

**Attentional Modulation of Cognition and Emotion: Evidence from Measures
of Mood, Self-Regulation, and Functional Connectivity
within the Cerebral Cortex**

by
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ABSTRACT

ATTENTIONAL MODULATION OF COGNITION AND EMOTION: EVIDENCE FROM MEASURES OF MOOD, SELF-REGULATION, AND FUNCTIONAL CONNECTIVITY WITHIN THE CEREBRAL CORTEX

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Attention allows us to select important aspects of incoming sensory information while filtering out irrelevant information. It has crucial significance in understanding neurophysiological, emotional and behavioral outcomes. The research reported here focused on one central question: how do attentional manipulations influence various stages of cognition and emotion to result in goal-directed behavior? In six experiments, I used behavioral and functional Magnetic Resonance Imaging (fMRI) measures to investigate the impact of attention on visual recognition, mood and self-regulation. The results showed that attention influences functional connectivity between body-selective visual processing areas in occipito-temporal cortex. Changes in the scope of attention were also found to influence mood and self-regulation. Broadening attentional focus improves mood and self-regulation. Narrowing attentional focus impairs mood and self-regulation. Self-regulation was also aided through the pre-engagement of attentional inhibition. This diverse set of methodologies and experimental paradigms provides converging evidence that attention influences goal-relevant functional connections to facilitate visual processing, promotes fluency of information to result in better mood and prioritizes goal-relevant representations to result in successful self-regulation.

Dedication

I dedicate this thesis to my parents- Ammi and Abbi- and to my nephews- Maaz and Taha.

I hope this makes you proud!

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Chapter 1: Introduction

“Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others.”

- William James (1890)

This statement by William James from ‘The Principles of Psychology’, one of the earliest psychological literatures, explained attention in terms of changing the focus of current mental resources to concentrate on goal relevant information and disengage from irrelevant information. The modern studies of attention have continued to work within this broad definition. Attention is the ability to select the most important aspects of the sensory information and filter out the irrelevant or interfering information (see Chun & Wolfe, 2001). The human brain cannot process all the information with which it is bombarded due to its limited processing capacity (Marois & Ivanoff, 2005) and attention is the process that selects which information gets access to the high-level cognitive processing (Kastner & Ungerleider, 2000). Our ability to represent the world around us in a coherent way and achieve goal-directed behavior depends on efficient attentional processes. Cognition requires the ability to continuously take in and interpret sensory information, interact with current emotional state, and respond accordingly to accomplish goal-directed behavior. This suggests that attention may interact and influence cognitive processing at different stages. Indeed, changes in focus of attention have crucial significance in understanding cognitive (Pashler, Johnston, & Ruthruff, 2001), social (Fiske & Taylor, 1991), emotional (Raymond, Fenske & Tavassoli, 2003), and neurophysiological (Desimone & Duncan, 1995) outcomes. But further evidence is needed in order to ascertain the role of attention at different stages of cognition to result in goal-directed behavior. The primary motivating research question of this investigation asks: How do changes in the allocation of attention influence various stages of cognition and emotion to result in goal-directed behavior? I will first discuss the theoretical framework of this research whereby I will discuss various theories of attention and relevant

background research. I will then describe three separate lines of research, each providing a unique perspective on this issue.

Theories of attention

Attention allows us to select the most important aspects of incoming sensory information and filter out irrelevant or potentially-interfering information (see Chun & Wolfe, 2001). The biased competition model (Desimone & Duncan, 1995) suggests that multiple sources of information present at the same time in the visual field compete for neural representation due to limited processing resources. Spatially directed attention enhances information processing at the attended location at the expense of processing irrelevant information from nearby distracters. Such biased competition was first found at the neuronal level. Single-cell recording studies conducted on monkeys (Moran & Desimone, 1985; Reynolds, Chelazzi & Desimone, 1999) showed that responses to multiple stimuli presented in the same receptive field (RF; a region of space in which the presence of a stimulus causes firing of a particular neuron) were the weighted average of the responses to the individual stimuli presented alone. Motter (1993) found that more than one third of neurons present in the extrastriate cortex display differential activity when attention is directed towards versus away from their RF. This sensory suppressive interaction among multiple stimuli was interpreted as an expression of competition for neural representation. Thus, attention biases the competition between multiple stimuli in the visual field at the neuronal level.

