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Self-Referential Processing: An Investigation of the Mediating Role of Alpha Power

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Graduate Program in Neuroscience
A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science

SELF-REFERENTIAL PROCESSING: AN INVESTIGATION OF THE MEDIATING ROLE OF ALPHA POWER

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Abstract

The EEG correlates of valenced self- and other-referential processing (SRP-ORP) are relatively little understood. This study examined the immediate effects of mindfulness meditation (MM) and EEG alpha neurofeedback (NFB) on resting state EEG alpha amplitudes and alpha event related (de-)synchronization (ERD/S) during an experimental implicit and explicit SRP-ORP task. Undergraduate students (n = 93) were randomized to a single session of MM, NFB alpha synchronization training ("alpha-up"), NFB alpha desynchronization training ("alpha-down"), or sham (placebo control) NFB before completing the *Visual-Verbal Self-Other Referential Processing Task* (VV-SORP-T). A reduction in resting-state alpha power over posterior cortex was observed across groups relative to pre-treatment baseline, with no differential effects observed between groups. During both SRP and ORP, however, less negative affect (NA) was experienced by participants in the alpha-down group. Alpha ERD was highest during negative ORP relative to other task conditions across groups, with the alpha-down group trending toward showing increased ERD across all conditions of the VV-SORP-T relative to the alpha-up group. Study limitations and future research directions are discussed.

Keywords

Self-referential processing, EEG Alpha, Desynchronization, Neurofeedback, Mindfulness Meditation.

Co-Authorship Statement

This thesis is the result of joint research of primary author Tanaz Javan with collaboration of co-investigator Theodore Chow under the supervision of Dr. Paul Frewen. In all cases, the key ideas, primary contributions, experimental designs, data analysis and interpretation, were performed by the author Tanaz Javan, with the contribution of the co-investigator being primarily through data collection and participant recruitment. Dr. Frewen extensively edited prior drafts of this manuscript for grammar and style. I certify that, with the above qualifications, this thesis, and the research to which it refers, is the product of my own work.

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Table of Contents

List of Tables

List of Figures

Figure Description

List of Abbreviations

Abbreviations	*Meaning*	*Page*
SRP	Self-Referential Processing	12
EEG	Electroencephalograph	12
FMRI	Functional magnetic resonance imaging	12
VV-SORP-T	Visual-Verbal Self-Other Referential Processing Task	12
RT	Reaction Time	15
IAT	Implicit Association Test	15
SELF NEGTATIVE	S-N	17
SELF POSITIVE	S-P	17
OTHER NEGATIVE	O-N	17
OTHER POSITIVE	O-P	17
ORP	Other-Referential Processing	18
CMS	Cortical Midline Structures	19
OMPFC	Orbital Medial Prefrontal Cortex	20
ACC	Anterior Cingulate cortex	20
DMPFC	Dorsomedial Prefrontal Cortex	20
PCC	Posterior Cingulate Cortex	20
RSC	Retrosplenial Cortex	20
VACC	Ventral Anterior Cingulate Cortex	20
RTPJ	Temporoparietal Junction	20
RTMS	Repetitive Transcranial Magnetic Stimulation	21
MIFG	Middle Inferior Frontal Gyrus	21
ERP	Event Related potential	23
ERS	Event Related Synchronization	23
ERD	Event Related Desynchronization	31
MM	Mindfulness Meditation	31
NFB	Neurofeedback	32
DASS	Depression Anxiety Stress Scale	37
POMS	Profile of Mood States	43

1 Introduction

I cannot totally grasp all that I am... For that darkness is lamentable in which the possibilities in me are hidden from myself: so that my mind, questioning itself upon its own powers, feels that it cannot rightly trust its own report. St. Augustine, Confessions

An understanding of the underlying nature of the "self" has been one of the chief goals of philosophy and psychology since the advent of each discipline. For present purposes, suffice it to say that what exactly the self *is*, or how it is defined, however, remains a matter of continuing debate. As but one influential example, William James categorized self as physical self (our body, immediate family, property), social self (favourably noticed by our kind), spiritual self (our consciousness, our moral sense) and the pure ego. In thesis, the term *self* will be similarly taken, as in lay usage, to refer each to a person's ego (or the means through which he or she consciously experiences the world) and his or her physical constitution. However, the present research primarily concerns the attributes by which an individual characterizes him or herself, in positive and negative terms, or those by which he or she would be described by others (i.e., his or her *identity*, e.g., his or her likes vs. dislikes, involved roles, personality traits, etc., and his or her *self-esteem*, i.e., whether such attributes are considered favorably or unfavorably).

More recently, the study of self-referential processing (SRP) has also become a subject of inquiry within cognitive neuroscience. This master's thesis considers the measurement of *individual differences* in SRP from both cognitive-experiential and cognitive-neuroscience perspectives. I will first review common methods used within psychology for measuring SRP, introducing the particular merits of a recently developed *Visual-Verbal Self-Other Referential Processing Task* (VV-SORP-T) as an experimental approach intended to assess the theoretical construct of "self" as both a set of informational *contents* as well as a particular form of information *processing* that is affectively salient. I will then review the results of past functional magnetic resonance imaging (FMRI) and electroencephalography (EEG) studies concerning the neural correlates of SRP, which motivate the design of the first EEG study of individual differences in response to the VV-SORP-T, the results of which are described herein. Finally I will consider the limitations of the present research and make suggestions for future studies.

1.1 Explicit/Direct Measures of Self-Referential Processing

Comparing how people evaluate themselves relative to others, and respond to stimuli that are inherently self-relevant (e.g., one's name, voice, or seeing oneself in a mirror or photograph) in comparison with responding to stimuli that are not immediately self-relevant, are methods by which individual differences in peoples' conscious sense of themselves can be measured. Perhaps the simplest way people can be assessed regarding how they think and feel about themselves is by administering questionnaires or, in short, by asking them. For example, people can be presented with a list of adjectives (e.g., "liked", "disliked") and asked how much each word describes how they think or feel about themselves in comparison with others. In fact, as I will review later, such a straightforward adjective rating task is the most often used experimental design in functional MRI and EEG studies of the neural correlates of SRP.

Self-report surveys measure the *explicit* aspect of self-esteem, defined as the conscious evaluation of self-worth, essentially reflecting how much people are aware of liking themselves (Rosenberg, 1965). A number of questionnaires have been developed to measure explicit self-esteem as such, for example the *Rosenberg Self Esteem Scale* (Rosenberg, 1956), the *Self-Liking and Self-Competence Scale* (Tafarodians Swann, 2001), and the *Self-attributes Questionnaire* (Pelham, & Swan, 1989). Although there are differences among these measures, they all ask participants to evaluate themselves directly. Bosson (2006) suggested that in so far as responses to explicit measures of self-esteem reflect information that is unavailable to others, they provide valuable knowledge about a person's self-concept that has high face validity. Moreover, the psychometric qualities of these measures have been consistently reported as being of high test-retest reliability and internal consistency (Blascovich & Tomaka,1991; Koestner & Mageau, 2006). For example, Schimmack & Diener, (2003) showed that self-esteem measures correlate positively with psychological well-being, life satisfaction and positive and negative affect.

Notwithstanding the general support for explicit self-esteem measures, there are some limitations and disadvantages to this direct approach to measuring self-esteem. In particular, Zeigler-Hill and Jordan (2010) argued that the assumption that people will respond to self-esteem surveys in an accurate and truthful way can sometimes be unfounded given significant correlations between measures of self-esteem and impression management, suggesting that individuals may seek to present a more socially desirable view of themselves than reflects their true feelings. For example, Mesmer-Magus and colleagues (2006) examined the correlation between social desirability and self-esteem, emotional intelligence and over-calming by asking participants to respond to a survey assessing candidacy for employment. They found that individuals with high self-esteem have a higher tendency to engage in socially desirable responding, being particularly likely to exaggerate their abilities when they are aware that they were unlikely to be reflected in objective measures such as a resume or application bank (Mesmer-Magnus, Chockalingam, Satish, & Jacob, 2006). Baumeister (1982) also suggested that differences between low and high scores on explicit self-esteem measures may reflect different strategies used by people. He argued that people with low self-esteem tend to be more cautious and self-protective, leading them to rate themselves lower on self-esteem measures in order to protect themselves from being in a *blame-worthy* situation, such as one of embarrassment and humiliation for having overrated themselves. On the other hand, people who score higher on explicit self-esteem measures tend to have a risky self-presentational strategy. Specifically, persons with high self-esteem are confident that they can succeed to be in *praise-worthy* situation, and approach personality trait evaluations more ambitiously, and attempt to cultivate their abilities more rigorously. Most substantively, explicit measures of self-esteem rely on the assumption that people are fully aware of the positive and negative aspects of themselves, in other words, that they have full introspective access to their self-attitudes and self-evaluations. This view seems unsubstantiated given that measures of explicit self-esteem also correlate with measures of self-deception. For example, Mar and colleagues (2006) showed that self-esteem is positively correlated with self-deception and negatively correlated with the five factor personality trait “openness”. Furthermore, there is a lack of support for consistent predictive validity of self-esteem measures in the literature (Baumeister, Campbell, Kryeger & Vohs, 2003).

1.1.1 Implicit/Indirect Measures of Self-Referential Processing

The contemporary concept of *implicit social cognition* has historical roots in the work of Greenwald and Banaji (1995) who defined it as an “introspectively unidentified (or inaccurately identified) trace of past experience that mediates [a] category of responses such as objective evaluative judgments” (Greenwald & Banaji, p. 5). They argued that direct survey measures are incapable of measuring implicit attitudes accurately for many of the reasons outlined above, and that there is therefore a need to develop indirect measures of implicit social cognition. Several indirect or *implicit* measures of self-esteem have therefore been developed based on the assumption that individuals have a valenced evaluation of themselves that partly functions outside of their awareness and in an automatic fashion (Greenwald & Farnham, 2000; Karpinski & Stienberg, 2006). In other words, these measures attempt to capture the unconscious aspect of self-esteem without asking the participants to directly evaluate themselves (Krizan, 2008). The design of these measures are based on two assumptions; first, that participants can be made unaware of the concept being measured, and second, that they are not aware of the cognitive mechanisms underlying measurement outcomes (Dehouwer, 2006).

Historically, prior to development of contemporary experimental measures of implicit social cognition, tasks such as judgment latency and projective measures were often used in order to provide indirect measures of social behaviours. For example, in an early study administering a dichotic listening task involving presentation of self-relevant and irrelevant trait adjectives simultaneously to different ears, and requiring participants to attend to one or the other ear and press a response button upon hearing the stimulus or indicating a self-relevance judgment, results showed that when self-relevant words were presented to the attended channel they demanded less attentional resources, with the opposite true for the unattended channel; these results were considered as an indirect measure of individual differences in implicit cognitive aspects of personality and social behaviour (Bargh, 1982, Perdue & Gurtman,1990). Projective measures involve presenting ambiguous drawings or photographs and asking participants to describe what they see on the assumption that their description reveals something about their internal organization such as, in the case of SRP, the ways in which they think and feel about themselves (McClelland, Koestner, & Weinberger, 1989; Spangler 1992).

More recent approaches to measuring implicit social-cognitive processes generally use different stimulus presentations or task instructions that pair self/other content (e.g., a person's name, or the word "me") with negative/positive valence, with the degree to which participants' response accuracy or reaction time (RT) differs as a function of trial type during performance of experimental tasks inferred as indicating the relative associative strength between the self/other and positivity/negativity. Probably the most well-known example of such a task is Greenwald and colleagues' *implicit association test* (IAT; Greenwald, McGhee, & Schwartz, 1998). In a typical IAT test, participants are trained via button-pressing to associate two target concepts, for example “flower” and “insect”, and two attributes, for example “pleasant” and “unpleasant”, with particular response keys on different trials (e.g., during certain task blocks *flower* and *pleasant* are assigned to a left response button, whereas during others one of the two concepts is assigned to a right response button). It has been shown that when highly associated words share the same response key, response time is reduced (e.g., assuming that most people will consider flowers more “pleasant” than insects, when *pleasant* is assigned to *left*, response is faster to flower-left than to insect-left). Greenwald et al. (1998) argued that this method reveals attitudes and other automatic associations that one may be unaware of, or is unwilling to express in survey measures. Indeed the IAT has been widely used in studies of prejudice, stereotypes, self-concept and self-esteem (Hofmann, Gawronski, Wschwendner, Le & Schimitt, 2005).

The first IAT tasks measuring self-esteem were developed by Farnham and Greenwald (2000) who paired button-press response options for the word “me” and “other” with positively or negatively valenced words during different task blocks. Farnham and Greenwald found that participants were faster in button-pressing when positive words were associated with “me” than when they were associated with “other”. In addition, Farnham and Greenwald (2000) found that performance levels of this intended *implicit* measure of self-esteem correlated positively with individual differences in explicit (i.e., survey) measures of self-esteem. Several other tasks have also been developed such as the *Go/No Go Association task* (Noesek, Banaji, 2001), *name-letter task* (Nuttin, 1985,1987), *Implicit Self-Evaluation Survey* (Hetts, Sakuma & Pelhem, 1999), *Extrinsic Affective Simon task* (De Houwer, 2003), and various *cognitive priming task*s (e.g., Bosson, Swann, & Pennebaker, 2000; Wentura Kulfanek, & Greve 2005). Although Farnham and Greenwald (2000) were able to demonstrate a strong correlation between explicit and implicit measures of self-esteem, the validation of these findings were questioned by more recent studies suggesting that the two measures target relatively independent concepts of self-evaluation (Spencer & Zanna, 2003; Bosson et al., 2000, Zeigler-Hill, 2006). For example, a study conducted by Zeilger-Hill (2006) using the *Rosenberg Self-Esteem Scale* (Rosenbegr, 1965) and the *Self-Esteem Implicit Association Test* (Greenwald & Farnham, 2000) compared people with so-called “fragile self-esteem” (discrepant high self-esteem, or high explicit self-esteem coupled with low implicit self-esteem) with people with “secure high self-esteem “(correspondingly high explicit and implicit self-esteem). The results showed that individuals with low implicit self-esteem but high explicit self-esteem scored highest on measurements of narcissism, whereas individuals with both high explicit and implicit self-esteem exhibited the highest self-esteem stability (measured by fluctuations in global self-evaluation over a short period of time, Kernis, Grannemann, & Barclay, 1989). In general, Zeilger-Hill's (2006) results suggest that implicit measures of self-esteem capture different aspects of self-esteem when compared to explicit measures.

