in the management of uncertainty. Thus, in the alpha bandwidth we see a complex combination of differences in both cognitive and affective processing together.

Keeping in mind delta activity at the scalp level was related to approach while alpha scalp activity was opposingly related to both approach and avoidance and theta was related to frustration, the 5-dimensional analysis of the data allows a deeper understanding of the role of approach and avoidance under an endogenous affective manipulation. Delta is the frequency most related to the subjective negative experience of the punishment manipulation and could be a measurement of the negative affects related to approach, while theta is related to cognitive demands and levels of frustration, and alpha corresponded to both the cognitive factors (action loop) and endogenous emotion (affect-loop), the interplay of which is supported by the correlations with avoidance and approach variables.

The source estimates from the EMO-SS task as well as their elicitation by a punishment manipulation implicate the salience network and affective networks for the delta effects (Barrett, 2006; Ochsner & Gross, 2005; Seeley et al., 2007), and the central executive network for the theta results (Fox et al., 2006). Considering the two source estimate regions alpha activity and their supporting fMRI research it is less clear which neural network those source estimates map onto; indeed, it may be that alpha activity maps onto more than one network. There is evidence of increased alpha activity to affective information, especially aversive stimuli (Uusberg et al., 2013) which supports an interpretation that the alpha effects are related to the affective network but may also be indicative of default mode network suppression and saliency network facilitation (Jilka et al., 2014; Rayner et al., 2016). Thus the EMO-SS provides preliminary support that the three main large scale functional networks from fMRI research, along with high temporal resolution provided by EEG to measure near-millisecond changes in oscillatory dynamics, can converge together to produce the proposed action and affect feedback networks of self-regulation at a neural level (Balconi, Falbo, et al., 2009; Balconi & Mazza, 2009; Carver & Scheier, 1998, 2013; Wacker et al., 2010). Lastly, the effects of delta and EEG source estimations support the linkage of delta activity with domain-general homeostatic/motivational processes and behavioral inhibition (Gennadij G. Knyazev & Slobodskaya, 2003; Gennady G. Knyazev, 2012; Gennady G. Knyazev et al., 2006).

Previous research demonstrated some support for affective modulation of the N170 component (Batty & Taylor, 2003; Pourtois et al., 2004, 2005) while others have not (Eimer & Holmes, 2007). The results from this dissertation are consistent with the latter showing little to no variation in N170 amplitude due to exogenous affect. Instead, the effect of different facial expressions is evident in the VPP, which is consistent with previous literature (Eimer & Holmes, 2007; Joyce & Rossion, 2005; Schupp et al., 2004; Schupp, Stockburger, et al., 2006). While only the VPP was sensitive to the exogenous affective manipulation both the N170 and VPP were sensitive to the unfair punishment manipulation evident by an overall positive shift in both ERPs, reducing the N170 amplitude and increasing the VPP amplitude, particularly following Angry faces in the punishment block. This supports the hypothesis that the VPP is related to rapid, automatic orientation to emotional expressions (Vuilleumier et al., 2003).

The ERP family of medial frontal negativities are elicited in distinct contexts including times of high conflict (Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003, p. 2; West et al., 2012, p. 2) (Nieuwenhuis et al., 2003; West et al., 2012; West & Travers, 2007), when suppression of a prepotent response set is required (Donkers & van Boxtel, 2004; Gehring et al., 1993; Liotti et al., 2007; Pliszka et al., 2000), and in response to error/performance feedback (Dehaene et al., 1994; Holroyd & Coles, 2002). Previous research has shown N2 amplitude is greater for No-Go and correct response inhibition conditions (Donkers & van Boxtel, 2004; Enriquez-Geppert, Konrad, Pantev, & Huster, 2010; Verbruggen & Logan, 2008). This pattern of results is demonstrated in the current study as well, with greater N2 amplitude following successful inhibitions than failed inhibitions in EMO-SS as well as No-Go trials in EMO-GNG, particularly for the punishment block. While the N2 in response to feedback, the fERN was not directly measured the EEG power spectra for the feedback condition in the BART experiment showed a broad range of differences in power between gain/loss trials as well as baseline activity (Balconi & Crivelli, 2010a; Kessler et al., 2017; Rao, Korczykowski, Pluta, Hoang, & Detre, 2008). The N2 is generally followed by a P3 ERP component which is thought to be related to conflict awareness (Lansbergen et al., 2007), compensatory response inhibition mechanisms (Bekker et al., 2005; Wessel & Aron, 2014b), and memory processing (Kiefer et al., 1998; Polich, 2007). The P3 in the EMO-SS did not vary due to response inhibition mechanisms but P3 amplitude was reduced in the punishment block. The P3 in EMO-GNG was greater in the No-Go

condition for the first block, after which P3 Go amplitudes increased to the same level as the P3 No-Go.

The affective ERPs, the EAP and LPP are greater in amplitude following salient, arousing affective stimuli both when they are task-irrelevant (Asmaro et al., 2014; Carolan et al., 2014; Taake et al., 2009) and task-relevant (Carretié, 2014; Carretié et al., 2004, 2001; Olofsson et al., 2008). The later effect, the LPP has been linked to perceptual facilitation and central executive cuing to the affect stimuli caused by prefrontal-occipital/parietal network connection (Moratti et al., 2011). In EMO-SS a posterior LPP in response to the exogenous affective manipulation was particularly sensitive to the presentation of Angry faces in the punishment block while a more anterior LPP was sensitive only to the punishment manipulation and not at all to the exogenous affective manipulation (Figures 3 and 4). ERPs timelocked to the presentation of the stop signal in EMO-SS also had an LPP-like effect over anterior scalp locations which was completely unexpected (Figure 6). This ERP complex was markedly different before and after the punishment manipulation.