Attentional biases are not just found at the neuronal level, but such effects are also found at the cortical level (Kastner, De Weerd, Desimone & Ungerleider, 1998). Sensory suppression among multiple stimuli presented simultaneously in the visual field has been found in several areas of the visual cortex, such as V2, V4, middle temporal (MT), medial superior temporal, and inferior temporal cortex. Kastner and Ungerleider (2001) suggested that this might be an important mechanism by which attention facilitates processing of relevant information and filters out irrelevant information. When encountered with multiple competing targets, attention biases the competition in favour of one of the stimuli by counteracting the suppressive influences of nearby stimuli and enhancing information processing at the attended location (Kastner et al., 1998). Additionally, Botvinick, Braver, Barch, Carter and Cohen (2001) explained how such

conflict between competing signals is resolved at cortical level. They proposed that dorsal anterior cingulate cortex (dACC) detects the conflict between competing signals and sends this information to lateral prefrontal areas. Lateral prefrontal areas, through their interaction with parietal and sensory cortices, bias the focus of attention toward task-relevant processing to ensure successful goal-directed behavior (Botvinick et al., 2001; MacDonald, Cohen, Stenger & Carter, 2000).

A number of researchers have explained visuospatial attention with a metaphor of a “spotlight”. LaBerge (1983) proposed that the attentional focus shifts from one spatial location to the other, just as a spotlight. It was proposed that information inside the spotlight is processed more quickly or more efficiently, whereas information outside the spotlight is processed less, differently, or not at all. The attentional spotlight can also move from one spot to another in the environment to process the most important information (Posner & Peterson, 1990). Rijpkema, van Aaldere, Schwarzbach, & Verstraten (2008) reported that attention to large objects in a visual scene increases activation in the higher visual areas and peripheral regions of the visual cortex, whereas attention to small objects increases activation in the central regions of the lower visual areas, providing evidence in support of spotlight metaphor of attention. Tootell et al. (1998) showed that attention to a specific visual field location produces higher cortical activity in the retinotopically corresponding location of cortex and the spotlight can be shifted from one spatial location to the other. In addition to enhancement of cortical activity when attention is allocated to a certain spatial location, suppression of cortical activity is also seen in those areas when attention spotlight moves to a new location. Somers et al. (1999) also provided evidence that attentional modulations show spatially specific, enhanced responses to the attended stimuli and suppressing responses when attention is shifted elsewhere. Additionally, recent evidence also suggests that retinotopic mapping of attention related activation are found in early visual areas of the primary visual cortex as well as higher order extrastriate areas (Brefczynski & DeYoe, 1999; Gandhi, Heeger & Boynton, 1998). Brefczynski & DeYoe (1999) used a task in which the subject’s gaze remained fixated on a central marker while spatial attention was directed to a cued location (target segment) within an array of segments. Subjects detected specific color/orientation conjunctions (for example, blue-horizontal) within the cued segment while ignoring other uncued segments. Attention related activations were found in primary visual cortex, as well as in dorsomedial and ventral occipital, and temporal cortex. Thus, neural activity

produced by visual stimuli is either enhanced or suppressed depending on whether the stimulus is attended or not, at both early (e.g. V1) and later stages of processing (e.g. temporal cortex). These studies provided support to the “attention as a spotlight” model. Attention can be directed to task relevant location and the focus can be broadened or narrowed according to the task demands and this effect is retinotopically mapped on the striate and extrastriate cortex.

A competing model of visuospatial attention uses a metaphor of a “zoom lens” (Eriksen & St. James, 1986; Eriksen & Yeh, 1985). This model suggests a trade-off between the size of the covered region and processing efficiency (i.e., resolution). Behavioral evidence suggests that spatial extent of attentional focus can be manipulated by providing cues prior to stimulus presentation and the processing efficiency decreases as the size of the area increases (Castiello & Umiltà, 1990). It is suggested that attentional focus can be broadened or narrowed, just as a zoom lens, to encompass large or small spatial extent. Neuroimaging evidence also supports the “zoom lens” model. Retinotopic activations in visual cortex maps to the size of the attended region. For example, attention to a large spatial area results in cortical activity spread in larger area as compared to narrow spatial area. Additionally, the level of neural activity in the given cortical area decreases as the spatial area covered increases (Muller, Bartelt, Donner, Villringer & Brandt, 2003). Furthermore, studies that used fMRI have found that different brain areas are involved with broad and narrow focus of attention. Chen, Marshall, Weidner and Fink (2008) presented a train of horizontal line segments consecutively at the same spatial location. Each pair of lines gradually changed from large to small in the zooming in trials, from small to large in the zooming out trials, or was kept constant in the baseline trials. Results suggested that the right inferior frontal gyrus (IFG) was activated in “zooming out” or broad attentional focus. The left intraparietal sulcus (IPS) was activated in “zooming in” or narrow attentional focus. Additionally, temporoparietal cortex was involved in top-down attentional control of such “zooming out” and “zooming in”. Thus, the focus of attention can be broad or narrow according to the task demands and the activations correspond to distinct neural correlates.