Despite the literature described above, the construct validity of measures of implicit self-esteem remains contentious (Buhrmester, Blanton, & Swann, 2011). Perhaps the strongest doubt on the construct validity of existing measures of implicit self-esteem was cast by Buhrmester and colleagues, who pointed out that current measures of implicit self-esteem, as compared to measures of explicit self-esteem, lack the temporal stability one would expect of global self-evaluations, perhaps stemming from a susceptibility to measurement error. In addition, they point out that these measures are less strongly predictive of related outcomes such as psychological wellbeing and depression than are explicit measures of self-esteem. Most substantively, however, Buhrmester et al. note that implicit measures, by virtue of encompassing an indirect approach to assessing self-esteem, fail to encourage conscious introspection or interoception, processes they regard as fundamental and irrevocable to any psychological understanding of self-esteem (Buhrmester et al., 2011). Related to this, Frewen and Lundberg (2012) point out that current implicit measures do not reliably elicit significant affective responses; providing that tests of implicit self-esteem are intended to prime self-associations that are evaluative, from a construct validity perspective, they considered it a cause for concern that performing these tasks is rarely affectively salient. In addition, since implicit self-esteem is assumed to reflect the unconscious, automatic evaluation of self, and is therefore measured in a way that is not intended to be introspective in nature, the conclusions concerning self-esteem level given by implicit measures may be considered to provide an inaccurate description of self as compared with that provided by explicit measures, as judged by the very persons completing them (see Gawronski & Bodenhausen, 2006).

1.2 Visual-Verbal Self-Other Referential Processing Task (VV-SORP-T)

In order to address concerns regarding the construct validity of existing implicit/indirect measures of self-esteem, Frewen and Lundberg (2012) designed a task that combines the direct and indirect measurement of valenced SRP within a single methodology that might better encourage self-reflection and be affectively salient (see Figure 1); they titled their task the *Visual-Verbal Self-Other Referential Processing Task* (VV-SORP-T). During performance of the VV-SORP-T, participants view pictures of themselves during certain trials and same-gender strangers during others, intermixed between valenced words, creating four trial types: self-negative (S-N), self-positive (S-P), other-negative (O-N), and other-positive (O-P). Participants internally-rehearse the words "I am" or "He/she is" when presented with the respective pictures and then read the words, thereby associating the self/other with positivity/negativity on different trials (e.g., "I am"..."negative word]"). Participants are instructed to self-monitor their affective response to the task throughout, and their degree of attention and/or rate of internal speech/reading speed is measured indirectly via button-press RT. Initial results published by Frewen and Lundberg (2012) showed that participants reported experiencing significantly more positive affect during S-P trials when compared to O-P trials, and greater negative affect during S-N than O-N trials. Additionally, slower reaction time during passive button-pressing was observed during self-referential trials (both S-P and S-N trials) in comparison with other-referential trials (both O-P and O-N trials). Frewen and Lundberg interpreted the latter results as evidence of greater "reflective processing" having occurred during self-referential processing (SRP) than during other-referential processing (ORP).

As further evidence of the affective salience of completing the VV-SORP-T, the construct validity of the VV-SORP-T has been supported through subsequent psychophysiological (Frewen, MacKinley, Lundberg, & Nguyen, manuscript in preparation) and FMRI studies (Frewen, Lundberg, Brimson-Theberge, & Theberge, 2013). Referring to psychophysiological arousal, Frewen, MacKinley, et al. (in preparation) found that, although heart-rate (HR) increased significantly relative to pre-trial fixation only for O-P trials (and marginally so for S-P and O-N trials), and skin conductance response (SCR) increased non-specifically relative to pre-trial fixation for all trial-types excepting O-N, individual difference analyses revealed correlations between measures of psychophysiological arousal (HR and SCR responses) and behavioural and subjective responses during performance of the VV-SORP-T. Referring to HR, participants who reported experiencing greater negative affect during S-N relative to O-N trials also exhibited less HR increases during S-N relative to O-N trials, and participants who endorsed more positive words for self than others evidenced greater HR increases during S-P relative to O-P trials. Additionally, participants who evidenced slower RT during S-P relative to O-P trials also evidenced greater HR increases during S-P relative to O-P trials. Further, referring to SCR, participants demonstrating greater SCR increases during S-P relative to O-P trials reported greater positive affect during S-P relative to O-P trials.

In addition, in an FMRI study, Frewen and colleagues found that the VV-SORP-T is sensitive to the functional neural correlates of individual differences in self-esteem. In brief, response within the following brain regions, among others, varied as a function of VV-SORP-T trial types and/or explicit subjective responses to the task: medial prefrontal cortex, ventral anterior cingulate, anterior insula, temporoparietal cortex, temporal poles, and right amygdala (Frewen, Lundberg, Brimson-Theberge, & Theberge, 2013). In general, the VV-SORP-T seems to provide a complementary approach to measuring both explicit and implicit aspects of self-esteem that deserves additional study. The following section examines SRP and ORP from a cognitive neuroscience perspective in greater detail.

1.3 Cognitive-Affective Neuroscience of Self-Referential Processing

To study SRP in cognitive neuroscience, participants are presented with one of two kinds of tasks. In the first, they are presented with stimuli that are intrinsically related to themselves, for example, a photograph or their name, and their task is simply to indicate whether the stimulus is related to them or not, or, particularly with visual stimuli, conduct some evaluation in which determination of the self-relatedness of the stimulus is irrelevant to SRP (e.g., determination of eye gaze) or only indirectly relevant (e.g., gender determination). In either case, the degree of self-relatedness of the stimulus is generally assumed to be consciously processed, that is, that participants will become aware of the self-relatedness of the stimulus during completion of the task (Kelley et al., 2002). In contrast, a second approach to examining SRP in cognitive neuroscience is essentially to administer an adjective-rating task requiring explicit determination of self-relatedness while brain metabolic activity is recorded.

1.3.1 FMRI Studies of Self-Referential Processing (SRP)

1.3.1.1 Verbal SRP: Adjective Rating Tasks

Most recent studies of SRP conducted in cognitive neuroscience have used FMRI due to its excellent balance between spatial and temporal sensitivity (localized activation in the mm range within a time window of a small number of seconds). Particularly in the case of verbal stimuli using the adjective rating approach, a now relatively large FMRI literature shows that SRP is at least partially mediated by activation of brain regions that have been collectively referred to as Cortical Medline Structures (CMS; Northoff et al., 2006) including orbital and adjacent medial prefrontal cortex (OMPFC), the anterior cingulate (ACC), the dorsomedial prefrontal cortex (DMPFC), the posterior cingulate cortex / retrosplenial cortex (PCC/RSC), and the precuneus (Northoff & Bermpolh, 2004; Denny, Kober, Wager, & Ochsner, 2012). Fossati et al. (2003) were the first to explicitly examine SRP of valenced adjectives, comparing explicit ratings of self-descriptiveness with the general desirability of each trait word; self-referential judgments were associated with increased activation of the DMPFC and PCC. Examining cognitive and affective components of self-reflection, Moran et al. (2006) asked participants to judge whether a favorable (e.g., “honest”) or unfavorable (e.g., “lazy”) adjective is descriptive of their personality. They found that response within MPFC was increased when participants judged the self-relevance of a stimulus, regardless of valence, whereas response within ventral anterior cingulate cortex (vACC) was decreased particularly when negative adjectives were considered self-relevant. Moran and colleagues suggested that the general personal-relevance of stimuli may be processed by MPFC, with vACC assessing the valence of the stimulus. Concerning the effect of valence on SRP, it is also relevant to note that mood and anxiety disorders, which are generally associated with negative SRP (Mennin & Fresco 2014), are also associated with abnormalities in neural responding during SRP including within CMS (review by Lemogne et al., 2012). For example, Grimm et al (2009) investigated 27 participants with major depression using an emotional self-attributing paradigm and found that, compared to a non-depressed control group, depressed participants exhibited less response within DMPFC particularly during SRP of negative words. In another study, Frewen et al. (2011) compared a group of healthy women with women with posttraumatic stress disorder (PTSD) during a verbal –visual self-referential task and found significantly greater response within the pregenual region of ACC during positive SRP only in healthy women. Collectively these studies are beginning to outline the neural correlates of negative SRP, of relevance to understanding individual differences in self-esteem.

1.3.1.2 Visual SRP: Facial and Bodily Self-Recognition

In comparison with studies utilizing verbal stimuli, studies contrasting response to self-face stimuli in comparison with response to other human faces often identify activation of the right hemisphere, including of the temporoparietal junction (rTPJ, e.g., Platek et al., 2006; Sugiura et al., 2005), cingulate and frontoinsular cortex (e.g., Keenan et al, 2000, 2001, 2003). For example, creating a "virtual lesion" in the rTPJ with low frequency repetitive transcranial magnetic stimulation (rTMS) interrupted the capacity to discriminate one's own face from the face of a famous person (Heinisch, Krüger, & Brüne, 2012). Adding self-evaluative judgments to facial self-recognition, Morita et al. (2008) asked participants to consider how photogenic their face was relative to others. Data form this study showed that viewing a "bad" picture of oneself resulted in experiencing negative affect and embarrassment, an effect that was absent in rating a "bad" picture of others. The authors argued that embarrassment experienced in this situation reflects a negative evaluation of oneself. In fact, the embarrassment experienced by participants correlated positively with trait differences in private self-consciousness (being anxiously aware of internal feelings and thoughts), but not with public self-consciousness (being anxiously aware of one's physical appearance). The increased experience of embarrassment correlated negatively with response within the antroventral part of right PFC (i.e., the middle inferior frontal gyrus; mIFG), suggesting that this region may be selectively engaged during negative self-evaluations. In addition, activation in the right precentral gyrus during self-recognition preceded the activation in mIFG; given that the precentral gyrus is often activated during visual self-recognition, this temporal order of activations is consistent with self-recognition preceding self-evaluation. Finally, self-recognition increased the activation of the bilateral insular cortex, ACC, right prefrontal cortex, and bilateral occipital cortex. Beyond the study of facial self-recognition, body-ownership has also been the subject of self-related studies as it provokes a physical, embodied sense of self. Studies have shown that lesions of the rTPJ disturb a person's coherent sense of his or her body, and can result in rejection of perceived ownership of the contralateral hand (Bottini, Bisiach, Sterzi, & Vallar, 2002). Furthermore, rTMS over the rTPJ can affect the accurate judgment of one's body, with participants failing to accurately discriminate between what is and is not part of their body.

Although, these studies have begun to localize the underlying neural substrates involved in SRP, there are important conceptual issues that have been neglected. First, these studies rely heavily on explicit self-evaluations; many of the studies essentially involve administering a self-esteem questionnaire within a brain scanner, such that all of the aforementioned limitations and biases associated with this approach to understanding valenced SRP remain, for example that healthy participants tend toward selecting positive words as more personally descriptive, confounding stimulus valence with SRP judgments (Mezulis, Abramson, Hyde, & Hankin, 2004). Moreover, most of these studies are concentrated on understanding the neural mediators of basic self-awareness and self-recognition in a presumed affectively "neutral" context, thereby being agnostic regarding the emotional states engendered by self-evaluation. Additionally, most studies require participants to perform the SRP tasks in a fast event-related manner (e.g., observe or recognize their face in a stream of stimuli when presented briefly, for only a few seconds or less). This methodology is limited as a means of understanding the generation of affective states in response to SRP, being that stimulus exposures are presumably simply too fast and change too rapidly for any sustained emotional state provoked by valenced introspection concerning the self to incur.

To address certain of these limitations, the aim of developing the VV-SORP-T was to present the participant with an opportunity to observe themselves being paired with positive and negative attributes, an emotionally challenging condition. In fact, during a block of the VV-SORP-T, participants are placed in a situation in which self-recognition is complimented by self-evaluation. A participant thus sees her or his image on the screen being paired with a valenced adjective while rehearsing "I am". Moreover, this series of stimulus presentations and accompanying internal mentations is repeated five times within a lengthy (30 second) experimental block, thus occurring over a time scale potentially more provocative of a sustained emotional state. This experimental condition is thought to significantly improve the possibility of (implicitly or explicitly) triggering self-evaluations, accompanied by emotional responses. As such, the VV-SORP-T is perhaps better suited to measuring the neural mediators of emotional processes associated with SRP than the typical adjective rating tasks typically used.

Indeed Frewen et al. (2013) examined the neural correlates valenced SRP via the VV-SORP-T. They found that spatial patterns of neural activity differed during SRP relative to baseline, as compared to ORP relative to baseline. In general, results cohered with prior literature suggestive of the role of CMS in SRP (Northoff et al., 2006). For example, self-positive trials resulted in activation of ventral MPFC and left middle frontal cortex, and self-negative trials activated the right superior cortex, posterior mid-cingulate and dorsal ACC-MPFC. Right DLPFC and right temporal pole were activated during other-positive trials, while other-negative trials activated a distributed set of brain regions: the right posterior insula, left posterior insula, right middle frontal gyros, left middle frontal gyrus, left precentral gyrus, left posterior mid-cingulate and left cuneus. In addition, relative to fixation, during self-negative trials, ventral MPFC/ACC was activated particularly in participants who reported a strong negative self-evaluation. In contrast, dorsal MPFC showed increased activation in participants who experienced greater positive emotion during positive SRP. These findings are especially interesting given that the authors were able to overcome the self-positivity bias and measure the corresponding neural activity related to negative self-evaluation, as well as provoke self-reported affective responses to the task that were attended by hypothesized responses within CMS and other brain regions known to be involved in emotional processing (e.g., amygdala, insula).

Given initial support for the VV-SORP-T as a method for probing the brain bases of SRP using FMRI, additional studies employing the VV-SORP-T and similar methodologies using alternative cognitive neuroscience methods could therefore be fruitful. Specifically, although the field of cognitive neuroscience of SRP has been dominated by the use of FMRI, a deeper understanding might accrue through the additional use of complementary methods such as EEG. Indeed, although EEG is a research methodology with a more established history within cognitive neuroscience when compared with FMRI, surprisingly the study of SRP via the EEG is only a nascent field; I review this emerging literature next.

1.4 EEG Studies of Self-Referential Processing (SRP)

Although most recent cognitive neuroscience studies of SRP utilize FMRI, EEG studies have also been recently conducted. One research design has been to correlate the amplitude of specific EEG bandwidths observed during resting state with introspective self-reports of the occurrence of spontaneous self-related thoughts occurring during the same period. The alpha rhythm (8-12 Hz activity) has been studied most often in resting state investigations of SRP given in its recognized role in internal mentation more generally (e.g., mental rotation; Knaysev, 2013). An alternative research design has involved presenting participants with a self-relevant stimulus or requiring them to explicitly perform SRP tasks while specific EEG measures are acquired, for example, event-related potentials (ERP) and/or event-related synchronization/desynchronization (ERS/D) of particular EEG bandwidths relative to baseline (e.g., again, typically regarding the alpha rhythm or 8-12 Hz activity; Knaysev, 2013). Referring to the latter, event-related oscillations are subdivided into induced and evoked periods, presenting non-phase-locked versus phase-locked EEG activity in response to the stimulus, respectively (Knyazev, 2013). Given alpha oscillations have been among the most often studied EEG parameter in relation to SRP, I discuss the cognitive neuroscience of alpha oscillations generally next.