Previous literature has linked ERPs and EEG frequencies to behavioral approach and avoidance. An anterior P3b, similar to the anterior LPP effect in EMO-SS, has been linked to behavioral avoidance and has been explained as arising due to alpha-driven increases in the right pre-frontal cortex (Wacker et al., 2010) while the more traditional posterior P3b has been related to Reward-Responsiveness (Balconi & Crivelli, 2010a). Medial frontal negativity amplitudes have been previously related to behavioral avoidance (Amodio et al., 2008; Leue et al., 2009). The N2, but not the P3 in EMO-SS related to both approach and avoidance while the VPP related only to approach. In EMO-GNG the latent variables related to N2/VPP/P3 and LPP processing related to both approach and avoidance.

In terms of oscillatory dynamics there is evidence of a hemispheric divergence of approach, linked to left frontal resting-state alpha power, and avoidance, linked to right frontal resting-state alpha power (Amodio et al., 2008; Coan & Allen, 2003), a pattern which occurs in task-related activity as well and additionally varies by exogenous affective information (Balconi & Mazza, 2009). Delta power in response to emotionally salient images has been left-lateralized and correlated to approach while right-lateralized delta power in response to emotionally salient images has been inversely correlated to

avoidance (Balconi, Brambilla, et al., 2009b; Balconi, Brambilla, & Falbo, 2009a; Balconi, Falbo, et al., 2009). Theta power has been related to increases in both approach and avoidance variables in response to salient images and performance feedback (Balconi, Brambilla, et al., 2009b; Balconi & Crivelli, 2010a, 2010b). In contrast, EMO-SS measured the relationship between oscillatory activity following successful response inhibition and trait approach and avoidance. In this case increases in delta power were related to increases in approach, but not avoidance; theta was not related to avoidance or approach; and alpha power increased with avoidance and decreased with approach.

In conclusion, this dissertation supports the model of a double-layer self-regulation mechanism comprised of action and affect feedback loops (Carver, 2006, 2008; Carver & Scheier, 1998, 2013) which is supported by electrophysiological measures at scalp and source levels. Theta processes related to the central executive network map onto action, delta processes related to salience and affective networks map onto affect, while alpha processes related to both salience and executive control networks (i.e. the interaction between cognition and emotion) map onto both action and affect loops. Here it is important to remember that the action and affect loops are by definition not independent from each other, rather they are constantly communicating via inputs and outputs. For example, the detailed role of theta may be to monitor task performance and send that information to the affect loop while delta may monitor endogenous affect and send that information to the action loop. Additionally, it could be that the frequencies are not feedback-loop specific and the frequency of communication may depend on the type of communication being sent (i.e. alerting exogenous stimuli, marked increase in endogenous affect, fear, conditioning, slow changes in goal orientation, sudden task switching, distance-enlarging, distance-reducing etc). The current study also suggests a utility to ongoing monitoring of emotional experience, especially in the interpretation of the participant's engagement and perception of the task. Finally, going beyond ERP analysis into EEG oscillations and/or source beamforming allows a deeper understanding of the underlying electrophysiology and the complexity of the additive effects and interactions between cognitive and affective processes (both endogenous and exogenous).

References

- Albert, J., López-Martín, S., & Carretié, L. (2010). Emotional context modulates response inhibition: Neural and behavioral data. *NeuroImage*, *49*(1), 914–921. <https://doi.org/10.1016/j.neuroimage.2009.08.045>
- Amodio, D. M., Master, S. L., Yee, C. M., & Taylor, S. E. (2008). Neurocognitive components of the behavioral inhibition and activation systems: Implications for theories of self-regulation. *Psychophysiology*, *45*(1), 11–19.
- Anderson, E., Siegel, E., White, D., & Barrett, L. F. (2012). Out of Sight but Not Out of Mind: Unseen Affective Faces Influence Evaluations and Social Impressions. *Emotion (Washington, D.C.)*, *12*(6), 1210–1221. <https://doi.org/10.1037/a0027514>
- Asmaro, D., Carolan, P. L., & Liotti, M. (2014). Electrophysiological evidence of early attentional bias to drug-related pictures in chronic cannabis users. *Addictive Behaviors*, *39*(1), 114–121.
- Balconi, M., Brambilla, E., & Falbo, L. (2009a). Appetitive vs. defensive responses to emotional cues. Autonomic measures and brain oscillation modulation. *Brain Research*, *1296*, 72–84. <https://doi.org/10.1016/j.brainres.2009.08.056>
- Balconi, M., Brambilla, E., & Falbo, L. (2009b). BIS/BAS, cortical oscillations and coherence in response to emotional cues. *Brain Research Bulletin*, *80*(3), 151–157. <https://doi.org/10.1016/j.brainresbull.2009.07.001>
- Balconi, M., & Crivelli, D. (2010a). FRN and P300 ERP effect modulation in response to feedback sensitivity: the contribution of punishment-reward system (BIS/BAS) and behaviour identification of action. *Neuroscience Research*, *66*(2), 162–172.