Broadening and narrowing the scope of attention

Most studies have investigated the changes of attention to broad and narrow focus with a paradigm known as global/local processing. Global/Local processing of hierarchical images

allows the perception of the same image at the level of whole object or “forest”, or at the level of its parts or “trees”, by varying the focus of attention. Participants are usually faster to respond to the global elements than the local elements, and inconsistent global information interferes with local processing, but not vice versa (Navon, 1977; 2003). Based on this observation, Navon explained the phenomenon of *global precedence* that suggests that perceptual processing of hierarchical stimuli proceed from the global level to the local level. Additionally, he also explained the phenomenon of *global interference* that suggests that when the two levels of the hierarchical stimulus are inconsistent and the local level is relevant, global dimension interferes with the local processing. Many researchers have supported these observations by using different methodologies (Kimchi, 1992; Sripati & Olson, 2009; Weissman, Giebrecht, Song, Mangun & Woldorff, 2003).

Global and local processing demonstrates differential preference for spatial frequency. Hellige (1996) observed that the right hemisphere is dominant for processing global aspects of visual stimuli that are carried by low spatial frequencies (LSF) and extract information from the magnocellular visual pathway. In a complementary manner, the left hemisphere is dominant for processing local aspects of visual stimuli that are carried by high spatial frequencies (HSF) and extract information from the parvocellular visual pathway. De Valois and De Valois (1990) showed that participants are slower to report targets at the global level after LSF than HSF adaptation and slower to report targets at the local level after HSF than LSF adaptation. Similarly, the detection threshold for frequencies following a global response is also found to be lower for LSF gratings and lower for HSF gratings following a local response (Shulman & Wilson, 1987). Various researchers have also speculated that spatial frequency content may impose a specific temporal hierarchy in the processing of visual information (Bar, 2003; Bullier, 2001; Hegde, 2008). According to these models, visual analysis starts with a parallel extraction of different elementary attributes at different spatial frequency, but with a predominant “coarse-to-fine” (low-to-high SF) sequence that privileges LSFs at initial stages of visual processing and HSFs at later stages of visual processing. Additionally, Bullier (2001) showed that LSF in a scene is conveyed by fast magnocellular visual channels and reach high-order processing brain areas more rapidly than HSF. This allows an initial percept of the visual inputs before the complete propagation of HSF that ultimately results in object recognition. Thus, global information gets the privilege of faster processing due to the LSF information contained therein

and propagation by magnocellular channels (Flevaris, Bentin & Robertson, 2011; Shulman, Sullivan, Gish & Skoda, 1986;).

Global and local processing differentially involve right and left temporal-parietal areas, respectively, as indicated by studies of performance in the two visual hemifields (Hubner, 1998), brain activation (Han et al., 2002, Martinez et al., 1997), and brain injury (Robertson & Lamb, 1991). Behavioral studies employ a method whereby hierarchical stimuli are shown in different visual fields and reaction times are recorded to global or local level of stimuli. It was found that global processing is faster if the stimuli are presented in left visual fields than those present in right visual fields, whereas the opposite holds for local processing (Hubner, 1998). Electrophysiological studies (Han et al., 2002; Martinez et al., 1997; Yamaguchi, Yamagata & Kobayashi, 2000) used event-related brain potentials (ERP) to investigate the neural correlates of cerebral asymmetry in directing attention to the global pattern and local components of a hierarchical stimulus. ERPs were recorded while the subjects shifted their attention to the global or local level of a hierarchically structured letter. A preceding cue stimulus directed attention to global or local dimension. The ERPs to the cue stimuli demonstrated that the right temporal-parietal and left posterior temporal regions were differentially activated during attentional allocation to the global and local levels, respectively. Researchers that used other methods to investigate broad and narrow focus of attention have also found similar hemispheric specialization (Chen et al., 2008). Changes in the scope of attention, from a broad focus to a narrow focus and vice versa, are linked with distinct neurophysiological states that uniquely influence behavior (Lutz, Slagter, Dunne, & Davidson, 2008). In Chapter 3 and 4, I will further discuss that how broad and narrow focus of attention, induced by global/local processing might play a significant role in influencing mood and self-regulation.

Attentional inhibition

Attentional mechanisms are thought to facilitate goal-directed behavior through both the enhancement of task relevant information and inhibition of task irrelevant information. The models of cognitive processing that emerged in 1960's and 1970's described attentional mechanisms mainly in terms of facilitatory processing (spotlight and zoom lens models: Eriksen & Yeh, 1985; LaBerge, 1985), but the last three decades have seen a renewed interest in understanding the nature of inhibitory processing (see Dagenbach & Carr, 1994). Cognitive