1.4.1 Cognitive Neuroscience of EEG Alpha Rhythm

Alpha band (8-12Hz) activity is the dominant oscillation form within the human brain. Alpha oscillations are thought to be mostly involved in inhibitory functions. Unlike other bands (excepting lower beta), which generally respond only with increases in synchronization, the alpha band responds to the presence of a stimulus either by increasing in amplitude (event-related synchronization, ERS) or by decreasing in amplitude (event-related desynchronization, ERD; Klimesch, 2007, 2012).

Much literature has addressed the cognitive and physiological significance of the human alpha rhythm. Alpha power suppression was first observed during eye opening, initially suggesting that this decrease in power occurs due to bottom-up sensory processing (Barger, 1929). This assumption, however, was later rejected when the same result (alpha suppression) was observed in a dark room in the absence of any visual stimulation (e.g., Moosmann et al., 2003). More recently it has been suggested that alpha suppression may be task specific (Pfurtscheller, 2003, Klimesch, 2007; Knyazev, 2007). Indeed, findings from several studies observing ERD of the alpha band now show that alpha ERD (7-13.5 Hz) occurs particularly in response to various externally-driven cognitive tasks, and that different alpha subbands show distinct topographic patterns of stimulus response, with the higher subband (10-13.5 Hz) typically restricted to different cortical regions and more associated with semantic processing demands, and the lower subband (7-10Hz) more distributed across the entire scalp and assumed to be associated with general attention; alpha-band ERS and ERD have also revealed specific patterns of temporal coherence in relation to stimulus response, with ERD typically beginning 200ms after stimulus onset and peaking at 350-600 ms post-stimulus, and ERS occurring around 900 to 2000 ms post-stimulus (see Klimesch, 2007, 2012 for a review). In reference to tasks involving external focus and high cognitive load it has been proposed that ERS has an inhibitory function on the basis that cortical areas thought to be directly involved in task-related processing show alpha ERD while surrounding regions exhibit alpha ERS (Klimesch, 2007).

Although ERD is the dominant response of the alpha band to various stimuli, ERS (i.e., an increase in alpha band amplitude) has been found to relate to certain task demands involving internal focus. For instance, alpha ERS could be observed during retention in memory tasks when the participants are asked to keep the encoded information online until the probe item is displayed, whereas ERD is observed during retrieval (Cooper et al .,2003; Klimesch et al., 1999). Klimesch (1999) interpreted this effect as alpha ERS functioning to inhibit the interference of the previously memorized items when the participant is presented with new items. His interpretation is in agreement with findings related to motor behavior; for example, when Hummel et al. (2002) asked their participants to withhold a motor response an increase in alpha power was observed over the sensorimotor areas, suggesting an inhibitory motor control. Similar increases in alpha power are found in patients with Gilles de la Tourette syndrome when they were asked to suppress voluntary movements; these patients display higher enhancement in alpha power over sensorimotor areas compared to healthy subjects (Serrien et al, 2005). Collectively these findings converge on the idea that alpha ERS reflects a local inhibition of task unrelated information whereas alpha ERD is associated with release of this inhibition in order to engage in the task at hand. They are also congruent with an interpretation of alpha band activity as reflecting an active top-down process that helps to establish selective patterns of neural oscillations relevant to task demands (Klimesch, 2007).

Of particular relevance to understanding SRP, increased alpha activity has been observed in tasks requiring internally driven cognitive processes such as mental imagery and introspection (Cooper et al., 2003; Knyazev, 2012). A few studies have also observed alpha band activity induced by emotional stimuli. For example, in comparison with viewing pleasant scenes such as landscapes, viewing movie clips of unpleasant scenes such as a thoracic operation or a cockroach invasion evoked alpha ERD over the right hemisphere (Sarlo et al., 2005). In another study, participants were presented with pictures of hands in painful circumstances versus natural pictures and asked to judge the experience of pain and unpleasantness experienced in response to these stimuli, with alpha band activity correlating negatively with experienced unpleasantness and the degree of perceived pain over left central and parietal regions. Moreover, less ERD was observed during judgment of pain compared to neutral pictures over the same areas (Mu et al., 2008). These studies suggest a possible role for alpha oscillations in *felt* experiences of SRP, although clearly further investigations are required before what possible role alpha oscillations may play in SRP is clarified. Another often studied EEG parameter in cognitive neuroscience is the event-related potential ERP); the next section reviews ERP studies of SRP.

1.4.2 Event-related Potential (ERP) Studies of Self-Referential Processing (SRP)

The physical basis of the EEG signal derives from small voltages generated through postsynaptic activity of pyramidal neurons in the brain, resulting in the electrical activity measurable from the scalp. Event-related potentials (ERPs) are electrophysiological signals recorded in response to a specific stimulus, thus thought to be a physiological signal of direct relevance to information processing. These responses could be related to various cognitive, emotional, sensory and motor events (Blackwood and Muir, 1990). The timing of the ERP has been rigorously studied, with characteristic positive and negative peaks or components within the waveform thought to be related to distinct aspects of information processing. For example, the P100 and N200 (positive and negative waveforms induced 100 and 200 ms post stimulus, respectively) are differentially associated with particular cognitive tasks such as subject’s state of arousal or spatial attention (Luck, 2005). The P300 ERP component is a particularly well-known response identifiable within the EEG to an unexpected and motivationally relevant stimulus (Polich & Kok, 1995).

Surprisingly there have been only a small number of ERP studies of SRP. For example, as compared with response to unfamiliar faces, Ninomiya et al. (1998) found that presenting self-faces generates greater P300 amplitudes. Sui, Zhu, and Han (2006) also asked participants to identify the head orientation of self-faces, familiar faces, and an unknown faces, and found that response to self-face stimuli were distinguished by a longer-latency positivity over the frontocentral area between 220-700 ms. However, these results were not replicated in other studies, with some researchers suggesting that repeated presentation of a subject’s own face will ultimately lead to habituation and a null response relative to control stimuli on the EEG (Caharel et al, 2002). Differential P300 responses have also been demonstrated in response to self-related stimuli in other modalities. For example, Perrin et al. (2005) found that a greater P300 was induced when hearing one’s own name in comparison with hearing other people’s names, and that the amplitude of the P300 correlated with regional blood flow changes in medial prefrontal cortex as assessed by positron emission tomography. However, Holler et al. (2011a, 2011b) failed to replicate greater P300 amplitudes to hearing one’s own name, and attributed their null results to differences in experimental design, whereby P300 responses may be indicative of SRP only in the context of an “oddball” response to novelty, wherein self-relevant stimuli are presented infrequently relative to non-self stimuli.

Besides the P300 response, differential ERPs to self faces have also been reflected in other temporal components of the ERP, including an increased negativity 130-200 ms post stimulus onset over occipito-temporal sites (i.e., in the N170, which is also referred to as vertex positive potential [VPP] at fronto-central sites; Joyce & Rossion, 2005). For example, Keyes et al. (2010), using a one-back repetition task involving facial expression discrimination, found that self-faces induced greater peak amplitude of the N170 over posterior sites, and a greater VPP over frontocental sites.

The discrepancies in results across ERP studies provide only weak evidence to date for the sensitivity of ERPs to discriminate a special “kind” of cognitive response that may exist in response to self-related information. Although the generally inconclusive results of ERP studies somewhat undermine confidence that some kind of a “self-specific” response exists, it might also be argued that ERP studies are fundamentally unequipped to the study of SRP. In particular, being that the analysis of ERPs involves, by definition, the analysis of cognitive-affective processes that occur over discrete moments in time, such analyses make no account of slower developing processes (e.g., over the course of tens of seconds to minutes in duration). Indeed the latter top-down cognitive phenomena, referred to as *induced responses*, are effectively cancelled out during signal averaging of the ERP (discussed in greater detail in the next section). However, as discussed above, such a time course is fundamental to models of SRP that prioritize slower developing introspective, interoceptive, and affective processes. Toward this end, we consider the results of studies examining event-related oscillations during SRP next.

1.4.3 Event-related Oscillations Studies of Self-Referential Processing (SRP)

In both ERP and event-related oscillations studies, EEG usually is recorded both during and before the task (baseline) in order to measure event-related changes in oscillatory activity. Although the examination of event related changes that are time-locked to stimuli are a powerful tool to study SRP, a portion of the neural activity relevant to SRP but that is not temporally synchronized with stimulus presentation will be canceled out during averaging (e.g., self-referential thoughts about a stimulus occurring sometime after its immediate presentation); these responses are labeled *induced responses* and are considered top-down processes. Although induced responses do not contribute directly to the perception and processing of the stimulus while it is present, they signify the oscillation of unfolding top-down processes such as attention, emotion and decision making that are relevant to its subsequent processing (David et al., 2006; Klimesch et al., 2004; Knyazev, 2013). These induced responses have been the subject of investigation in recent EEG studies of SRP, with a replicated effect being that modulation of EEG alpha (8-12 Hz) oscillations often occurs during the explicit processing self-related stimuli.

For example, Mu and Han (2011) examined the EEG correlates of SRP induced by a positive and negative adjective rating task and demonstrated that, relative to baseline, self-judgments yield alpha band ERD over posterior regions at 400-800ms and ERS over central regions at 600-1000ms, interpreted as indicating an inner-directed attention demand related to SRP. Moreover, examining the effect of valence, results suggested that self-judgments of negative traits induced enhanced alpha band ERS relative to self-judgments of positive traits, whereas a reverse pattern was observed in response to judgments regarding the applicability of negative vs. positive traits to a familiar other person. In another study, Mu and Han (2013) compared induced activity related to self-related attentional orientation (i.e., simply priming of SRP by a self-relevant cue, that is, the participants' name) versus self-related evaluation (adjective rating task). They found that self-related evaluation resulted in a stronger desynchronization in alpha and gamma bands, whereas self-related attentional orientation (response to the presence of self-name in comparison with a friend's name) showed an increase in synchronization in these bands. In comparison, Holler et al. (2011a,b) demonstrated greater alpha-band (8 to 13 Hz) dysynchronization within the frontal lobe when participants heard their own name when compared to hearing others' names.

Across different EEG measures and experimental paradigms, it thus appears that the power of the EEG alpha band may fluctuate during processing of external self-related information, although the direction of these effects (i.e., ERS vs. ERD) likely depends at least in part on the time course with which it is measured relative to stimulus onset, as well as in accordance with participants' task in relation to being presented with self-relevant information. However, generally existing studies have tended to rely on variations of a simple adjective rating task. As such, these studies are limited in their ability to capture the neural underpinnings of the implicit nature of SRP as well as any strong experience of positive or negative affect related to one's sense of self primed by disagreement between external (i.e., task-driven) and internal self-representations. Finally, although the examination of induced responses allows the neural characterization of cognitive responses that occur over a longer duration in comparison with the evaluation of the ERP, study designs have continued to administer stimuli discretely, such that fundamental issues regarding the time course of SRP remain. Studies of resting state responses somewhat amend for such issues, but have their own unique problems, discussed next.

1.4.4 EEG Resting State Studies of Self-Referential Processing (SRP)

A small number of studies of resting-state EEG have attempted to correlate individual differences in the frequency of occurrence of spontaneous self-referential thoughts to distributed networks of EEG bandwidth amplitudes including within the default mood network (DMN), a set of often coactivated brain regions that include the previously specified CMS (cortical midline structures). For example, in Knyazev,et al.'s (2011) study, after completing a 6 minute EEG baseline (eyes opened and eyes-closed conditions), participants were asked to report their thought processes during the baseline by responding to a set of questions such as how often they experienced "recollected episodes of own life", "recollected pleasant episodes of relationships with my boy/girl-friend" and "thoughts of something pleasant that I expect in the near future". Applying ICA and sLoreta analysis, the authors showed that greater alpha activity in midline posterior cortex correlated with a greater preponderance of self-related thoughts (Knyazev et al., 2011). Moreover, in a subsequent study these researchers found that such effects interacted with participants' ethnic background whereby increases across participants in self-reported occurrence of self-referential thoughts were correlated to increases in EEG alpha activity in midline posterior cortex specifically in Russian participants, but correlated to increases in EEG alpha activity within midline frontal cortex in Taiwanese participants. They considered whether cultural differences in self-construal may be responsible for the differences observed. Taking into account that individuals from Western vs. Eastern backgrounds tend to score higher in extroversion, and that individual differences in extraversion have been found to be associated with increase in alpha power within the posterior hub and decreases within the anterior hub of the DMN, the authors suggested that individuals from a Western background may be exhibiting a pattern of brain activity characteristic of greater extroversion (Knyazev et al., 2013).

Although providing interesting results supportive of the role of alpha oscillations in SRP, the relevance of correlations between free floating spontaneous thoughts to understanding *valenced* SRP remains unclear, given that the occurrence of overtly negative vs. positive thoughts about oneself has not been specifically examined. Although it can be argued that spontaneous thoughts can be emotionally coloured, a proper measure to distinguish the emotional valence of SRP has been absent in these studies. Moreover, the fact that these experiences are experimentally unprovoked renders them entirely correlational nature, limiting causal inference concerning the neural processes mediating the subjective phenomena assessed. The accuracy of the observations of these studies rests significantly on the experiential self reports given by the participants during the resting state; there is no obvious way of confirming the accuracy of these reports. Finally, that the neural processes examined are linked only superficially in time, that is, over an entire 3-6 minute period, renders these results rather non-specific. In other words, whereas existing ERP and ERS/ERD studies suffer from being overly restrictive in the time course over which analyses are carried out, resting state studies are arguably overly diffuse, making it difficult to ascertain effects unique to SRP relative to other cognitive processes. Therefore, applying a task such as VV-SORP-T could ideally provide a middle ground that begins to address these issues because it measures SRP under experimentally provoked circumstances including indirectly through pairing images of oneself to valenced adjectives over 30-second epochs conducive to generating affective experience as assessed by subsequent self-report. Even stronger scientific grounds for assessing the potential role of alpha oscillations in SRP, however, would be provided by a study designed to causally manipulate the amplitude of alpha oscillations and assess outcomes for SRP; several interventions exist for regulating the alpha rhythm in humans, including mindfulness meditation and EEG neurofeedback, considered next.