- Balconi, M., & Crivelli, D. (2010b). Veridical and false feedback sensitivity and punishment-reward system (BIS/BAS): ERP amplitude and theta frequency band analysis. *Clinical Neurophysiology*, *121*(9), 1502–1510.
- Balconi, M., Falbo, L., & Brambilla, E. (2009). BIS/BAS responses to emotional cues: Self report, autonomic measure and alpha band modulation. *Personality and Individual Differences*, *47*(8), 858–863. <https://doi.org/10.1016/j.paid.2009.07.004>
- Balconi, M., & Mazza, G. (2009). Brain oscillations and BIS/BAS (behavioral inhibition/activation system) effects on processing masked emotional cues.: ERS/ERD and coherence measures of alpha band. *International Journal of Psychophysiology*, *74*(2), 158–165.
<https://doi.org/10.1016/j.ijpsycho.2009.08.006>
- Barrett, L. F. (2006). Are emotions natural kinds? *Perspectives on Psychological Science*, *1*(1), 28–58.
- Barrett, L. F., & Satpute, A. B. (2013). Large-scale brain networks in affective and social neuroscience: Towards an integrative functional architecture of the brain. *Current Opinion in Neurobiology*, *23*(3), 361–372.
- Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research*, *17*(3), 613–620.
- Bekker, E. M., Kenemans, J. L., Hoeksma, M. R., Talsma, D., & Verbaten, M. N. (2005). The pure electrophysiology of stopping. *International Journal of Psychophysiology*, *55*(2), 191–198.
- Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological Studies of Face Perception in Humans. *Journal of Cognitive Neuroscience*, *8*(6), 551–565. <https://doi.org/10.1162/jocn.1996.8.6.551>

- Bergström, Z. M., Williams, D. G., Bhula, M., & Sharma, D. (2016). Unintentional and intentional recognition rely on dissociable neurocognitive mechanisms. *Journal of Cognitive Neuroscience*, *28*(11), 1838–1848.
- Bernat, E. M., Nelson, L. D., Steele, V. R., Gehring, W. J., & Patrick, C. J. (2011). Externalizing psychopathology and gain–loss feedback in a simulated gambling task: Dissociable components of brain response revealed by time-frequency analysis. *Journal of Abnormal Psychology*, *120*(2), 352.
- Bötzel, K., Schulze, S., & Stodieck, S. R. (1995). Scalp topography and analysis of intracranial sources of face-evoked potentials. *Experimental Brain Research*, *104*(1), 135–143.
- Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: emerging methods and principles. *Trends in Cognitive Sciences*, *14*(6), 277–290.
- Carolan, P. L., Jaspers-Fayer, F., Asmaro, D. T., Douglas, K. S., & Liotti, M. (2014). Electrophysiology of blunted emotional bias in psychopathic personality. *Psychophysiology*, *51*(1), 36–41. <https://doi.org/10.1111/psyp.12145>
- Carretié, L. (2014). Exogenous (automatic) attention to emotional stimuli: a review. *Cognitive, Affective & Behavioral Neuroscience*, *14*(4), 1228–1258. <https://doi.org/10.3758/s13415-014-0270-2>
- Carretié, L., Hinojosa, J. A., Martín-Loeches, M., Mercado, F., & Tapia, M. (2004). Automatic attention to emotional stimuli: neural correlates. *Human Brain Mapping*, *22*(4), 290–299.
- Carretié, L., Martín-Loeches, M., Hinojosa, J. A., & Mercado, F. (2001). Emotion and attention interaction studied through event-related potentials. *Journal of Cognitive Neuroscience*, *13*(8), 1109–1128.

- Carver, C. S. (2003). Pleasure as a sign you can attend to something else: Placing positive feelings within a general model of affect. *Cognition and Emotion*, 17(2), 241–261. <https://doi.org/10.1080/02699930302294>
- Carver, C. S. (2004). Negative affects deriving from the behavioral approach system. *Emotion*, 4(1), 3.
- Carver, C. S. (2006). Approach, Avoidance, and the Self-Regulation of Affect and Action. *Motivation and Emotion*, 30(2), 105–110. <https://doi.org/10.1007/s11031-006-9044-7>
- Carver, C. S. (2008). Two distinct bases of inhibition of behaviour: viewing biological phenomena through the lens of psychological theory. *Eur. J. Pers*, 22, 388–390.
- Carver, C. S., & Harmon-Jones, E. (2009). Anger is an approach-related affect: evidence and implications. *Psychological Bulletin*, 135(2), 183.
- Carver, C. S., & Scheier, M. F. (1998). *On the Self-Regulation of Behavior*. Cambridge University Press.
- Carver, C. S., & Scheier, M. F. (2013). Self-regulation of action and affect. In *Handbook of self-regulation: Research, theory, and applications* (2nd ed., pp. 1–21). Guilford Press.
- Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: the BIS/BAS scales. *Journal of Personality and Social Psychology*, 67(2), 319.
- Chen, A. C., Oathes, D. J., Chang, C., Bradley, T., Zhou, Z.-W., Williams, L. M., ... Etkin, A. (2013). Causal interactions between fronto-parietal central executive and default-mode networks in humans. *Proceedings of the National Academy of Sciences*, 110(49), 19944–19949.
- Chen, Y., & Wallraven, C. (2017). Pop or not? EEG correlates of risk-taking behavior in the balloon analogue risk task. *2017 5th International Winter Conference on*