inhibition has been defined as “stopping or overriding of a mental process, in whole or in part, with or without intention” (MacLeod, 2007). The concept of inhibition has been studied in a wide range of domains; ranging from mechanisms governing behavioral output, to interactions between brain regions, to cellular firing, to enzymes. Additionally, researchers have observed phenomena attributed to inhibition in a wide array of cognitive faculties, including in memory, language, perception, and decision-making. I will focus on how the concept of inhibition is used in attention research. Tipper (1985) explained the phenomenon of *negative priming*, which refers to the observation that after a stimulus is ignored, its subsequent processing is slowed down. For instance, if one stimulus is actively ignored while trying to identify some other stimulus, the internal representations of the ignored stimulus will be inhibited. On the next trial, if the task is to identify the previously ignored stimulus, you will need access to the previously inhibited representations. Because the stimulus was recently inhibited, access to corresponding representations is slowed, thereby leading to a slower behavioral response than when the item was initially encountered. Hence negative priming will be observed. Another phenomenon that results from attentional inhibition is known as *inhibition of return* (IOR; Posner & Cohen, 1984). The typical procedure consists of three boxes with subjects instructed to fixate on the center box and to move only their attention (not their eyes) during the trial. Then one of the two peripheral boxes brightens, drawing attention to the cued location despite the cue not being informative. Shortly thereafter, a target appears. When the time between cue and target is brief, target detection is faster at the cued location, which is the usual pattern of capture of attention by a cue. However, when the cue-target interval is longer than 300 milliseconds, detection is slower at the cued location. Thus, it has been suggested that attentional inhibition applied to the cued location results in slower processing due to reorientation of attention caused by the time lag (Klein, 2000). While the role of inhibitory processes in several paradigms has been debated (MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003), many researchers maintain that some kind of inhibition is involved in deliberately stopping a prepared response to an attentional cue (see Boucher, Palmeri, Logan, & Schall, 2007; Tipper, 2001).

Two experimental paradigms that have been applied thoroughly to induce attentional inhibition are the Go/No-Go paradigm (Donders, 1969) and the stop-signal paradigm (Logan & Cowan, 1984). In the Go/No-Go paradigm, subjects are presented with a series of stimuli and are told to respond when a ‘Go’ stimulus is presented and to withhold their response when a ‘No-

Go' stimulus is presented (e.g., press the response key for all the digits that are presented, except '3', when the digit '3' is presented do not press any response key). In this paradigm, an index of response inhibition is the probability of executing a response on a No-Go trial. In the stop-signal paradigm, instead of a pre-specified 'No-Go' stimulus, a 'stop' signal is presented after a variable delay which instructs subjects to withhold the response to the 'Go' stimulus on that trial (e.g., press the response key for all the digits that are presented, if the digit is replaced by a green dot, do not press any response key). In this paradigm, the index of response inhibition is the probability of executing a response on a stop signal trial. Performance in both paradigms is typically described in terms of a race between two competing processes: a go process and a stop process. In the Go/No-Go paradigm, the Go process is triggered by stimulus presentation because of habituation of the response tendency, and the stop process is triggered by the identification of the No-Go stimulus. In the stop-signal paradigm, the go process is triggered by the presentation of the go stimulus, and the stop process is triggered by the presentation of the stop signal. The probability of responding on a no-go trial or a stop-signal trial depends on the relative finishing time of the go process and the stop process. When the stop process finishes before the go process, attentional inhibition is successful and no response is emitted; when the go processes finishes before the stop process, attentional inhibition is unsuccessful and the response is incorrectly emitted (see Logan & Cowan, 1984). I will further discuss the contribution of inhibitory processing in effective attentional processing and self-regulation in Chapter 4.

Hierarchical architecture of the visual processing stream

The past three decades of research in cognitive neuroscience have informed us a lot about the functional organization of the visual cortex. The broad consensus of this work suggests a hierarchical architecture through which visual recognition is achieved via a gradual process in which information is first represented in a simple or local form and, through a sequence of processes, is transformed into more complex and holistic representation (DeYoe & Van Essen 1988). The pioneering studies by Hubel and Wiesel (1963, 1965), which examined cat visual cortex, found initial evidence of hierarchical architecture whereby visual information is processed by simple cells, complex cells, hypercomplex cells, and higher-order hypercomplex cells with growing complexity of information. The output of several simple cells is combined to provide the input to a complex cell- several of which are in turn combined to provide the input to

hypercomplex cells. Consequently, the size of the RFs of neurons in V1, V2 are much smaller than those farther down the ventral stream. During the early visual processing, the occipital cortex parses the visual information into simple features such as color and orientation. Virtually all visual-processing tasks activate V1 and V2. However, as information proceeds to more anterior areas, the neuronal response properties become increasingly complex. For example, V1 cells are responsive to orientation information (Hubel & Wiesel, 1968), V2 cells respond to illusory contours of figures (Peterhans & von der Heydt, 1991), some V4 cells respond only if a stimulus has a specific color or pattern (Schein & Desimone, 1990), and in occipito-temporal regions cells respond selectively to particular object categories (Kanwisher & Dilks, 2012; Sigala & Logothetis, 2002).