1.5 Experimental Manipulation of Self-Referential Processing (SRP) through Self-Regulation of the EEG Alpha Rhythm

Mindfulness meditation (MM) generally involves maintaining one's attention toward internal sensations (e.g., breathing) and disengaging from sources of distraction (i.e., mind wandering), with or without the aid of external reminders (e.g., the regular sounding of a bell). Repeatedly practicing MM is known to be associated with improvements in psychological well-being and lowering of experiences of anxiety and depression (see Hofmann et al, 2010 for a review), and is therefore of relevance as an intervention to modulate the valence of SRP.

MM has also been shown to influence the neural correlates of SRP in various ways. For instance, examining the effect of mindfulness-based stress reduction (MBSR) on SRP, Farb et al. (2007) asked participants to respond to positive and negative words, during distinct task blocks, either non-elaboratively, by attending only to the effect each word had on their bodily and emotional state, or elaboratively, for instance by explicitly considering whether the adjective is self-descriptive (i.e., as in adjective rating tasks). The cortical networks involved in elaborative SRP included increases in ventral and dorsal MPFC and PCC, although participants trained in MM evidenced less activation in these regions, coupled with increased activation of dorsal and ventrolateral PFC, brain regions associated with cognitive control. The authors suggest that MM could therefore be effective in reducing negative self-rumination. Goldin, Ramel, and Gross

(2009) also showed that completion of an MM-based intervention enhanced participants' endorsement of positive relative to negative adjectives in persons with social anxiety disorder. The authors argued that MM encourages a moment-to-moment awareness accompanied by non-judgmental attitudes toward negative thoughts, therefore disengaging MM practitioners from negative self-evaluation and negative self-focused rumination. Goldin et al. (2009) also found that these subjective effects were associated with decreases in response of CMS, specifically MPFC, DMPFC and PCC, during the adjective rating task.

In addition to findings from FMRI, a plausible neurophysiological mechanism partly through which MM practice may improve well-being is via the regulation of EEG alpha (8-12 Hz) oscillations over posterior, central, and anterior midline cortex (Cahn & Polich, 2006; Jindal, Gupta & Das, 2013), long known to be associated with eyes-closed states of relaxed alertness and inward focus as reviewed above (Chun, Golomb, & Turk-Browne, 2011). The neurophysiological correlates of MM, particularly in terms of modulating EEG alpha power, have been the subject of several studies. In an extensive review of more than 60 studies Chan and Polich (2006) reported that increases in alpha and frontal-theta power were associated with MM practice. For example, Huang and Lo (2009) compared changes in alpha oscillation after 40 minutes of meditation with 40 minutes of rest in a between groups design and showed that alpha power over frontal cortex significantly increased in the meditators whereas in the control group it was theta power which increased relative to baseline. Takahashi et al. (2005) also examined the effect of 20 minutes of Su-soku meditation, in which participants started counting from one when they exhaled, and inhaled naturally without counting, up to 100 before starting over. Results of this study indicated that meditation was associated with increases in frontal alpha and theta power. Also an inhibition of sympathetic tone and activation of parasympathetic tone measured by heart rate variability was observed. Further, Travis (2001) asked participants to report their experiences during meditation when they heard a bell rung at 5, 10 and 15 minutes into a MM session, and results showed that whenever participants experienced a sense of "transcendence" ("self-awareness and pure consciousness") during the bell rings they were more likely to be exhibiting higher frontal alpha power. In summary it appears that alpha power increases are associated with practice of different forms of meditation including mindfulness, however, there are few studies investigating the EEG correlates of SRP as a function of meditation practice.

Whereas MM practice modulates EEG-alpha activity only *indirectly* as an outcome of practicing a form of sustained inward attentional focus, during EEG-alpha neurofeedback (NFB) participants learn to self-regulate their ongoing EEG-alpha oscillations *directly* as aided by real time visual and/or auditory feedback. Generally, NFB is the process of recording an individual's electrical brain activity and sending this data back to the participant so that he/she can learn to influence it. NFB does not involve any input in the form of electrical impulses or subliminal messages. Participants simply receive feedback from audio output signals that relate to the ongoing physiological state of their central nervous system.

The trainability of the alpha amplitude via NFB has been the subject of several studies. For instance, an increase in alpha power was observed by Dekker et al. (2014) after ten sessions of NFB training on upregulating amplitude of the alpha band. Similar findings were reported by Zoefel, Huster, and Herrmann (2011) who observed an enhancement in alpha sub-bands relative to baseline after training the alpha band, which was in turn predictive of improved performance in an inward directed cognitive task (mental rotation). In fact, only a single session of a NFB EEG-alpha intervention resulted in improved calmness and impacted connectivity within the default-mode network relative to sham ("placebo control") NFB in a study previously conducted at Western University (Ros, et a., 2013).

Moreover, alpha-NFB interventions have been shown to impact psychological disorders known to be associated with SRP. In a comprehensive review of NFB treatment for psychiatric disorders, Schoenberg and David (2014) showed that significant improvements of depression, OCD symptoms, and autistic symptoms have been reported in studies of NFB directed toward enhancing alpha power. Moreover, a significant reduction in anxiety and a positive enhancement of quality of life have also been reported by studies applying alpha-enhancement protocols to reduce anxiety. For example, Choi et al. (2011) reported a significant reduction in anxiety symptoms after completion of alpha-enhancement NFB as compared to placebo psychotherapy.

However, to our knowledge the effects of NFB explicitly for SRP have not been studied, including in contrast with those for MM. A novel research question thus arises as to whether, by experimentally manipulating the amplitude of the baseline alpha rhythm, one can impact the quality of valenced SRP, in turn furthering our understanding of the role of alpha brain oscillations in SRP.

1.6 Study Overview and Hypotheses

To our knowledge, this is the first study to investigate neural responses to the VV-SORP-T using EEG. Moreover, it is the first to assess whether the modulation of baseline EEG-alpha activity through MM or NFB as brief, single-session experimental manipulations can positively or negatively affect the subjective, cognitive, and neurophysiological (EEG) response to SRP. In order to further investigate the role of neural oscillations in SRP, particularly regarding that of the alpha band (8-12 Hz), we investigated whether experimentally modulating alpha-band amplitudes, either indirectly, through MM practice, or directly, through EEG neurofeedback, can effect SRP as assessed by response to the VV-SORP-T subjectively (via self-reports), behaviourally (via RT) and electrophysiologically (i.e., via EEG alpha oscillations observed during the task). Participants were randomized to one of the following 4 groups: 1) MM, 2) NFB-alpha-up (involving training participants to *increase* resting-state alpha amplitudes), 3) NFB-alpha-down (involving training participants to *decrease* resting-state alpha amplitudes), and 4) sham ("placebo") NFB.

This study was designed to evaluate the possible role of EEG-Alpha oscillations in mediating valenced self- and other-referential processing (SRP-ORP). We predicted that alpha ERD/S would vary across the experimental conditions of the VV-SORP-T, examining whether SRP vs. ORP would differentially implicate alpha-ERD as a function of valence. To further assess the possible causal role of EEG-alpha oscillations in SRP-ORP, we also examined whether brief MM and NFB interventions, expected to modulate the resting state EEG-Alpha amplitude, would further affect valenced SRP-ORP. Finally, of particular relevance to the cognitive neuroscience of self-esteem and related traits, we also examined individual differences (across participant variability) in VV-SORP-T alpha-ERD in association with self-report and behavioural measures of valenced SRP-ORP. Due to the nascent nature of current literature, analyses were conducted non-directionally (2-tailed) unless otherwise specified.

Chapter 2

2 Methods

2.1 Participants

Ninety-three University of Western Ontario (UWO) students (33 male, age 18-30) were recruited either from the Department of Psychology undergraduate research participation pool or were undergraduates registered in a third-year undergraduate course. All students received partial course credit for participating.

Data were excluded from statistical analysis for one of the three reasons: 1) no reaction time data was collected from the experimental task; 2) they did not complete one of the questionnaire measures; 3) EEG data was unusable due to a preponderance of artifacts as a result of eye blinking, head, neck and leg movement (retention rate < 60%). Participants' data was also excluded form statistical analysis due to outliers in DASS-Depression scores and outliers in current mood state rating scale scores (POMS; described below). Figure 1 illustrates the number of participants retained. Usable EEG baseline data was collected from 81 participants, with 60 of these participants' having usable data for VV-SORP-T analysis.

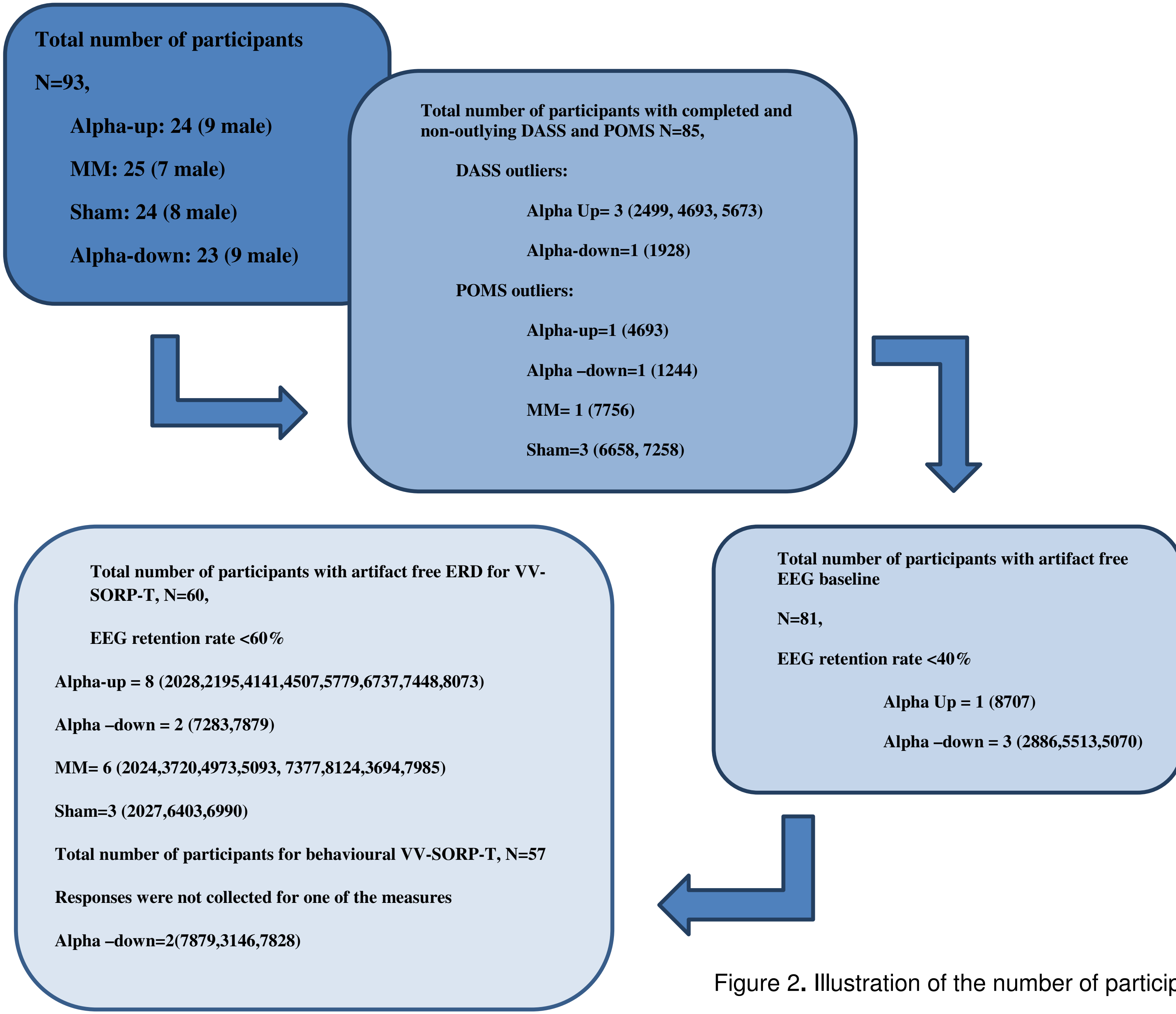

Figure 2. Illustration of the number of participants retained

2.2 Ethics Approval and Informed Consent

The University of Western Ontario Health Sciences Research Ethics Board (HSREB, Study ID: 103335) approved the study. Participants provided written consent to participate after being introduced to the background and the purpose of the study along with potential risks and discomforts involved in participating. There were no adverse events for any participant.

2.3 Self-Report Measures

All the self-report measures were collected online using the Qualtrics Research Suite (Qualtrics, Prov, UT). Participants' anonymity was maintained through use of a de-identified subject number, entered at the beginning of each survey. All participant survey responses were collected using a laptop computer with internet connection.

2.3.1 Depression Anxiety Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

The short version of the DASS is a 21-item self-report questionnaire designed to measure depression, anxiety and stress symptoms occurring during the week prior to survey completion. Each item is scored on a 4–point Likert-scale ranging from 0 ("Did not apply to me at all") to 3 ("Applied to me very much or more of the time"). The 21 items are divided into three 7-item subscales: depression (e.g., "I felt down-hearted and blue"), anxiety (e.g., "I felt I was close to panic") and stress (e.g., "I found it difficult to relax"). This measure is one of the most widely used for the purpose of measuring depression, anxiety, and stress symptoms via a single scale.

2.3.2 Profile of Mood States (POMS-SF; Curran, S.L. et al, 1995)

The POMS-SF is a 37-item measure of six different mood states experienced at the time of survey completion: depression, tension-anxiety, vigor-energy, fatigue, anger-hostility, and confusion-bewilderment. Responses are provided on a five-point Likert-scale ranging from 0 ("not at all") to 4 ("extremely"). Items are single words, for example: "helpless", "worthless", “energetic”, and “cheerful”. This measure is commonly used and exhibits acceptable psychometric properties.

2.4 Experimental Manipulation

2.4.1 EEG-Alpha Neurofeedback (NFB)

In NFB sessions of this study, participants were trained to either enhance their EEG alpha amplitude (“alpha-up” group) or to reduce it (“alpha-down” group). The training site Pz was chosen for the placement of the electrode since EEG-alpha rhythm is typically highest at this site (Ergenoglu et al. 2004). Before electrode placement, the skin of participants’ scalp was cleaned with NuPrep and the electrode was attached to the scalp using Ten20 conductive paste. The ground electrode was placed on the right earlobe and the reference electrode was placed on the left earlobe. The three electrodes were connected to a Spectrum4 amplifier (J&J Engineering, United States) interfacing with EEGer 4.3 neurofeedback software (EEG Spectrum Systems, CA). Impedances for all electrodes were maintained at maximum 5kΩ. A 3-minute baseline was recorded followed by the 15-min NFB intervention, both while participants’ eyes were closed. The protocol of the study was set such that participants either heard a reward tone when the alpha amplitude at the Pz site was enhanced (“alpha-up” group) or diminished (“alpha-down” group) beyond a moving last-minute threshold. With an epoch size of 0.5 seconds, the raw EEG signal was IIR (infinite impulse response) band-pass filtered to extract the moving average alpha (8-12Hz) amplitude. Participants heard the reward tone only 65% of the time when their recorded alpha amplitude was above (“alpha-up” group) or below (“alpha-down” group) the prior minute average threshold.