- Brain-Computer Interface (BCI)*, 16–19. <https://doi.org/10.1109/IWW-BCI.2017.7858146>
- Cheng, G. L., & Lee, T. M. (2016). Altering risky decision-making: Influence of impulsivity on the neuromodulation of prefrontal cortex. *Social Neuroscience*, 11(4), 353–364.
- Coan, J. A., & Allen, J. J. (2003). Frontal EEG asymmetry and the behavioral activation and inhibition systems. *Psychophysiology*, 40(1), 106–114.
- Crowley, M. J., van Noordt, S. J., Wu, J., Hommer, R. E., South, M., Fearon, R. M. P., & Mayes, L. C. (2014). Reward feedback processing in children and adolescents: Medial frontal theta oscillations. *Brain and Cognition*, 89, 79.
- Cunningham, W. A., Van Bavel, J. J., & Johnsen, I. R. (2008). Affective flexibility: evaluative processing goals shape amygdala activity. *Psychological Science*, 19(2), 152–160.
- Davidson, R. J. (1992). Emotion and affective style: Hemispheric substrates. *Psychological Science*, 3(1), 39–43.
- Davidson, R. J., Jackson, D. C., & Kalin, N. H. (2000). Emotion, plasticity, context, and regulation: perspectives from affective neuroscience. *Psychological Bulletin*, 126(6), 890.
- Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a Neural System for Error Detection and Compensation. *Psychological Science*, 5(5), 303–305.
- DeLaRosa, B. L., Spence, J. S., Shakal, S. K., Motes, M. A., Calley, C. S., Calley, V. I., ... Kraut, M. A. (2014). Electrophysiological spatiotemporal dynamics during implicit visual threat processing. *Brain and Cognition*, 91, 54–61.
- Demianczyk, A. C., Jenkins, A. L., Henson, J. M., & Conner, B. T. (2014). Psychometric Evaluation and Revision of Carver and White's BIS/BAS Scales in a Diverse Sample of Young Adults. *Journal of Personality Assessment*, 96(5), 485–494.

- Derryberry, D., & Tucker, D. M. (1994). *Motivating the focus of attention*. Retrieved from <http://psycnet.apa.org/psycinfo/1994-97332-007>
- Donkers, F. C. L., & van Boxtel, G. J. M. (2004). The N2 in go/no-go tasks reflects conflict monitoring not response inhibition. *Brain and Cognition*, *56*(2), 165–176. <https://doi.org/10.1016/j.bandc.2004.04.005>
- Eimer, M. (2000). Event-related brain potentials distinguish processing stages involved in face perception and recognition. *Clinical Neurophysiology*, *111*(4), 694–705. [https://doi.org/10.1016/S1388-2457\(99\)00285-0](https://doi.org/10.1016/S1388-2457(99)00285-0)
- Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. *Neuropsychologia*, *45*(1), 15–31.
- Enriquez-Geppert, S., Konrad, C., Pantev, C., & Huster, R. J. (2010). Conflict and inhibition differentially affect the N200/P300 complex in a combined go/nogo and stop-signal task. *NeuroImage*, *51*(2), 877–887. <https://doi.org/10.1016/j.neuroimage.2010.02.043>
- Fein, G., & Chang, M. (2008). Smaller feedback ERN amplitudes during the BART are associated with a greater family history density of alcohol problems in treatment-naive alcoholics. *Drug and Alcohol Dependence*, *92*(1), 141–148.
- Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: a review. *Psychophysiology*, *45*(1), 152–170.
- Forstmann, B. U., van den Wildenberg, W. P., & Ridderinkhof, K. R. (2008). Neural mechanisms, temporal dynamics, and individual differences in interference control. *Journal of Cognitive Neuroscience*, *20*(10), 1854–1865.
- Fox, M. D., Corbetta, M., Snyder, A. Z., Vincent, J. L., & Raichle, M. E. (2006). Spontaneous neuronal activity distinguishes human dorsal and ventral attention systems. *Proceedings of the National Academy of Sciences*, *103*(26), 10046–10051. <https://doi.org/10.1073/pnas.0604187103>

- Fransson, P. (2005). Spontaneous low-frequency BOLD signal fluctuations: An fMRI investigation of the resting-state default mode of brain function hypothesis. *Human Brain Mapping, 26*(1), 15–29.
- Fulford, D., Johnson, S. L., Llabre, M. M., & Carver, C. S. (2010). Pushing and Coasting in Dynamic Goal Pursuit: Coasting Is Attenuated in Bipolar Disorder. *Psychological Science, 21*(7), 1021–1027.
<https://doi.org/10.1177/0956797610373372>
- Gehring, W. J., Goss, B., Coles, M. G., Meyer, D. E., & Donchin, E. (1993). *A Neural System for Error Detection and Compensation*.
- Gigerenzer, G., Czerlinski, J., & Martignon, L. (1999). How Good are Fast and Frugal Heuristics? In J. Shanteau, B. A. Mellers, & D. A. Schum (Eds.), *Decision Science and Technology* (pp. 81–103). https://doi.org/10.1007/978-1-4615-5089-1_6
- Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: reappraisal and suppression of negative emotion. *Biological Psychiatry, 63*(6), 577–586.
- Goulden, N., Khusnulina, A., Davis, N. J., Bracewell, R. M., Bokde, A. L., McNulty, J. P., & Mullins, P. G. (2014). The salience network is responsible for switching between the default mode network and the central executive network: replication from DCM. *Neuroimage, 99*, 180–190.
- Gray, J. A. (1972). The psychophysiological basis of introversion-extraversion: A modification of Eysenck's theory. In V. D. Nebylitsyn & J. A. Gray (Eds.), *Biological bases of individual behavior* (pp. 182–205). New York: Academic Press.
- Gray, J. A., & McNaughton, N. (2003). *The neuropsychology of anxiety: An enquiry into the function of the septo-hippocampal system*. Oxford university press.