Occipito-temporal cortex is the seat for visual recognition and consists of focal regions involved in different category specific processing for faces (Fusiform face area (FFA) and occipital face area (OFA)), objects (lateral occipital (LO) and occipital fusiform (OF)), scenes (parahippocampal place area (PPA)) and bodies (extrastriate body area (EBA) and fusiform body area (FBA)). Interestingly, within the occipito-temporal cortex, these focal regions also possess a hierarchical architecture. It has been suggested that posterior-lateral structures of occipito-temporal cortex are involved in part-based representation of the category-specific stimuli and ventro-medial structures provide a relatively high level holistic representation of the category-specific stimuli. There is a considerable amount of research evidence that supports this hypothesis in face- and object-selective processing (Lerner, Hendler, Ben-Bashat, Harel & Malach, 2001; Lerner, Hendler & Malach, 2002; Yovel & Kanwisher, 2005; Schiltz & Rossion, 2006), but there is lack of research in body-selective processing. One study that has investigated the functional distinction between EBA and FBA has found that EBA activation gradually increases as a function of the amount of body shown, but FBA shows no significant activation for individual fingers or hands and responds to the whole body (Taylor, Wiggett & Downing, 2007). This study hints at the hierarchical organization present in the occipito-temporal cortex where EBA is involved in part-based processing of the bodies and FBA is involved in higher order holistic body processing, in analogy with the respective roles of the face-selective areas OFA and FFA in processing the parts of the face and whole face (Liu et al., 2009). Attentional manipulations to body-parts versus whole bodies might inform us more about such hierarchical architecture and visual recognition in the occipito-temporal cortex. The impact of attentional

manipulations on hierarchical architecture and visual recognition in the occipito-temporal cortex will be further discussed in Chapter 2.

How does attention influence perceptual, conceptual and social processes?

An important question that I address in this thesis concerns the influence that manipulations of attention have on cognitive functioning. A wide range of research evidence suggests that changes in scope of attention influence the way we process information. Changes in scope of attention influence early visual processes, such as spatial processing. Jacobs and Kosslyn (1994) proposed that size of attentional focus plays an important role in spatial relation processing. In a simulation study, Kosslyn, Chabris, Marsolek, and Koenig (1992) reported that networks that receive input from smaller RFs computed categorical spatial relations efficiently, whereas networks that receive input from larger RFs computed coordinate spatial relations between objects efficiently. According to Kosslyn (1987; 1994), the brain computes two kinds of spatial relationships in different neuronal systems. The categorical spatial processing subsystem assigns a category such as left/right or above/below to a spatial relation and the coordinate spatial processing subsystem represents precise location and distance information by use of a coordinate system. Further research (Borst & Kosslyn, 2010; Michimata, Saneyoshi, Okubo & Laeng, 2011) investigated whether activation of smaller and larger RFs can be induced by global/local processing to investigate their influence on spatial relations. Broad attention induced by global processing leads to faster responses in a coordinate task and narrow attention induced by local processing leads to faster RTs in a categorical task (Borst & Kosslyn, 2010; Michimata, Saneyoshi, Okubo & Laeng, 2011). These studies provide evidence that the manipulations of scope of attention have clearly different effects in the processing of spatial relationships, which is a lower order visual process.

Changes in the scope of attention not only influence lower-level early visual processes, but also influence higher-level mental processes such as creativity, social judgments etc., and subcortical emotional and motivational processes. Forster and Dannenberg (2010) proposed the “GLOMOsys model” which suggests that global/local processing carries over to other tasks and that changes in the perceptual scope of attention also influence the conceptual scope of attention. Additionally, Friedman and Forster (2001) found that broad and narrow

attentional focus influences creative processes. Participants in their study were primed for global or local processing using a Navon-letter task and were then asked to generate unusual uses for a brick as indices of creativity. Participants in the global processing condition produced relatively creative uses, such as “grind it up and use it as makeup”, whereas locally primed participants generated less creative solutions such as “build a wall”. In a global or broad focus, more abstract concepts are activated that trigger more remote concepts which enhance performance in creativity tasks. Conversely, in a local or narrow focus, only concrete and dominant associations are activated and innovation is impeded. Broad and narrow attention is also thought to influence psychological distances. Lieberman and Forster (2009), for example, primed a global or local processing style using the Navon-letter-task and then asked participants to estimate temporal distance (e.g., estimating how many days from now they would go to a dental cleaning), spatial distance (e.g., estimating the distance between them and a different city), social distance (e.g., estimating closeness between them and their family doctor), or hypothetical distance (e.g., estimating the probability to become one of the 5% best people in their field). In all the conditions, globally primed participants estimated distances to be larger whereas locally primed participants estimated distances to be smaller, compared to the control group. Additionally, Macrae and Lewis (2002) showed that face recognition was improved following a global processing task, but was impaired following a local processing task, supporting the idea that face recognition requires more holistic processing (Tanaka & Farah, 2003). Srinivasan and Hanif (2010) used a global/local priming task to assess the effects of a global or local prime on the identification of happy and sad faces, and found that broad attentional focus induced by global processing facilitated identification of happy faces, while local processing facilitated identification of sad faces. This provides evidence that not only emotional information can influence global/local processing (see Gasper & Clore, 2002), but the reciprocal effect also exists. Consequently, there is considerable evidence that the changes in the scope of attention differentially affect perceptual, conceptual, and social processes. Importantly, the effect of broad versus narrow focus of attention, induced by global/local processing, on mood and self-regulation has not been studied to date. This void is addressed by the research presented in Chapters 3 and 4.