To ensure that the necessary level of cognitive effort to achieve a positive feedback signal was approximately consistent for all participants during the NFB session, the threshold set up was constantly monitored and was readjusted whenever a participant was receiving disproportionately larger (>90%) or lower (>30%) reward rates. Further investigation of the number of audio feedback received by participants indicated that participants have received 240-275 audio feedback on the average. Participants were not given any specific cognitive strategies by which to implement during NFB; rather they were asked to use the audio tones and their own experience as a guide.

2.4.2 Sham Neurofeedback (NFB)

The procedure and set up for the sham group remained identical to the real NFB sessions. However, participants in the sham group received a pre-recorded session instead of receiving real reward tones related to their own brain activity (Raymond et al., 2005). The intention was to provide a similar intervention experience of having conducted a NFB session to the sham group that was in fact fully independent of their actual recorded alpha amplitude.

2.4.3 Mindfulness Meditation (MM)

Participants in the MM group were instructed to practice MM for 15 minutes. They were asked to sit in a comfortable position, keeping their eyes closed. They were instructed not to change their breathing pattern but merely to become aware of the natural pace and quality of their breathing. They were further instructed to become aware of wandering thoughts and in these cases to bring their attention back to their breathing. In addition, *Meditation Breath Attention Scores* (MBAS) were assessed during the MM such that participants' periodically indicated, as prompted by a bell sound, whether they were attending toward their breathing, as instructed, or whether they had become distracted from breathing, via a simple keyboard button-press while keeping their eyes closed (Frewen et al., 2008, 2011, 2014). The results of this self-report are discussed in another master's thesis (Chow, 2014).

2.5 Cognitive Task

2.5.1 Visual Verbal Self/Other-Referential Processing Tasks (VV-SORP-T)

The VV-SORP-T, developed by Frewen and Lundberg (2012), was used in this study. This task contains three parts: 1) an adjective rating survey in which participants indicate the applicability of a list of negative and positive adjectives to the survey respondent him or herself as well as, via a separate rating, unknown individuals (strangers, or "people in general"); (2) a cognitive task measuring reaction time; and (3) an affect rating questionnaire referring to emotions experienced during the cognitive task, being collected after its completion.

In the first part of the VV-SORP-T task, the adjective rating procedure, participants were asked to read a list of 10 negative and 10 positive words and to rate "… how much each word describes: (a) how you think about yourself , and (b) how you think about other people, in general". Responses to each adjective were provided on an 11-point (0-10) scale between "Not at all" (0), "Moderately" (5), and "Completely" (10). Participants were asked to consider the "other person" as a typical person who they do not know personally but might meet in their day to day life. The 20 words in the list covered social and achievement-related themes such as *strong* (positive-achievement), *cared for* (positive-social), *failure* (negative-achievement), and *rejected* (negative-social). The list was identical to the one used by Frewen and Lundberg (2012).

For the cognitive task, using a standard-use electronic camera (4.1 megapixel), a photograph was taken of each participant (above shoulder) against an off-white lab wall. Participants were encouraged to pose in neutral expression, as if for a passport picture. The photographs were then standardized in order to match in all essential respects the features of the NimStim set of facial expressions (Tottenham et al., 2009). The NimStim set of facial expressions was then used to find a match for each participant in terms of gender, ethnicity, and approximate age; this individual served as the "stranger" used in the cognitive component of the task.

Figure 2 illustrates an example block of the cognitive task procedure of the VV-SORP-T. Stimuli were delivered by E-Prime (Psychological Software Tools,Inc.). Each cognitive task block began with presentation of a fixation cross (+) for 15 seconds. After presentation of the fixation cross, at the onset of each block, the word " Self" or "Other" was displayed, indicating whether the participant should expect to see a picture of their own face or a picture of the stranger's face in the upcoming block. After this, 10 stimuli were presented in on-off order: 5 pictures and 5 words (i.e., picture-word-picture-word-picture...). The words used in each block were the same as those used in the adjective rating survey and were of one valence (i.e., were all positive or were all negative). Likewise, the 5 pictures were all of the same individual. As such, the task was blocked in terms of the factors *Reference* (self-vs-other photograph) and *Valence* (positive-vs-negative words). All the words were presented in capital letters, in black ink using

44 point, Calibri font. Stimuli were presented in the center of the computer screen against a white background.

Participants were instructed to consider three things when completing the VV-SORP-T: (1) when they see the picture silently rehearse the statement “I am” or “He/She is” and upon seeing the word to read it silently; (2) press a response button with either their index/middle fingers (counter-balanced) of their dominant hand after rehearsing each statement or word; and (3) pay attention to how they are feeling emotionally throughout the different parts of the task.

Participants were presented with eight-blocks in each of two 6 minute runs. The order of blocks within each run was randomized across participants. Moreover, prior to the task, participants took part in two practice trials, one presenting the self-picture, and the other presenting the stranger’s picture. Words used in these practice trials were repetitively “WORD” instead of the negative and positive adjectives.

After completing the cognitive task, participants were presented with an affect rating scale, as well as open-ended questions phrased in terms of the following structure: ‘‘What did you notice about how you were feeling and reacting when you viewed [either ‘‘your OWN’’ or ‘‘the OTHER PERSON’s’’] face paired with [either ‘‘NEGATIVE’’ or ‘‘POSITIVE’’] words?’’ Participants were asked to rate from zero (‘‘Not at all’’) to 100% (‘‘Strongly’’), with 50% indicating ‘‘Moderately’’, ‘‘... how much you felt certain specific feelings in response to each picture and word type combination.’’ Participants made such ratings for the following five negative affective states: ‘‘Anger’’, ‘‘Sad’’, ‘‘Anxiety-Fear’’, ‘‘Disgust’’, ‘‘Bad About Self’’, which were averaged as a ‘‘Negative Affect Rating’’, as well as for ‘‘Happy’’, which served as a ‘‘Positive Affect Rating’’.

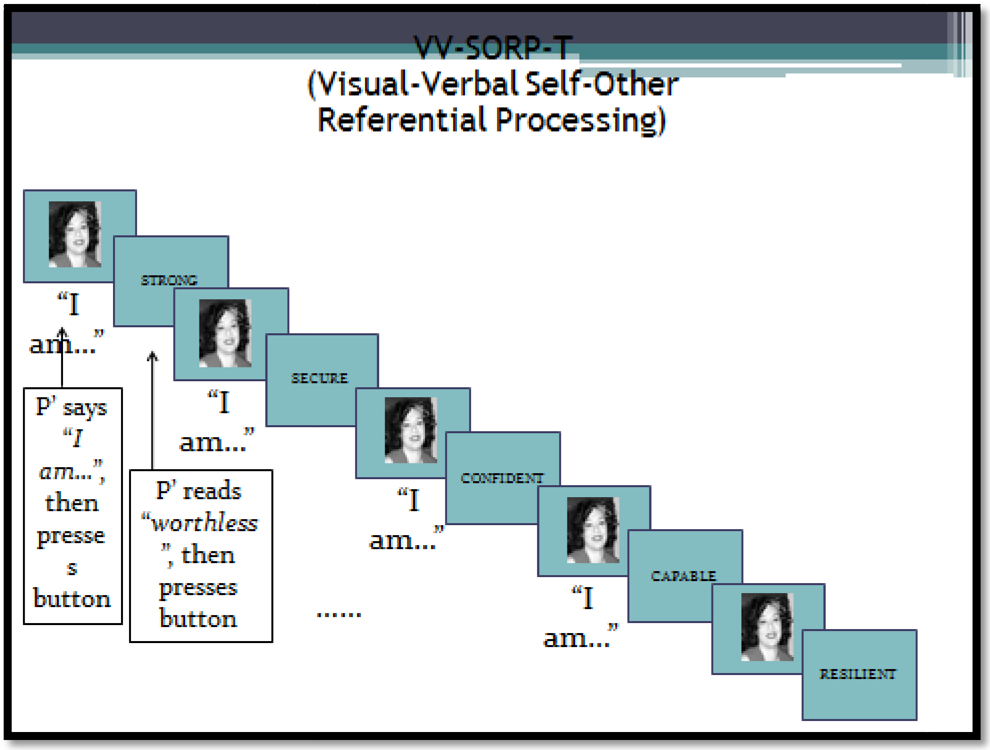

Figure 2. Illustration of one block of the Visual-Verbal Self/Other-Referential Processing Task

2.6 Electrophysiological Measures

2.6.1 EEG Recording and processing

Scalp voltage was recorded using a 32Ag/AgCl electrode cap with electrode placements positioned according to the 10-20 international system: FP1, FP2, AF3, AF4, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5,CP1, CP2, CP6, P7, P3, Pz, P4, P8, PO3, PO4, O1, Oz, O2. A "Common Mode Sense" active electrode and a "Driven Right Leg" passive electrode were used as ground electrodes (see www.biosemi.com/faq/cms&drl.htm for details). The average reference was used for off-line analysis. Electrooculogram was also recorded with electrodes placed on the outer canthus of each eye (horizontal) and above and below the left eye (vertical). The impedance of all electrodes was maintained below 5kΩ. All bioelectric signals were digitally filtered using ActiView software (BioSemi) at a rate of 512 Hz with a bandpass filter of 0.1– 100 Hz via personal computer.

Offline analyses were performed using routines taken from EEGLab v12, an open source toolbox running in the MATLAB environment for electrophysiological signal processing (Delorme & Makeig, 2004; http://sccn.ucsd.edu/eeglab/). Data were imported into MATLAB and referenced using a common-average head reference algorithm.

EEG baseline data were bandpass filtered with cutoffs of 1Hz and 30Hz. EEG data streams were then divided into 1s epochs for artifact rejection. Data for trials contaminated with EOG activity greater than ±75 microvolts (µv) were excluded from further analysis. Epochs were also visually examined and rejected if they were contaminated by gross-movements or other non-stereotyped artifacts.

2.6.2 Event-related Desynchronization (ERD)

ERD data acquired during performance of the VV-SORP-T were FIR filtered offline between 0.1Hz to 30Hz, 12dB/octave. Data for trials contaminated with EOG activity greater than ±75 microvolts (µv) were excluded from further analysis. ICA decomposition was applied to remove stereotypical artifacts. Epochs were also visually examined and rejected if they were contaminated by gross-movements or other non-stereotyped artifacts.

ERD data were assessed within a time window from 0 to 33s that was time-locked to the VV-SORP-T stimulus onset in each of the four *Reference*-by-*Valence* conditions and continued over an entire block consisting of eleven 3-second stimuli (see Figure 2) in comparison with the baseline period (i.e., pre-stimulus interval; -15 seconds to block onset). ERD, as it will be described in the following section, was calculated separately for the four distinct *Reference*-by-*Valence* conditions: Self-Positive, Self-Negative, Other-Positive, and Other-Negative.

2.6.3 Spectral Analysis for Continuous EEG at Baseline

EEG power was calculated using Welch's power spectral density estimate in the Neurophysiological Biomarker Toolbox, an open source toolbox running in MATLAB (NBT; Hardstone et al., 2012; www.nbtwiki.net). Continuous EEG was Fast Fourier Transformed (FFT) and averaged in the frequency domain using a hamming window (1024 sampling points). The FFTs were then grouped into overall alpha (8-12Hz) frequency band and log-transformed. Responses observed for specific electrodes were grouped into nine different regions: Left-Frontal (Fp1, AF3, F7, F3), Mid-Frontal (Fz, FC1, FC2), Right-Frontal (Fp2, AF4, F8, F4), Left-Central (T7, FC5, C3, CP5), Mid-Central (Cz), Right-Central (T8, FC6, C4, CP6), Left-Posterior (P7, P3, PO3, O1), Mid-Posterior (CP1, CP2, Pz), and Right-Posterior (P8, P4, PO4, O2). The average alpha (8-12 Hz) amplitude was calculated for the nine respective regions for three minutes both before and after the respective interventions (MM, NFB alpha-up, NFB alpha-down, and NFB-sham). The nine electrode regions formed two independent factors: REGION (Left, Right, Midline) and LOBE (Frontal, Central, Posterior). Figure 3 displays the topography of the EEG electrode positions in terms of the REGION and LOBE factors.

2.6.4 Event Related Desynchronization Analysis during VV-SORP-T

Before calculating ERD/S, data were digitally band-pass filtered, squared (in order to obtain simple power estimates) and averaged. To calculate ERD the percentage of increase (ERS; synchronization) in the alpha band power during a post-stimulus interval (A) was compared to a baseline reference interval (R) as follows: ERD% = $(A - R)/R \times 100\%$. This method for calculation of the ERD was originally proposed by Pfurtscheller and Lopes da Silva (1999) and is in wide use. The time window of -15s to the stimulus onset specific to each condition was used as the baseline reference interval (R). The post-stimulus test interval was that of an entire VV-SORP-T block, that is, the 33s period in which participants were internally-rehearsing statements, button-pressing, and attending toward their affective state in response to doing so. This was calculated separately for each of the four experimental conditions (S-P, S-N, O-P, O-N). ERD values were finally collapsed into the 9 cortical regions as described above referring to the REGION and LOBE factors (Figure 3).