- Green, J. J., & McDonald, J. J. (2009). A practical guide to beamformer source reconstruction for EEG. *Brain Signal Analysis: Advances in Neuroelectric and Neuromagnetic Methods*, 79–98.
- Gross, J., Kujala, J., Hämäläinen, M., Timmermann, L., Schnitzler, A., & Salmelin, R. (2001). Dynamic imaging of coherent sources: studying neural interactions in the human brain. *Proceedings of the National Academy of Sciences*, 98(2), 694–699.
- Harmon-Jones, E., & Allen, J. J. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: covariation of putative indicators related to risk for mood disorders. *Journal of Abnormal Psychology*, 106(1), 159.
- Harper, J., Malone, S. M., & Bernat, E. M. (2014). Theta and delta band activity explain N2 and P3 ERP component activity in a go/no-go task. *Clinical Neurophysiology*, 125(1), 124–132.
- Heubeck, B. G., Wilkinson, R. B., & Cologon, J. (1998). A second look at Carver and White's (1994) BIS/BAS scales. *Personality and Individual Differences*, 25(4), 785–800.
- Holmes, C. J., Hoge, R., Collins, L., Woods, R., Toga, A. W., & Evans, A. C. (1998). Enhancement of MR images using registration for signal averaging. *Journal of Computer Assisted Tomography*, 22(2), 324–333.
- Holroyd, C. B., & Coles, M. G. (2002). The neural basis of human error processing: reinforcement learning, dopamine, and the error-related negativity. *Psychological Review*, 109(4), 679.
- Holroyd, C. B., Krigolson, O. E., & Lee, S. (2011). Reward positivity elicited by predictive cues. *Neuroreport*, 22(5), 249–252.
- Holroyd, C. B., Nieuwenhuis, S., Yeung, N., & Cohen, J. D. (2003). Errors in reward prediction are reflected in the event-related brain potential. *Neuroreport*, 14(18), 2481–2484.

- Itier, R. J., & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: a repetition study using ERPs. *Neuroimage*, *15*(2), 353–372.
- Itier, R. J., & Taylor, M. J. (2004). Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. *Neuroimage*, *21*(4), 1518–1532.
- Jilka, S. R., Scott, G., Ham, T., Pickering, A., Bonnelle, V., Braga, R. M., ... Sharp, D. J. (2014). Damage to the Salience Network and Interactions with the Default Mode Network. *The Journal of Neuroscience*, *34*(33), 10798–10807.
- Joyce, C., & Rossion, B. (2005). The face-sensitive N170 and VPP components manifest the same brain processes: the effect of reference electrode site. *Clinical Neurophysiology*, *116*(11), 2613–2631.
- Kalanthroff, E., Cohen, N., & Henik, A. (2013). Stop feeling: inhibition of emotional interference following stop-signal trials. *Frontiers in Human Neuroscience*, *7*, 78. <https://doi.org/10.3389/fnhum.2013.00078>
- Kessler, L., Hewig, J., Weichold, K., Silbereisen, R. K., & Miltner, W. H. R. (2017). Feedback negativity and decision-making behavior in the Balloon Analogue Risk Task (BART) in adolescents is modulated by peer presence. *Psychophysiology*, *54*(2), 260–269. <https://doi.org/10.1111/psyp.12783>
- Kiefer, M., Marzinzik, F., Weisbrod, M., Scherg, M., & Spitzer, M. (1998). The time course of brain activations during response inhibition: evidence from event-related potentials in a go/no go task. *Neuroreport*, *9*(4), 765–770.
- Knyazev, Gennadij G., & Slobodskaya, H. R. (2003). Personality trait of behavioral inhibition is associated with oscillatory systems reciprocal relationships. *International Journal of Psychophysiology*, *48*(3), 247–261.

- Knyazev, Gennady G. (2012). EEG delta oscillations as a correlate of basic homeostatic and motivational processes. *Neuroscience and Biobehavioral Reviews*, 36, 677–695.
- Knyazev, Gennady G., Bocharov, A. V., Levin, E. A., Savostyanov, A. N., & Slobodskoj-Plusnin, J. Yu. (2008). Anxiety and oscillatory responses to emotional facial expressions. *Brain Research*, 1227(Supplement C), 174–188.
<https://doi.org/10.1016/j.brainres.2008.06.108>
- Knyazev, Gennady G., Levin, E. A., & Savostyanov, A. N. (2008). Impulsivity, anxiety, and individual differences in evoked and induced brain oscillations. *International Journal of Psychophysiology*, 68(3), 242–254.
<https://doi.org/10.1016/j.ijpsycho.2008.02.010>
- Knyazev, Gennady G., Savostyanov, A. N., & Levin, E. A. (2005). Uncertainty, anxiety, and brain oscillations. *Neuroscience Letters*, 387(3), 121–125.
<https://doi.org/10.1016/j.neulet.2005.06.016>
- Knyazev, Gennady G., Schutter, D. J., & van Honk, J. (2006). Anxious apprehension increases coupling of delta and beta oscillations. *International Journal of Psychophysiology*, 61(2), 283–287.
- Lacadie, C. M., Fulbright, R. K., Arora, J., Constable, R. T., & Papademetris, X. (2008). Brodmann Areas defined in MNI space using a new Tracing Tool in BiImage Suite. *Proceedings of the 14th Annual Meeting of the Organization for Human Brain Mapping*, 771.
- Lacadie, C. M., Fulbright, R. K., Rajeevan, N., Constable, R. T., & Papademetris, X. (2008). More accurate Talairach coordinates for neuroimaging using non-linear registration. *Neuroimage*, 42(2), 717–725.
- Lancaster, J. L., Rainey, L. H., Summerlin, J. L., Freitas, C. S., Fox, P. T., Evans, A. C., ... Mazziotta, J. C. (1997). Automated labeling of the human brain: a preliminary