Not only does the selection of attention influence perceptual, conceptual and social processes, inhibition also results in distinct effects on these processes. Neural activations in

striate and extrastriate cortex are modulated by inhibition (Luck, 1995; Slotnick, Schwarzbach, & Yantis, 2003; Somers et al., 1999). It has been found that a reduction in the amplitude of a specific ERP component (P1) reflects attentional inhibition at unattended locations as opposed to amplification of amplitude of N1 that reflects attentional selection at the attended location. Yantis and colleagues found evidence that retinotopic mapping in striate and extrastriate cortex demonstrate both attentional facilitation of the attended location and attentional inhibition of surrounding stimulus (Yantis et al., 2005; Slotnick, Schwarzbach, & Yantis, 2003). Furthermore, inhibition also has affective consequences. Inhibitory devaluation is the phenomenon that refers to affective devaluation of objects that have been inhibited earlier. This effect has been shown with abstract stimuli (Raymond, Fenske, & Tavassoli, 2003), faces (Fenske, Raymond, Kesler, Westoby & Tipper, 2005), and sexually appealing and drug stimuli (Ferrey, 2012). Recent work from our lab has shown that such affective devaluation increases with the number of instances a target is inhibited (Frischen, Ferrey, Burt, Pistchik & Fenske, 2012) proving that more inhibition leads to more disliking. Similar effects are found in visual search paradigms, wherein affective devaluation is greater for distractors that are in close spatial proximity to visual search targets and provide greater levels of interference (Raymond, Fenske & Westoby, 2005). Additionally, affective devaluation for previously inhibited stimuli also results in a decrease of the motivational salience of high motivationally-relevant stimuli, such as sexually appealing images (Ferrey, 2012). Participants who inhibit sexually appealing images were found to be less likely to make repeated key-presses to see brief presentations of such stimuli as compared to those participants for whom sexually appealing stimuli previously appeared as response targets. Thus, attentional inhibition not only results in affective devaluation, but also reduces the amount of work done to obtain the motivationally-relevant stimuli.

Lack of attentional inhibition is linked with maladaptive behaviors, such as self-regulatory failure and poor mood (Baumeister & Heatherton, 1996; Bridgett, Oddi, Laake, Murdock & Bachmann, 2012; Goeleven, De Raedt, Baert, Koster, 2006). Participants with low inhibition abilities are more likely to make socially inappropriate actions and are more likely to give into temptation (Hofmann, Friese, & Roefs, 2009; von Hippel & Gonsalkorale, 2005). Anhedonia and rumination, two core symptoms of clinical depression, have also been shown to be associated with lack of response inhibition (deLange, 2010; King, Emmons, & Woodley, 1992). Patients with clinical depression also show impaired inhibition of negative information

(Goeleven et al., 2006). Additionally, inhibition is positively correlated with dispositional negative affect (Bridgett et al., 2012) and negatively correlated with emotion regulation abilities (Carlson & Wang, 2007). Thus, there is ample evidence that efficient inhibitory processing is essential for healthy mental functioning and further research is needed to understand how efficient inhibitory processing can improve cognitive functioning. The effect of inhibition on self-regulation is discussed further in Chapter 4.

Thesis outline

The overarching goal of this thesis is to investigate the influence of attentional manipulations on various stages of cognition and emotion to result in goal-directed behavior. This thesis is a compilation of three different lines of research, each addressing a specific research aim.

Chapter 2 will examine how early stages of cognition (i.e. visual recognition in occipito-temporal cortex) can be influenced by attentional manipulations. Occipito-temporal cortex consists of highly specialized regions for visual recognition of category-specific stimuli. The Extrastriate Body Area (EBA) and Fusiform Body Area (FBA) are two brain regions that are selectively involved in visual recognition of human bodies. Chapter 2 includes one functional magnetic resonance imaging (fMRI) experiment (Experiment 1) that investigates communication between these regions—the functional connectivity at rest between EBA and FBA—and how attention to goal-relevant body related stimuli may influence functional connectivity between these body-selective regions. This line of research used recent neuroimaging techniques to assess functional connectivity to investigate how attention influences the early stages of cognition when goal-relevant visual information is processed by the occipito-temporal cortex. Note that this experiment was conducted during a four month research practicum at Prof. Paul Downing’s laboratory in the Centre for Cognitive Neuroscience at Bangor University (Wales).