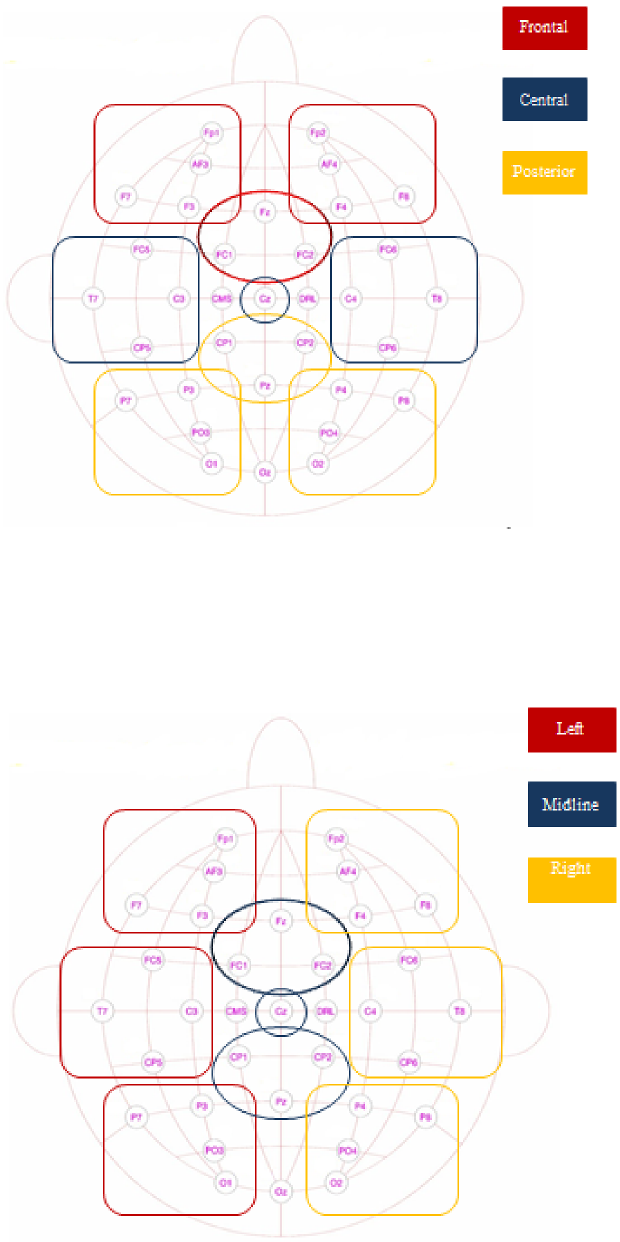

Figure 3. Display of the topography of EEG recorded electrodes positions

2.7 Procedures

Participants were randomly assigned to MM, NFB-Alpha-Up, NFB-Alpha-Down, or NFB-Sham. Each session required approximately 75-90 minutes including conduct of the experimental manipulation itself in addition to survey completion and EEG electrode placement and removal.

EEG was recorded during the entire study period, with participants wearing a whole-head multi-channel EEG cap. Each session began with participants completing the self-report questionnaires (DASS, POMS, VV-SORP-T adjective rating list) using a laptop.

Following questionnaire completion, the EEG cap and electrodes were affixed, with three extra electrodes placed on the scalp for participants in the NFB-Alpha-Up, NFB-Alpha-Down, and NFB-Sham groups, at the Pz training site (midline parietal cortex), as well as at the right and left earlobes (reference and ground). Three-minute baseline EEG was then recorded, during which participants were asked to relax passively with their eyes closed. Continuous EEG recording was then obtained while participants engaged in MM, or NFB, for 15-minutes uninterrupted. All treatments were delivered with participants' eyes-closed by two MSc students Tanaz Javan and Theodore Chow supervised by Dr. Paul Frewen. The MBAS self-report scale was also collected from participants during practice of MM. Following the experimental manipulations, a second 3-minutes eye-closed baseline EEG was acquired. To measure the subjective experience of the participants after the experimental manipulations, two additional self-report measures were collected referring to the assessment of mindful states, followed by completion of a standard Stroop task. The results of the Stroop task and the mindfulness questionnaires are the subject of another Master's thesis and therefore will not be described here. VV-SORP-T was then completed as the final cognitive task of the testing session. Participants were then debriefed and thanked for their participation in the study.

2.8 Statistical Analyses

2.8.1 Self-reports scales

Group differences were calculated for last week depression, anxiety and stress symptoms (DASS scores), as well as for mood (POMS) before vs. after completion of the interventions

(MM, NFB, Sham-NFB). DASS was subjected to one-way independent measure ANOVA and the POMS subscales were subjected to repeated measures ANOVA.

2.8.2 EEG-Alpha amplitude during continuous EEG baselines

The mean values for the alpha frequency band amplitude were analyzed subjected to a four-way split-plot ANOVA having GROUP (NFB-Alpha-UP, NFB-Alpha-Down, Sham, MM) as a between-subject factor and time point of the assessment (pre-vs-post intervention) as a within-subject factor.

2.8.3 Behavioural VV-SORP-T and ERD during task

Preparation of the self-report and behavioural (reaction time) data acquired during performance of the VV-SORP-T matched previously published approaches (Frewen & Lundberg, 2012). Specifically, across blocks and runs for each of the four trial-types (S-N, S-P, O-N, O-P), VV-SORP-T adjective rating scores were summed, and button-press RT and affect ratings were averaged.

The four self-report or behavioural dependent measures of the VV-SORP-T: 1) adjective ratings, 2) positive affect ratings, 3) negative affect ratings, 4) reaction time), were analysed separately from EEG results (ERD). Both were analysed using ANOVA with GROUP as a between-subjects factor (alpha-up, alpha-down, MM, Sham-NFB) and REFERENCE (Self-vs-Other) and VALENCE (Positive-vs-Negative) as within-subjects factors. In the analysis of ERD, we additionally examined LOBE (Frontal-vs-Central-vs-Posterior) and HEMISPHERE (Left-vs-Right-vs-Midline) as within-subjects factors. Correlations between subjective-behavioural results and ERD were calculated only for conditions involving significant REFERENCE by VALENCE interactions for ERD.

Chapter 3

3 Results

3.1 Self-reported Prior Week Depression, Anxiety, and Stress (DASS-21)

To compare possible differences between groups in depression, anxiety and stress prior to randomization, a one-way ANOVA was performed on DASS subscale scores. No significant differences between groups were found for any of the DASS subscales; results are reported in Table 1.

Table 1. Descriptive statistics of Self-Reported Depression, Anxiety, and Stress (DASS)

	Alpha-up		*Alpha-down*		*MM*		*Sham*		*ANOVA*
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	
Depression	2.473	1.954	3.454	3.188	2.333	2.219	3.300	3.585	F(3,81)=.890 P=.450
Anxiety	4.368	3.562	2.409	2.500	3.083	2.685	3.450	3.136	F(3,84)=1.542 P=.210
Stress	6.315	3.575	4.272	3.057	5.166	3.963	6.850	3.199	F(3,84)=2.315 P=.082

3.2 Self-Reported Mood (POMS) Before versus After Experimental Manipulations

The POMS was administered both before and after each experimental manipulation. An ANOVA was performed with GROUP as a between-subjects factor and TIME (Pre-vs-Post experimental manipulation) as a within-subjects factor. Results showed a significant main effect of TIME for all POMS subscales and the total POMS score. No significant main effects of GROUP nor a significant GROUP by TIME interaction were found. Results are reported in

Table 2. Follow-up post-hoc tests referring to the main effect of TIME were therefore conducted across groups. Participants reported feeling less depressed, vigorous, angry, tense, confused, and fatigued after in comparison with before the experimental manipulations ($p < .001$).

Table 2. Descriptive statistics of Mood Scale (POMS) After Experimental Manipulations

GROUP	*Alpha-up*				*Alpha-down*				*MM*				*Sham*			
	PRE		*POST*		*PRE*		*POST*		*PRE*		*POST*		*PRE*		*POST*	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Depress	4.631	3.904	3.368	3.284	5.090	5.415	3.045	3.429	4.208	3.270	3.250	3.339	5.650	5.415	3.400	4.381
Vigor	10.052	3.550	9.526	4.501	10.318	4.040	8.454	5.578	12.208	4.211	9.625	5.443	12.500	3.734	9.700	5.629
Anger	5.631	4.152	4.210	5.318	4.500	3.661	2.500	3.362	4.458	3.092	3.083	3.361	5.000	3.060	3.100	3.782
Tension	9.368	5.024	6.736	4.851	6.636	3.125	4.181	3.431	8.000	4.863	5.333	4.330	8.550	4.817	4.600	3.965
Confus.	6.631	2.521	5.894	2.884	5.090	3.727	3.318	3.061	6.166	3.655	4.625	3.359	6.550	3.705	3.800	3.334
Fatigue	7.052	4.156	5.631	3.932	6.500	4.553	4.500	3.876	6.416	4.074	5.458	3.945	7.550	4.160	6.200	4.085
TMD	23.263	17.396	16.315	17.397	17.500	18.963	9.090	15.641	17.041	18.037	12.125	16.814	20.800	18.531	11.400	15.397

ANOVA	*Effect*	*F*	*p*	*η^2-partial*
Depression	Group (G)	.168	.918	.006
	Time(T)	17.211	<.001**	.175
	TxG	.673	.593	.023
Vigor	Group (G)	.824	.484	.030
	Time(T)	22.152	<.001**	.215
	TxG	1.452	.234	.051
Anger	Group (G)	.685	.574	.024
	Time(T)	22.893	<.001**	.220
	TxG	.217	.884	.008
Tension	Group (G)	1.564	.205	.055
	Time(T)	50.218	<.001**	.383
	TxG	.675	.570	.024
Confusion	Group (G)	1.639	.187	.057
	Time(T)	29.424	<.001**	.265
	TxG	1.615	.192	.056
Fatigue	Group (G)	.500	.683	.018
	Time(T)	17.645	<.001**	.179
	TxG	.429	.733	.016
TMD	Group (G)	.626	.600	.023
	Time(T)	25.467	<.001**	.239
	TxG	.464	.708	.017

3.3 EEG Baselines Before versus After Experimental Manipulations

An ANOVA was conducted on resting EEG alpha amplitudes with GROUP as a between-subjects factor (alpha-up, alpha-down, MM, Sham-NFB) and LOBE (Frontal-vs-Central-vs-Posterior), HEMISPHERE (Left-vs-Right-vs-Midline), and TIME (Pre-vs-Post experimental manipulation) as within-subjects factors. Results are reported in Table 3. There was no significant main effect of GROUP, nor any significant interactions involving GROUP. A significant main effect of HEMISPHERE was found $F(2,152) = 122.097$, $p < .001$, η^2-partial = .616, that was further qualified by a significant TIME x LOBE x HEMISPHERE interaction, $F(4,304) = 2.820$, $p = .025$, η^2-partial = .036. Significant interactions between TIME x HEMISPHERE were observed only within the posterior lobe, $F(2,158) = 3.683$, $p = .027$, η^2-partial = .045, showing alpha amplitudes were higher over midline-posterior cortex, $t(79) = 2.530$, $p = .013$, prior to in comparison with after the experimental manipulations; results within frontal and central cortex only showed main effects of hemisphere.

Table 3. Descriptive statistics of EEG Alpha Amplitude (8-12 Hz) pre-post experimental manipulations

	Alpha-up				*Alpha-down*				*MM*				*Sham*			
	Pre		Post		Pre		Post		Pre		Post		Pre		Post	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Left-Frontal	.302	.098	.285	.093	.317	.116	.285	.089	.367	.228	.398	.255	.347	.116	.321	.153
Left-Central	.311	.191	.281	.108	.287	.085	.288	.143	.309	.139	.315	.109	.354	.184	.305	.131
Left-Posterior	.297	.062	.308	.097	.301	.120	.335	.162	.339	.134	.327	.119	.366	.120	.356	.097
Mid-Frontal	.204	.041	.197	.034	.197	.035	.196	.035	.219	.040	.229	.045	.221	.046	.212	.040
Mid-Central	.206	.047	.196	.041	.184	.031	.179	.026	.223	.049	.221	.050	.215	.042	.207	.044
Mid-Posterior	.201	.040	.195	.030	.185	.028	.181	.027	.218	.045	.213	.042	.217	.042	.203	.035
Right-Frontal	.288	.076	.278	.069	.325	.153	.318	.110	.366	.161	.415	.219	.381	.188	.319	.126
Right-Central	.286	.138	.319	.188	.300	.110	.354	.236	.320	.120	.356	.170	.346	.166	.319	.178
Right-Posterior	.309	.097	.321	.092	.339	.120	.401	.197	.322	.099	.333	.124	.351	.121	.332	.126

ANOVA	*Effect*	*F*	*P*	η^2-partial
	Group (G)	1.383	.254	.964
	Time (T)	.004	.947	.000
	Lobe (L)	.922	.400	.012
	Hemisphere (H)	122.097	.001**	.616
	G x T	1.170	.327	.044
	G x H	.871	.518	.033
	G x L	1.066	.385	.040
	T x H	2.438	.091	.031
	T x L	.857	.427	.011
	H x L	.708	.587	.009
	H x L x G	1.019	.431	.039
	T x H x L	2.820	.025*	.036
	T x L x G	1.731	.117	.064
	T x H x G	1.325	.249	.050
	T x H x L x G	.393	.508	.036

3.4 Visual-Verbal Self-Other Referential Processing Task

3.4.1 Self-report and Behavioural Performance of the VV-SORP-T

Table 4 reports the dependent measures referring to subjective-behavioural results obtained for the VV-SORP-T. In partial replication of previous findings, we observed significant main effects of REFERENCE for reaction time, VALENCE for adjective rating and positive affect rating, and an interaction between REFERENCE x VALENCE for negative affect rating. Referring to reaction time, replicating previous findings, button-pressing was slower for trials involving SRP (S-P and S-N trials) than for trials involving ORP (O-P and O-N trials), $t(56) = 3.498$, $p = .001$. Referring to adjective ratings, positive adjectives were more often endorsed for both self and other than were negative adjectives, $t(56) = 17.471$, $p < .001$. Referring to positive affect ratings, positive trials were more associated with positive affect than were negative trials, independent of reference, $t(56) = 10.238$, $p < .001$. Finally, referring to negative affect ratings, it was found that negative affect was greater during S-N than O-N trials, $t(56) = 4.288$, $p < .001$, during S-N than S-P trials, $t(56) = 8.900$, $p < .001$, and during O-N than O-P trials, $t(56) = 5.363$, $p < .001$.

Referring to the effects of GROUP, significant results were obtained only for negative affect ratings, within which a significant main effect, $F(3,53) = 4.488$, $p = .007$, η^2-partial = .148, qualified by a significant GROUP x REFERENCE interaction was observed, $F(3,53) = 3.075$, $p = .035$, η^2-partial = .203. Follow-up tests revealed that for SRP trials the alpha down group reported less negative affect when compared to the sham $t(29) = -3.738$, $p = .001$, alpha up $t(23) = -1.784$, $p = .088$ and MM groups, $t(25)=-2.144$, $p=.042$. Also, both the alpha up $t(28) = -1.798$, $p = .083$, and MM groups, $t(30) = -1.746$, $p = .091$, trended toward experiencing less negative affect when compared to the sham group. During ORP trials, less negative affect was also reported by the alpha down group when compared to the sham group, $t(29) = -3.197$, $p = .003$, alpha up $t(23) = -3.031$, $p = .006$, and MM groups, $t(25) = 1.991$, $p = .058$, although there were no significant differences between the latter three groups.