- report on the development and evaluation of a forward-transform method. *Human Brain Mapping*, 5(4), 238–242. [https://doi.org/10.1002/\(SICI\)1097-0193\(1997\)5:4<238::AID-HBM6>3.0.CO;2-4](https://doi.org/10.1002/(SICI)1097-0193(1997)5:4<238::AID-HBM6>3.0.CO;2-4)
- Lancaster, J. L., Woldorff, M. G., Parsons, L. M., Liotti, M., Freitas, C. S., Rainey, L., ... Fox, P. T. (2000). Automated Talairach atlas labels for functional brain mapping. *Human Brain Mapping*, 10(3), 120–131.
- Lansbergen, M. M., Böcker, K. B., Bekker, E. M., & Kenemans, J. L. (2007). Neural correlates of stopping and self-reported impulsivity. *Clinical Neurophysiology*, 118(9), 2089–2103.
- LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, 23(1), 155–184.
- Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., ... Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, 8(2), 75.
- Leue, A., Chavanon, M.-L., Wacker, J., & Stemmler, G. (2009). On the differentiation of N2 components in an appetitive choice task: Evidence for the revised Reinforcement Sensitivity Theory. *Psychophysiology*, 46(6), 1244–1257. <https://doi.org/10.1111/j.1469-8986.2009.00872.x>
- Lewis, M. D., Lamm, C., Segalowitz, S. J., Stieben, J., & Zelazo, P. D. (2006). Neurophysiological correlates of emotion regulation in children and adolescents. *Journal of Cognitive Neuroscience*, 18(3), 430–443.
- Liotti, M., Mayberg, H. S., Brannan, S. K., McGinnis, S., Jerabek, P., & Fox, P. T. (2000). Differential limbic–cortical correlates of sadness and anxiety in healthy subjects: implications for affective disorders. *Biological Psychiatry*, 48(1), 30–42.

- Liotti, M., Mayberg, H. S., McGinnis, S., Brannan, S. L., & Jerabek, P. (2002). Unmasking disease-specific cerebral blood flow abnormalities: mood challenge in patients with remitted unipolar depression. *American Journal of Psychiatry*, *159*(11), 1830–1840.
- Liotti, M., Pliszka, S. R., Perez, R., Luus, B., Glahn, D., & Semrud-Clikeman, M. (2007). Electrophysiological correlates of response inhibition in children and adolescents with ADHD: Influence of gender, age, and previous treatment history. *Psychophysiology*, *44*(6), 936–948. <https://doi.org/10.1111/j.1469-8986.2007.00568.x>
- Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The Karolinska Directed Emotional Faces-KDEF. CD-ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet, Stockholm, Sweden*. ISBN 91-630-7164-9.
- Luus, B. M., Van Snellenberg, J. X., & Liotti, M. (2007). To stop or not to stop: A high spatio-temporal resolution study of response inhibition using MEG. *International Congress Series*, *1300*, 425–428. <https://doi.org/10.1016/j.ics.2007.03.016>
- MacLean, P. D. (1949). Psychosomatic Disease and the "Visceral Brain": Recent Developments Bearing on the Papez Theory of Emotion. *Psychosomatic Medicine*, *11*(6), 338–353.
- Mayberg, H. S., Liotti, M., Brannan, S. K., McGinnis, S., Mahurin, R. K., Jerabek, P. A., ... others. (1999). Reciprocal limbic-cortical function and negative mood: converging PET findings in depression and normal sadness. *American Journal of Psychiatry*, *156*(5), 675–682.
- McIntosh, A. R., & Lobaugh, N. J. (2004). Partial least squares analysis of neuroimaging data: applications and advances. *Neuroimage*, *23*, S250–S263.
- Menon, V. (2011). Large-scale brain networks and psychopathology: a unifying triple network model. *Trends in Cognitive Sciences*, *15*(10), 483–506.

- Mercure, E., Cohen Kadosh, K., & Johnson, M. (2011). The N170 shows differential repetition effects for faces, objects, and orthographic stimuli. *Frontiers in Human Neuroscience*, 5, 6.
- Mercure, E., Dick, F., Halit, H., Kaufman, J., & Johnson, M. H. (2008). Differential Lateralization for Words and Faces: Category or Psychophysics? *Journal of Cognitive Neuroscience*, 20(11), 2070–2087.
<https://doi.org/10.1162/jocn.2008.20137>
- Moadab, I., Gilbert, T., Dishion, T. J., & Tucker, D. M. (2010). Frontolimbic activity in a frustrating task: covariation between patterns of coping and individual differences in externalizing and internalizing symptoms. *Development and Psychopathology*, 22(02), 391–404.
- Moore, R. A., Gale, A., Morris, P. H., & Forrester, D. (2006). Theta phase locking across the neocortex reflects cortico-hippocampal recursive communication during goal conflict resolution. *International Journal of Psychophysiology*, 60(3), 260–273.
- Moratti, S., Saugar, C., & Strange, B. A. (2011). Prefrontal-Occipitoparietal Coupling Underlies Late Latency Human Neuronal Responses to Emotion. *The Journal of Neuroscience*, 31(47), 17278–17286. <https://doi.org/10.1523/JNEUROSCI.2917-11.2011>
- Nieuwenhuis, S., Yeung, N., Van Den Wildenberg, W., & Ridderinkhof, K. R. (2003). Electrophysiological correlates of anterior cingulate function in a go/no-go task: effects of response conflict and trial type frequency. *Cognitive, Affective, & Behavioral Neuroscience*, 3(1), 17–26.
- Nitschke, J. B., & Heller, W. (2002). The neuropsychology of anxiety disorders: Affect, cognition, and neural circuitry. *Biological Psychiatry*, 975–988.
- Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, 9(5), 242–249.

- Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: an integrative review of ERP findings. *Biological Psychology, 77*(3), 247–265.
- Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.-M. (2010). FieldTrip: Open Source Software for Advanced Analysis of MEG, EEG, and Invasive Electrophysiological Data. *Computational Intelligence and Neuroscience, 2011*, e156869. <https://doi.org/10.1155/2011/156869>
- Oostenveld, R., Stegeman, D. F., Praamstra, P., & van Oosterom, A. (2003). Brain symmetry and topographic analysis of lateralized event-related potentials. *Clinical Neurophysiology, 114*(7), 1194–1202.
- Papez, J. W. (1937). A proposed mechanism of emotion. *Archives of Neurology & Psychiatry, 38*(4), 725–743.
- Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews Neuroscience, 9*(2), 148–158. <https://doi.org/10.1038/nrn2317>
- Phan, K. L., Wager, T., Taylor, S. F., & Liberzon, I. (2002a). Functional Neuroanatomy of Emotion: A Meta-Analysis of Emotion Activation Studies in PET and fMRI. *NeuroImage, 16*(2), 331–348. <https://doi.org/10.1006/nimg.2002.1087>
- Phan, K. L., Wager, T., Taylor, S. F., & Liberzon, I. (2002b). Functional Neuroanatomy of Emotion: A Meta-Analysis of Emotion Activation Studies in PET and fMRI. *NeuroImage, 16*(2), 331–348. <https://doi.org/10.1006/nimg.2002.1087>
- Picton, T. W., Lins, O. G., & Scherg, M. (1995). The recording and analysis of event-related potentials. *Handbook of Neuropsychology, 10*, 3–3.
- Pliszka, S. R., Liotti, M., & Woldorff, M. G. (2000). Inhibitory control in children with attention-deficit/hyperactivity disorder: event-related potentials identify the processing component and timing of an impaired right-frontal response-inhibition mechanism. *Biological Psychiatry, 48*(3), 238–246.

- Polich, J. (2007). Updating P300: an integrative theory of P3a and P3b. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology*, 118(10), 2128–2148.
<https://doi.org/10.1016/j.clinph.2007.04.019>
- Popov, T., Steffen, A., Weisz, N., Miller, G. A., & Rockstroh, B. (2012). Cross-frequency dynamics of neuromagnetic oscillatory activity: Two mechanisms of emotion regulation. *Psychophysiology*, 49(12), 1545–1557. <https://doi.org/10.1111/j.1469-8986.2012.01484.x>
- Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex*, 14(6), 619–633.
- Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: what is magic and what is not. *Biological Psychology*, 92(3), 492–512.
- Pourtois, G., Thut, G., de Peralta, R. G., Michel, C., & Vuilleumier, P. (2005). Two electrophysiological stages of spatial orienting towards fearful faces: early temporo-parietal activation preceding gain control in extrastriate visual cortex. *Neuroimage*, 26(1), 149–163.
- Rao, H., Kordzykowski, M., Pluta, J., Hoang, A., & Detre, J. A. (2008). Neural correlates of voluntary and involuntary risk taking in the human brain: an fMRI Study of the Balloon Analog Risk Task (BART). *NeuroImage*, 42(2), 902–910.
<https://doi.org/10.1016/j.neuroimage.2008.05.046>
- Rayner, G., Jackson, G., & Wilson, S. (2016). Cognition-related brain networks underpin the symptoms of unipolar depression: evidence from a systematic review. *Neuroscience & Biobehavioral Reviews*, 61, 53–65.

- Ribary, U., Doesburg, S. M., & Ward, L. M. (2014). Thalamocortical network dynamics: a framework for typical/atypical cortical oscillations and connectivity. In *Magnetoencephalography* (pp. 429–449). Retrieved from http://link.springer.com/chapter/10.1007/978-3-642-33045-2_19
- Sambrook, T. D., & Goslin, J. (2015). *A neural reward prediction error revealed by a meta-analysis of ERPs using great grand averages*. Retrieved from <http://psycnet.apa.org/journals/bul/141/1/213/>
- Scherg, M., Vajsar, J., & Picton, T. W. (1989). A Source Analysis of the Late Human Auditory Evoked Potentials. *Journal of Cognitive Neuroscience*, 1(4), 336–355. <https://doi.org/10.1162/jocn.1989.1.4.336>
- Schimmack, U., & Derryberry, D. (2005). Attentional Interference Effects of Emotional Pictures: Threat, Negativity, or Arousal? *Emotion*, 5(1), 55–66. <https://doi.org/10.1037/1528-3542.5.1.55>
- Schmajuk, M., Liotti, M., Busse, L., & Woldorff, M. G. (2006). Electrophysiological activity underlying inhibitory control processes in normal adults. *Neuropsychologia*, 44(3), 384–395.
- Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: event-related brain potential studies. *Progress in Brain Research*, 156, 31–51.
- Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. *Neuroreport*, 14(8), 1107–1110.
- Schupp, H. T., Öhman, A., Junghöfer, M., Weike, A. I., Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: an ERP analysis. *Emotion*, 4(2), 189.

- Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2006). Stimulus novelty and emotion perception: the near absence of habituation in the visual cortex. *Neuroreport*, *17*(4), 365–369.
- Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., ... Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *27*(9), 2349–2356.
<https://doi.org/10.1523/JNEUROSCI.5587-06.2007>
- Segarra, P., Poy, R., López, R., & Moltó, J. (2014). Characterizing Carver and White's BIS/BAS subscales using the Five Factor Model of personality. *Personality and Individual Differences*, *61*, 18–23.
- Shufman, E., Perl, E., Cohen, M., Dickman, M., Gandaku, D., Adler, D., ... Ginath, Y. (1996). Electro-encephalography spectral analysis of heroin addicts compared with abstainers and normal controls. *The Israel Journal of Psychiatry and Related Sciences*, *33*(3), 196–206.
- Sridharan, D., Levitin, D. J., & Menon, V. (2008). A critical role for the right fronto-insular cortex in switching between central-executive and default-mode networks. *Proceedings of the National Academy of Sciences*, *105*(34), 12569–12574.
<https://doi.org/10.1073/pnas.0800005105>
- Stellar, J. (2012). *The neurobiology of motivation and reward*. Springer Science & Business Media.
- Taake, I., Jaspers-Fayer, F., & Liotti, M. (2009). Early frontal responses elicited by physical threat words in an emotional Stroop task: Modulation by anxiety sensitivity. *Biological Psychology*, *81*(1), 48–57.
- Takács, Á., Kóbor, A., Janacsek, K., Honbolygó, F., Csépe, V., & Németh, D. (2015). High trait anxiety is associated with attenuated feedback-related negativity in

- risky decision making. *Neuroscience Letters*, 600, 188–192.
<https://doi.org/10.1016/j.neulet.2015.06.022>
- Todd, R. M., Taylor, M. J., Robertson, A., Cassel, D. B., Doesberg, S. M., Lee, D. H., ... Pang, E. W. (2014). Temporal-Spatial Neural Activation Patterns Linked to Perceptual Encoding of Emotional Salience. *PLoS ONE*, 9(4), e93753.
<https://doi.org/10.1371/journal.pone.0093753>
- Uusberg, A., Uiho, H., Kreegipuu, K., & Allik, J. (2013). EEG alpha and cortical inhibition in affective attention. *International Journal of Psychophysiology*, 89(1), 26–36.
- Verbruggen, F., & De Houwer, J. (2007). Do emotional stimuli interfere with response inhibition? Evidence from the stop signal paradigm. *Cognition and Emotion*, 21(2), 391–403.
- Verbruggen, F., & Logan, G. D. (2008). Automatic and controlled response inhibition: associative learning in the go/no-go and stop-signal paradigms. *Journal of Experimental Psychology: General*, 137(4), 649.
- Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Sciences*, 9(12), 585–594.
- Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron*, 30(3), 829–841.
- Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. *Nature Neuroscience*, 6(6), 624–631.
- Wacker, J., Chavanon, M.-L., Leue, A., & Stemmler, G. (2010). Trait BIS predicts alpha asymmetry and P300 in a Go/No-Go task. *European Journal of Personality*, 24(2), 85–105. <https://doi.org/10.1002/per.740>

- Wadlinger, H. A., & Isaacowitz, D. M. (2006). Positive mood broadens visual attention to positive stimuli. *Motivation and Emotion*, *30*(1), 87–99.
<https://doi.org/10.1007/s11031-006-9021-1>
- Wang, H., Kleffner, K., Carolan, P. L., & Liotti, M. (2018). Spatiotemporal dynamics of reward and punishment effects induced by associative learning. *PloS One*, *13*(11), e0199847.
- Wessel, J. R., & Aron, A. R. (2014a). Inhibitory motor control based on complex stopping goals relies on the same brain network as simple stopping. *NeuroImage*, *103*, 225–234.
- Wessel, J. R., & Aron, A. R. (2014b). It's not too late: The onset of the frontocentral P3 indexes successful response inhibition in the stop-signal paradigm. *Psychophysiology*, n/a-n/a. <https://doi.org/10.1111/psyp.12374>
- West, R., Bailey, K., Tiernan, B. N., Boonsuk, W., & Gilbert, S. (2012). The temporal dynamics of medial and lateral frontal neural activity related to proactive cognitive control. *Neuropsychologia*, *50*(14), 3450–3460.
- West, R., & Travers, S. (2007). Tracking the temporal dynamics of updating cognitive control: An examination of error processing. *Cerebral Cortex*, *18*(5), 1112–1124.
- Wise, R. A., & Rompre, P.-P. (1989). Brain dopamine and reward. *Annual Review of Psychology*, *40*(1), 191–225.
- Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). NeuroSynth: a new platform for large-scale automated synthesis of human functional neuroimaging data. *Frontiers in Neuroinformatics*, *58*.
- Zadra, J. R., & Clore, G. L. (2011). Emotion and perception: the role of affective information. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(6), 676–685.
<https://doi.org/10.1002/wcs.147>

Zhang, Y., Zhang, G., & Liu, B. (2017). Investigation of the influence of emotions on working memory capacity using ERP and ERSP. *Neuroscience*, 357(Supplement C), 338–348. <https://doi.org/10.1016/j.neuroscience.2017.06.016>