Chapter 3 will examine the role of attentional manipulations in influencing mood. Cognition research has traditionally distanced itself from emotion research but growing research has provided evidence of interactions between cognition and emotion. Successful interaction between cognitive mechanisms like attention and emotion results in healthy cognitive functioning and emerging evidence suggest that efficient attentional processing may lead to

improvements in mood, but little is known about the exact mechanisms through which attention might influence mood. Chapter 3 includes one experiment that investigates the influence of attentional manipulations (i.e. changes in the focus of attention) on mood. This line of research will provide insight into how attention manipulations influence the intermediate stage of cognition when it interacts with affective state or mood.

Chapter 4 will examine the role of attentional manipulations in improving self-regulation. Goal-directed behavior is the last stage or output stage of cognition. Successful goal-directed behavior requires self-regulation to override competing impulses. Although self-regulation has been traditionally studied in the context of social psychology, emerging evidence suggests that cognitive mechanisms of attention may mediate such acts. However, little is known about the specific operations through which attention might influence self-regulation. Chapter 4 includes a series of experiments (Experiments 3 to 6) that investigates the influence of attentional manipulations on self-regulation. In these experiments, attentional manipulations are applied in two ways: one changing the scope of attention; the other controlling the inhibition of inappropriate responses. Note that this chapter, in part, reports results I have already published as:

Hanif, A., Ferrey, A.E., Frischen, A., Pozzobon, K., Eastwood, J.D., Smilek, D., & Fenske, M.J. (2012). Manipulations of attention enhance self-regulation. *Acta Psychologica*, *139*, 104-110.

The general discussion presented in Chapter 5 leads to the conclusion that attention does play a crucial role in influencing cognition at three stages- input of visual information, interaction with affective state and output of behavior.

Chapter 2: Attention and functional connectivity in visual cortex

Visual recognition is one of the earlier stages of cognition and is accomplished mainly in the ventral *what* pathway. Changes in attention impact neural activity in the extrastriate cortex and higher-order visual pathways. However, how attention influences the functional interactions between brain areas of the ventral *what* pathway has not been investigated thoroughly. The extrastriate body area (EBA) and fusiform body area (FBA) are the two brain areas involved in higher order visual processing of human bodies. The main objective of this part of the thesis was to investigate the impact of attentional manipulations on visual recognition in the ventral *what* pathway by examining the functional connectivity between EBA and FBA.

Category-specific processing and hierarchical organization in occipito-temporal cortex

The occipito-temporal cortex is the seat of higher order visual processing. Ungerleider and Mishkin (1982) found this area to be the primary brain region for visual recognition, comprising the ventral *what* pathway. A notable feature of occipito-temporal cortex is that it contains highly specific regions that are specialized for perception of different stimulus categories. Focal regions that respond strongly and selectively to stimulus categories, such as faces, objects, and bodies, have been found on occipito-temporal cortex (see Taylor & Downing, 2011). Attention to faces elicit neural activations in the inferior occipital gyrus (occipital face area, OFA) and the lateral fusiform gyrus (fusiform face area, FFA) (Haxby, Hoffman, & Gobbini, 2000; Kanwisher, McDermott, & Chun, 1997). The lateral occipital area, which is subdivided into a posterior-lateral region known as lateral occipital and a more medial and anterior region known as posterior fusiform, is specialized in object processing (Grill-Spector et al., 1999). Downing and colleagues found two body-selective regions in the human brain: the extrastriate body area (EBA) found in the posterior lateral temporal sulcus (Downing, Jiang, Shuman, & Kanwisher, 2001), and the fusiform body area (FBA) found in the ventro-medial surface of the fusiform gyrus (Peelen & Downing, 2005). Pitcher and colleagues used transcranial magnetic stimulation (TMS) to prove the exclusive contribution of these category-specific areas in processing their selective category (Pitcher, Charles, Devlin, Walsh & Duchaine, 2009). These category-specific regions do not appear alone, but instead appear as twin

structures on posterior-lateral and ventro-medial cortical surface. In the posterior-lateral occipitotemporal cortex, focal selectivity is found for faces (OFA), bodies (EBA), and objects (lateral occipital). Similarly, in the ventro-medial occipito-temporal cortex, three similar category-selective regions are found for faces (FFA), bodies (FBA), and objects (posterior fusiform). Although research has found that attention prioritizes category-specific information by enhancing the evoked responses in cortical areas that represent the particular category, how attention influences visual recognition of category-selective stimuli by enhancing the functional connectivity between these twin structures has not been studied.