Table 4. Descriptive statistics and paired comparisons between conditions of the Visual-Verbal Self/Other-Referential Processing Task

Dependent Measure	*Group*	*S-P*		*S-N*		*O-P*		*O-N*	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Adjective Rating	Alpha-up	22.833	4.877	13.083	3.476	22.333	3.651	11.750	2.895
	Alpha-down	24.538	4.033	11.307	2.123	22.923	4.733	12.153	2.577
	MM	25.071	4.008	11.000	1.698	23.500	3.057	12.071	2.200
	Sham	23.333	5.122	12.611	3.070	22.166	4.743	11.666	2.300
NA	Alpha-up	29.250	48.593	129.416	94.631	36.666	48.888	119.500	85.603
	Alpha-down	6.923	11.094	79.000	66.563	6.461	14.192	52.923	32.479
	MM	31.071	52.630	136.857	94.709	34.785	53.415	80.285	84.144
	Sham	57.777	91.031	196.333	93.682	44.055	74.381	126.222	90.035
PA	Alpha-up	44.833	29.538	6.750	11.924	42.250	26.608	8.916	16.222
	Alpha-down	34.615	25.068	3.153	8.522	31.692	20.945	1.692	2.780
	MM	56.000	31.632	9.785	19.450	41.571	35.004	7.642	17.543
	Sham	56.166	32.489	4.500	11.803	49.555	30.262	6.277	14.636
RT	Alpha-up	76.118	30.938	77.079	32.944	71.697	27.831	73.419	26.434
	Alpha-down	75.159	35.219	77.546	33.541	69.698	32.111	72.037	35.022
	MM	77.385	37.986	77.353	28.947	76.458	30.061	74.527	28.371
	Sham	78.174	33.701	78.397	38.528	71.378	37.268	75.745	39.586

ANOVA Measure	*Effect*	*F*	*p*	η^2-partial
Adjective Rating	Group (G)	0.438	.726	.024
	Reference (R)	6.507	.104	.109
	R x G	0.352	.788	.020
	Valence (V)	294.500	<.001**	.847
	V x G	0.694	.560	.038
	R x V	1.026	.316	.019
	R x V x G	0.599	.618	.033
Positive Affect	Group (G)	1.873	.145	.096
	Reference (R)	3.352	.073	.059
	R x G	0.921	.437	.050
	Valence (V)	97.537	<.001**	.648
	V x G	0.914	.441	.049
	R x V	2.205	.143	.143
	R x V x G	0.259	.855	.014
Negative Affect	Group (G)	4.488	.007	.203
	Reference (R)	16.321	<.001**	.235

	R x G	3.075	.035*	.148
	Valence (V)	69.868	<.001**	.569
	V x G	1.288	.288	.068
	R x V	8.319	.006**	.136
	R x V x G	0.600	.618	.033
Reaction Time	Group (G)	0.021	.996	.001
	Reference (R)	11.461	.001**	.178
	R x G	0.427	.735	.024
	Valence (V)	0.977	.327	.018
	V x G	0.392	.759	.022
	R x V	0.154	.696	.003
	R x V x G	0.523	.668	.029

3.4.2 Event-related Desynchronization (ERD) in response to the VV-SORP-T

An ANOVA was performed with GROUP as a between-subjects factor (alpha-up, alpha-down, MM, Sham-NFB), and REFERENCE (Self-vs-Other), VALENCE (Positive-vs-Negative), LOBE (Frontal-vs-Central-vs-Posterior) and HEMISPHERE (Left-vs-Right-vs-Midline) as within-subjects factors. Results are reported in Table 5. Results showed significant main effects for Hemisphere, and various interactions involving Reference (R), Valence (V), Lobe (L), and Hemisphere (H), that were each qualified by a significant 4-way interaction (RxVxLxH, $F[4,224] = 4.378$, $p = .002$, η^2-partial = .073). There was also a non-significant main effect of group, $F(3,56) = 2.711$, $p = .054$, η^2-partial = .127, with group failing to interact with any within-subjects factor (RxVxLxH). Follow-up analyses of the trend toward a GROUP main effect indicated that the alpha-down group evidenced greater alpha desynchronization across all conditions of the VV-SORP-T relative to the alpha-up group, $t(26) = 2.484$, $p = .020$, 2-tailed; no other group differences were statistically significant.

Referring to the significant 4-way interaction, follow-up 3-way ANOVAs (RxVxH) were conducted separately by lobe. Within the frontal lobe, the RxVxH interaction remained statistically significant, $F(2,118) = 3.589$, $p = .031$, η^2-partial = .057. Therefore, the 2-way interaction involving REFERENCE and VALENCE was examined separately within each hemisphere, and found to be statistically significant within the right frontal cortex, $F(1,59) = 6.878$, $p = .001$, η^2-partial = .106, and within the left frontal cortex, $F(1,59) = 5.614$, $p = .021$, η^2-partial = .087, but not within midline frontal cortex, $F(1,59) = 1.400$, $p = .241$, η^2-partial = .023. In contrast, within the central lobe, follow-up tests showed only a main effect of hemisphere, $F(2,118) = 9.408$, $p < .001$, η^2-partial = .138. Finally, within the posterior lobe, both a main effect of hemisphere, $F(2,118) = 5.698$, $p = .004$, η^2-partial = .088, and a REFERENCE-x-VALENCE interaction were found, $F(1,59) = 5.045$, $p = .028$, η^2-partial = .079. Follow-up post-hoc tests referring to the interaction of REFERENCE by VALENCE were therefore conducted within the left and right frontal cortex, as well as within the posterior lobe as a whole. Table 5 shows these results, which indicated that Other-Negative trials were associated with greater ERD than were Self-Negative and Other-Positive trials within both right and left frontal cortex; no other comparisons were statistically significant, although the same pattern of findings was obtained within posterior cortex (p's ≤ .089, see Figure 4).

Table 5. Descriptive statistics of Event-related Desynchronization (ERD) during VV-SORP-T

Group	*Condition*	*R-F*	*L-F*	*M-F*	*R-C*	*L-C*	*M-C*	*R-P*	*L-P*	*M-P*
Alpha-Down	S-P	-8.168	-10.022	-6.011	-8.734	-8.241	-4.370	-10.057	-11.005	-9.005
		(27.535)	(26.437)	(28.271)	(26.792)	(28.415)	(30.373)	(26.736)	(26.384)	(26.869)
	S-N	-15.336	-14.266	-12.736	-16.032	-17.374	-10.822	-12.240	-12.427	-9.217
		(14.518)	(13.006)	(15.542)	(15.222)	(15.600)	(16.545)	(12.473)	(11.429)	(12.924)
	O-N	-15.378	-14.150	-4.886	-6.837	-8.128	-4.525	-9.108	-8.093	-5.751
		(7.004)	(5.661)	(3.859)	(5.712)	(6.851)	(2.840)	(4.469)	(3.352)	(2.445)
	O-P	-10.337	-8.266	-8.795	-8.571	-7.436	-5.027	-7.993	-9.473	-5.320
		(26.330)	(25.658)	(25.204)	(25.939)	(27.714)	(29.635)	(25.478)	(25.977)	(26.910)
Alpha-Up	S-P	-6.976	-6.581	-7.213	-7.578	-3.761	-4.922	-6.249	-7.384	-5.997
		(28.204)	(28.643)	(28.335)	(28.335)	(29.389)	(29.909)	(30.066)	(26.384)	(29.850)
	S-N	8.177	6.679	14.703	13.016	14.975	21.325	5.378	5.674	10.762
		(35.884)	(34.721)	(65.553)	(57.719)	(57.284)	(81.379)	(34.597)	(35.597)	(47.787)
	O-N	-8.810	-3.689	3.317	-2.921	0.0959	0.0403	-3.733	-5.330	-3.558
		(21.993)	(25.142)	(47.428)	(33.459)	(32.200)	(25.738)	(22.999)	(22.499)	(23.021)
	O-P	8.812	12.402	13.974	16.825	16.002	20.740	13.129	13.808	15.548
		(33.985)	(33.922)	(32.922)	(48.496)	(42.021)	(48.758)	(30.207)	(31.849)	(36.590)
MM	S-P	-4.112	2.103	2.062	-3.395	-2.442	3.428	5.742	3.639	2.978
		(21.576)	(29.651)	(18.612)	(23.139)	(25.989)	(18.751)	(31.325)	(23.871)	(27.426)
	S-N	1.252	1.235	3.065	4.041	-0.862	0.863	3.065	6.292	2.106
		(19.891)	(19.891)	(26.489)	(26.489)	(22.199)	(26.495)	(24.438)	(31.532)	(32.725)
	O-N	-16.580	-13.326	-4.814	-7.086	-8.536	-6.083	-8.640	-7.928	-6.643
		(11.845)	(7.868)	(4.250)	(5.435)	(5.902)	(5.908)	(5.461)	(5.827)	(4.221)
	O-P	3.456	3.566	5.189	3.791	1.564	12.450	3.861	2.690	3.850
		(31.446)	(31.057)	(35.788)	(38.014)	(33.292)	(41.935)	(28.618)	(29.484)	(31.939)
Sham	S-P	-7.296	-5.344	-5.384	-6.265	-6.420	-4.193	-5.551	-7.030	-4.323
		(17.403)	(16.728)	(15.913)	(14.365)	(16.008)	(16.981)	(17.467)	(16.138)	(16.455)
	S-N	5.794	4.383	6.745	5.536	5.106	7.505	5.640	6.114	7.115
		(21.103)	(23.540)	(20.087)	(20.215)	(22.381)	(20.073)	(20.876)	(19.997)	(20.811)
	O-N	-4.298	-5.159	0.448	-2.511	0.963	-2.968	-3.070	-3.470	-0.805
		(21.634)	(21.214)	(21.089)	(20.443)	(20.595)	(20.651)	(21.456)	(20.731)	(20.058)
	O-P	-7.046	-6.651	-6.490	-6.633	-8.073	-3.621	-2.493	-2.473	-1.004
		(15.961)	(16.140)	(20.646)	(16.162)	(19.708)	(15.304)	(17.101)	(17.800)	(16.791)

ANOVA Effect	*F*	*P*	η^2-partial
Group (G)	2.711	.054	.127
Reference (R)	.020	.888	<.001
Reference x Group (G)	.498	.685	.026
Valence (V)	.016	.900	<.001
V x G	.783	.508	.040
Lobe (L)	3.047	.051	.052
L x G	1.163	.331	.059
Hemisphere	16.285	**<.001	.225
H x G	.466	.832	.024
R x V	5.847	*.019	.095
R x V x G	1.933	.135	.094
R x L	.510	.602	.009
R x L x G	.430	.876	.021
V x L	.173	.841	.003
V x L x G	.682	.664	.035
R x V x L	.031	.969	.001
R x V x L x G	1.717	.123	.084
R x H	.782	.460	.014
R x H x G	.434	.855	.023
V x H	.923	.400	.016
V x H x G	.820	.557	.042
R x V x H	.506	.640	.009
R x V x H x G	1.225	.299	.062
L x H	2.622	*.036	.045
L x H x G	.877	.572	.045
R x L x H	.928	.448	.016
R x L x H x G	.334	.982	.018
V x L x H	5.764	**<.001	.093
V x L x H x G	1.045	.408	.053
R x V x L x H	4.378	**.002	.073
R x V x L x H x G	.615	.829	.032

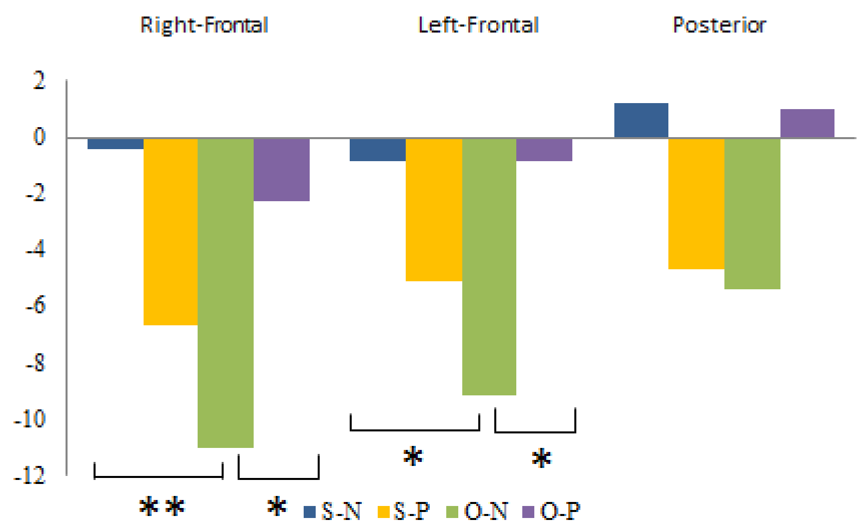

Figure 4. Follow-up Comparisons of Reference-by-Valence effect for ERD during VV-SORP-T

3.5 Correlations between Self-report and Behavioural Performance and Event-related Desynchronization (ERD) in response to the VV-SORP-T

We examined correlations between subjective and behavioural responses to the VV-SORP-T with the ERD response during Other-Negative trials within left and right frontal cortex, given that ERD during different trials of the VV-SORP-T was found to significantly vary only within left and right frontal cortex and only during Other-Negative trials. Although significant correlations were observed ($p < .05$, 2-tailed), specifically, indicating that increasingly negative ratings of others correlated with less ERD during Other-Negative trials within right frontal cortex ($r = .266$) and left frontal cortex ($r = .242$), these associations failed to remain statistically significant after removing apparent outlier ratings regarding the negativity of others; associations with negative affect and reaction time were also non-significant. Given the significant associations observed for negative adjective ratings toward others within the right and left frontal cortex, we explored whether similar associations would be obtained within other electrode groups; results suggested that the association was also statistically significant within right-central cortex, $r = .291$, $p < .05$, including after removing outlier scores.

Chapter 4

4 Discussion

How people think and feel about themselves and others has been investigated in various ways in psychology and more recently in cognitive neuroscience under the banner construct of "self-referential processing" (SRP). In this thesis I sought to examine the central nervous system electrophysiological correlates of SRP alongside subjective (self-report) and behavioural (reaction time) measures of the same using a *Visual-Verbal Self-Other Referential Processing Task* (VV-SORP-T; Frewen & Lundberg, 2012; Frewen et al., 2013). The VV-SORP-T was designed to measure SRP both directly, in the context of explicit SRP (i.e., via self-report adjective endorsement and affect ratings in response to the task), and indirectly, in the context of implicit SRP (i.e., via analysis of button-press reaction time and EEG measures including alpha event-related [de-]synchronization [ERD/S]) (Frewen & Lundberg, 2012). Individual differences in response to the VV-SORP-T were previously shown to correlate with activity in cortical midline structures including dorsal and ventral medial prefrontal cortex as well as brain regions known to be involved in emotional processing including the amygdala and insula (Frewen et al, 2013), although no previous studies had assessed response to this task using the EEG. Given emerging literature suggesting the possible role of the EEG alpha rhythm in SRP, I assessed alpha ERD/S in response to this task including in an individual differences design. Moreover, I sought to more rigorously assess the causal role of EEG alpha oscillations in SRP by assessing the immediate effects of experimentally manipulating the amplitude of such oscillations through brief interventions previously shown to modulate the alpha rhythm, specifically, EEG neurofeedback (NFB) and mindfulness meditation (MM). Indeed participants have been shown to be able to self-regulate the amplitude of their EEG alpha rhythm using NFB (Zoefel et al., 2011, Dekke et al., 2014) and MM (Cahn & Polich, 2006; Jindal, Gupta & Das, 2013) in previous research. This chapter considers the results of this master's thesis research, alongside acknowledgement of study limitations and remaining future research directions.

4.1 Effects of Mindfulness Meditation and Neurofeedback on EEG Alpha Amplitude and Self-reported Mood State

Analysis of EEG alpha amplitude during resting state before versus after administration of MM and NFB, in comparison to sham (placebo) NFB, failed to reveal any significant effects. In other words, there was no indication of a significant effect for the differential effects of these brief interventions for resting-state EEG alpha amplitude. Instead, a decrease in alpha amplitude was observed, particularly within midline posterior cortex, across all four experimental groups, that is, independent of the different brief interventions to which different participants were randomized.

Similarly, there were no apparent differential effects of group randomization on self-reported fluctuations in mood state. Instead, participants reported feeling less depressed, angry, tense, confused, and fatigued, and vigorous at the second (post-intervention) assessment, but independent of the intervention to which they practiced (MM, NFB, or control ["placebo"] NFB). Although such nonspecific outcomes could be attributable to a common therapeutic effect across the different interventions for increasing subjective wellbeing, it is more parsimonious to interpret them as reflecting demand effects or simply the passage of time in the context of the given experimental setting (e.g., growing interest in the experience of research participation or the experimental session being completed). Although these experimental manipulations seem to have had a null effect on EEG alpha amplitudes measured at rest, and for self-reported affective state during the same, significant effects for treatment were observed in response to the VV-SORP-T. It is therefore possible that measurement of EEG baselines and self-reported mood lacked sufficient sensitivity to reveal differential results of these brief treatments, which nevertheless became more apparent when valenced SRP and attendant affective states were experimentally provoked, that is, in response to the VV-SORP-T; such results are discussed subsequently, following a more general overview of the subjective, behavioural, and EEG-alpha results observed during performance of the VV-SORP-T across treatment groups.

4.2 VV-SORP-T: Psychological Outcomes

The VV-SORP-T is a relatively newly developed experimental approach to assessing explicit and implicit (indirect) aspects of valenced SRP in comparison with other-referential-processing (ORP) as is relevant to understanding individual differences in self-esteem and related emotional processes. Previous results in student populations (Frewen & Lundberg, 2012) showed that Self-Positive (S-P) trials were associated with increased positive affect when compared to Other-Positive (O-P) trials. In addition, negative affect was more salient during Self-Negative (S-N) relative to Other-Negative (O-N) trials. In addition, reaction times were slower during self-related trials independent of valence, and positive valence trials independent of self vs. other reference. Finally, positive adjectives were more endorsed self-referentially than other-referentially, the opposite being true for negative adjectives.

In the present study, results concerning self-report and behavioural (button-press reaction time) measures partially replicated the results reported in prior publications (Frewen & Lundberg, 2012; Frewen et al., 2013), indicating the reliability of the VV-SORP-T as an experimental approach to measuring SRP and ORP. First, regarding simple adjective ratings, participants were more likely to endorse positive words than the negative words for both self and others trials, although no significant effect for a self-positivity bias was observed (i.e., for participants to rate themselves more positively than others, on average). Participants also reported experiencing more positive affect during the positive than negative valence trials, although the participants did not report experiencing greater positive affect during positive SRP than during positive ORP. Investigating self-reported negative affect in response to negative valence trials, the prior effect for an interaction between SRP and ORP was replicated, with trials that paired negative words with the self in comparison with others associated with greater negative affect. Finally, analysis of reaction times during passive button-pressing again showed that participants were slower to respond during SRP than during ORP irrespective of valence, replicating prior findings. As interpreted previously, such findings may indicate that participants were more engaged in reflective processing during SRP than during ORP, and that affective salience of SRP trials was overall greater than that of ORP trials, consistent with self-reports as noted previously (Frewen and Lundberg, 2012).

4.3 VV-SORP-T: Effects for EEG Alpha Event-related (De) Synchronization (ERD/S)

Prior EEG literature had suggested the possible role of the alpha rhythm during SRP, thus we prioritized examination of the alpha band in this the first EEG investigation of response to the VV-SORP-T. In general, most active blocks of the VV-SORP-T evidenced alpha ERD relative to fixation baseline, with general effects partly depending on electrode placement (i.e., frontal/central/posterior and left/right hemisphere or midline); as these effects did not interact with VV-SORP-T trial types they will not be considered further here. However, the extent of alpha ERD was also determined to vary across trial types, with ERD found to be especially pronounced within left and right frontal cortex during trials pairing negativity with ORP (rather than SRP); similar non-significant effects were observed within posterior cortex.

A pronounced alpha ERD during negatively valenced ORP in comparison with SRP is an interesting study finding. To aid in the interpretation of this finding, individual differences in alpha ERD during trials pairing negativity with ORP were correlated with variability in how negatively participants rated others in general, as well as in terms of their self-reported affective response and passive button-press reaction time to such trials. Whereas null results were observed for associations with affective state and reaction time, participants who rated others more negatively exhibited less alpha ERD (i.e., more alpha ERS) within left and right frontal cortex during such trials, although this study finding seemed unduly driven by the results of a single participant and thus must be treated with caution. Independent of the correlational results, these study findings may signify, in part, alpha ERD as a marker of empathic distress during incongruent negative ORP, that is, being forced to view others negatively when normally one would not. This explanation, however, fails to account well for the certain number of participants who demonstrated ERS during negative ORP, particularly those reporting that they tend to view others non-negatively; future conceptual work and empirical studies will be required to better appreciate the role of alpha ERD/S in valenced ORP. Such findings however are interesting in light of prior evidence showing greater alpha band ERD over the right hemisphere when participants view movie clips with negative emotional content and empathic responses are thereby engaged (Sarlo et al., 2005). Experiencing negative emotions during O-N trials of the VV-SORP-T has indeed has been shown to relate to empathic responses, for example guilt, in a prior study (Frewen & Lundberg, 2012). Alpha band ERDs within the left hemisphere have also been shown to be linked to subjective feeling of emotional pain in others (Mu et al., 2008). Contrary to expectations, however, salient effects for alpha ERD during SRP were not observed, including over central midline structures. These null findings are potentially explained by the generally low spatial resolution of EEG data.

4.4 VV-SORP-T: Effects for Brief Mindfulness Meditation and Neurofeedback Interventions

As already discussed, group randomization to single session brief interventions of MM and NFB in comparison with sham ("placebo") NFB failed to provoke significant group differences for alpha amplitudes on the resting EEG nor in terms of self-reported mood state. However, a trend level effect was observed for group randomization to effect alpha ERD across the entire VV-SORP-T, and significant effects were found regarding self-reported negative affect experienced in response to the task. In particular, participants trained to desynchronize their alpha amplitudes through NFB (i.e., the "alpha down group") exhibited greater alpha desynchronization during the VV-SORP-T, specifically, in comparison with those trained to synchronize their alpha amplitudes (i.e., the "alpha up group"). Moreover, concerning self-reported affective response, the alpha-down NFB group reported experiencing less negative affect across all conditions when compared to all other groups. In general, the treatment effect observed particularly for the alpha-down group is in line with previous findings concerning the single session benefits of alpha suppression training observed by Ros et al. (2013). Ros and colleagues observed a single session of alpha suppression NFB training evoked greater calmness relative to sham NFB training, which is broadly similar to the experience of less negative emotion during performance of the VV-SORP-T in the alpha-down NFB group examined within the current study (although in the absence of affecting general mood state).

In addition, randomization to MM and alpha-up NFB training resulted in less negative affect during VV-SORP-T performance when compared to the sham NFB group. Alpha power enhancing NFB has been associated with reduction in anxiety and enhancement of positive feeling in prior research (Choi et al , 2011). Interestingly, the experience of negative affect in response to the VV-SORP-T was also diminished in participants who had before practiced MM in comparison to sham NFB. The findings are consistent with the broad benefits of MM practice for well-being and anxiety reduction (Hoffman et al., 2010). This set of results support the notion that modulation of alpha power, in either direction, may somehow diminish negative affect under circumstances in which self and others are associated with negativity and positivity, although effects were strongest for alpha suppression training within the current study.

Although the effects of group randomization failed to interact significantly with trial types, a more careful investigation of the means reported in Table 5 across the different experimental conditions of the VV-SORP-T suggest a more nuanced interpretation of the results obtained that might be tested in future studies with a larger sample size. In particular, whereas alpha band ERDs could be observed across all VV-SORP-T conditions within the alpha-down NFB group, findings consistent with ERS seem to be salient during trials pairing both self and other with negativity for the alpha-up NFB and MM groups. In fact, in prior research enhanced alpha band ERS was correlated closely to self-judgment of negative traits relative to positive words, and the reverse pattern was found for the judgment of negative vs. positive traits for a familiar other person (Knyazev, 2013; Mu & Han, 2011, 2013). Indeed the alpha-up intervention in the present study was the one most associated with alpha-ERS, while the alpha-down intervention was most reliably associated with alpha-ERD, in parallel with the treatment goals of these interventions toward alpha synchronization and desynchronization, respectively. It therefore may be interesting to evaluate whether these findings are reliable at a larger sample size with continued testing in the future.

4.5 Limitations and Future Directions

The current study represents the first attempt to examine the causal role of self-regulation of the EEG alpha rhythm through MM and NFB on the processing of self-related information. In addition, this is the first study to investigate the electrophysiological correlates of performance of the VV-SORP-T. Nevertheless, several limitations of the current study require mentione. First, a larger sample size would increase confidence in the reliability of the findings obtained; indeed the current results seem particularly vulnerable to type 2 errors being that statistical power was low to detect between-group differences. For instance, whether alpha ERS can occur during S-N trials as a result of brief alpha-up NFB and MM interventions should be evaluated in a larger sample. Moreover, a more diverse sample, inclusive of different ethnic backgrounds, could also shed more light on the EEG correlates of SRP since it has been shown that cultural differences in SRP could influence distinctive EEG correlates (Knyazev et al., 2013).

Second, the length of the experimental session could also be considered as a limiting factor. In fact the VV-SORP-T was administrated as the final task of the experimental session, with participants asked to complete a standard Stroop task between completion of MM or NFB and the VV-SORP-T, the results of which were considered in another master's thesis. Therefore, participants may have experienced fatigue by the time the VV-SORP-T was introduced, and may have also encountered greater difficulty controlling inadvertent body movements, leading to artifacts in EEG measurement.

Third, these results are limited to a single session application of MM and NFB. However, in order to yield a therapeutic benefit of MM and NFB, multiple sessions may be required. It would be interesting to further explore the effect of multiple sessions of NFB and MM on alpha modulation of SRP in future studies. Moreover, no formal assessment was collected regarding the cognitive-attentional strategies that were used by participants during NFB and MM. Further studies could benefit from collecting this information since a possible explanation for the lack of differences between groups for modulating resting-state alpha amplitudes may be due to use of similar attentional strategies across the different participant groups. For instance, it is possible that participants randomized to NFB focused on their breathing or attempted to "meditate" in order to achieve increases or decreases in their alpha amplitudes, thereby serving to nullify the potential for observing group differences. The degree to which modulation of the alpha rhythm in MM versus NFB occurs through similar or distinct neurophysiological mechanisms is thus a clear subject for future research. A different approach, however, would be to integrate the two interventions whereby NFB is used as an aid during the practice of MM. As such, combining the two interventions could enhance the potential outcomes associated with both practices; the efficacy of such an intervention for self-regulation of the alpha rhythm, wellbeing and valenced SR,P in comparison with each intervention alone, is also a prime question for future studies.

Fourthly, we asked our participants to close their eyes during NFB sessions in order to minimize procedural differences between NFB and MM, the latter of which is most often practiced with eyes closed. Since an increase in alpha amplitude can be observed when eyes are closed (Berger, 1929), it could be argued that participants in the alpha-up NFB group experienced difficulty enhancing their alpha power above an eyes-closed baseline. Further studies could examine the possible differential effectiveness of eyes-open versus eyes-closed alpha-NFB.

Finally, this study examined non-phase locked alpha activity related to SRP, however ERP is also a powerful tool to study neural processes that are phase-locked to an overt stimulus. In addition, very few studies have investigated the ERP correlates of SRP, as well as ERD studies that examine different alpha subbands. Future EEG studies may wish to examine multiple measures to arrive at a more comprehensive understanding of the EEG signatures of SRP. In fact, based on current knowledge of EEG correlates of SRP, it appears that different processes could be involved depending on the type of cognitive task and situational context in which participants are assessed (see Knayzev, 2013 for a review).

4.6 Conclusion

This is the first study to investigate whether manipulation of alpha amplitude through different brief interventions such as neurofeedback and mindfulness meditation affects self-referential processing by employing the VV-SORP-T. To this end, we aimed to identify the neurophysiological correlates of valenced self-referential processing compared with other-referential processing. It appears a single session of the respective interventions can evoke some emotion related changes such as experiencing less negative affect during negatively valenced self- and other-referential stimuli, although future studies are needed to confirm these findings and investigate whether more intensive treatments could yield stronger effects. An enhanced ERD in right and left frontal lobe was also observed during negative other-referential processing. Future studies using advanced analytic techniques should continue to map the neural underpinnings of SRP and ORP onto specific cortical and subcortical regions and clarify the functional connectivity between these regions.

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6 Curriculum Vitae

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Javan, T., Chow, T.R., Frewen, P.A. (2014 June) EEG alpha neurofeedback in anxiety-stress reduction, and Self-referential processing: an investigation of the mediating role of alpha power involved guided by EEG neurofeedback. Canadian psychological association Annual Conference , Vancouver, Canada.

Javan, T., Chow, T.R., Frewen, P.A. (2014 June) Alpha neuro feedback treatment on anxiety and valenced Self-referential processing. Canadian psychological association Annual Conference ,Vancouver, Canada.

Javan, T., Chow, T.R., Frewen, P.A. (2013 June). Mindfulness meditation versus EEG Alpha Neurofeedback in anxiety and stress reduction: the mediating role of alpha power. Schulich Department of Psychiatry Research Day. London, Canada

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