Attention and functional connectivity

Attention influences the way human beings interact with their environment. Desimone and colleagues explained how attention exerts effects on different levels of the extrastriate visual cortex (Chelazzi, Miller, Duncan, & Desimone, 1993; Luck, Chelazzi, Hillyard, & Desimone, 1997; Moran & Desimone, 1985; Reynolds, Pasternak, & Desimone, 2000). Spatially directed attention enhances information processing at the attended location at the expense of processing irrelevant information from nearby distracters. Similar effects were found in the dorsal processing stream (dorsal *how* pathway) with single cell recordings (Recanzone & Wurtz, 2000; Treue & Maunsell, 1996). Compared to these early attentional modulations of low-level visual processing, the process of selection and identification of complex visual objects in the ventral *what* pathway is not fully understood.

Recent research suggests a functional distinction and a hierarchical organization between these twin structures. It has been suggested that posterior-lateral structures are involved in part-based representation of the category-specific stimuli and ventro-medial structures provide a relatively high level holistic representation of the category-specific stimuli. There is a considerable amount of research evidence that supports this hypothesis in face- and object-selective processing (Lerner, Hendler, Ben-Bashat, Harel & Malach, 2001; Lerner, Hendler & Malach, 2002; Schiltz & Rossion, 2006; Yovel & Kanwisher, 2005) but there is a lack of research in body-selective processing. One study that has investigated the functional distinction between EBA and FBA has found that EBA activation gradually increases as a function of the amount of body shown but FBA shows no significant activation for individual fingers or hands

and responds to the whole body (Taylor, Wiggett & Downing, 2007). This study hints at the hierarchical organization present in the occipito-temporal cortex where EBA is involved in part-based processing of the bodies and FBA is involved in higher order holistic body processing, analogous to the respective roles of the face-selective areas OFA and FFA in processing the parts of the face and whole face (Liu et al., 2009). One technique that could be helpful in providing evidence of such a hierarchical scheme is the analysis of functional connectivity and how attention to body versus parts may influence the functional connectivity. The hypothesis that attention can be expressed as a change in functional connectivity was first suggested by LaBerge (2005). He noted that ‘The expression of attention in a brain area appears to be described effectively as an enhancement of activity in the attended set of pathways relative to the unattended set of pathways.’ Although fMRI has been robustly used to infer modulation of extrastriate cortical areas by attentional processes (O’Craven, Rosen, Kwong, Triesman & Savoy, 1997), the use of functional connectivity for inferring hierarchical organization by attentional modulation is a novel approach.

What is functional connectivity?

Functional connectivity is defined as the temporal correlation between anatomically distant areas of the brain (Poldrack, Mumford & Nichols, 2011). Temporal correlation can arise due to many reasons. Firstly, one region could receive afferent signals from another region. Secondly, both the regions might receive afferent signals from a third region. And lastly, a third region might mediate the signal processing between the two regions. Interestingly, only the first condition can be considered as a true case of functional connectivity where there is direct causal influence between two regions. Thus, it is suggested that functional connectivity analyses must be evaluated and interpreted with great care (see Poldrack, Mumford & Nichols, 2011).

There are various methodological approaches that have been used for investigating functional connectivity. Some researchers have employed a data-driven approach by using techniques like seed voxel correlations, psychophysiological interactions, etc. Others have employed a hypothesis-driven approach by using techniques like dynamic causal modeling, structure equation modeling, etc. In this study, I adopted a data driven approach of seed voxel correlations. I chose seed voxels from region of interests (ROIs) EBA and FBA, specialized for

body processing, and examined functional connectivity in two ways: (a) resting state connectivity to assess the intrinsic functional connectivity that exist at resting state, and (b) background connectivity to assess the effect of attentional manipulation on the functional connectivity.

What is resting state connectivity?

Spontaneous intrinsic neural activity represents a significant part of the brain's activity dynamics (Fox & Raichle, 2007). A particularly robust example of spontaneous intrinsic neural activity is the resting state connectivity, which involves the temporal correlations in low-frequency brain signals at passive or resting states. Biswal, Tetkin, Haughton & Hyde (1995) observed that low frequency fluctuations (less than 0.1 Hz) are correlated among functionally related brain regions, such as the left and right primary motor cortices. Resting state connectivity is thought to reflect functional relationships mediated by anatomical connections (Greicius, Supekar, Menon & Dougherty, 2009; Honey et al., 2009). A number of resting state connectivity studies have identified a number of functionally dissociable ‘resting-state networks’ (e.g., Fox et al. 2006; Vincent et al. 2008). Functionally related face-selective regions: OFA and FFA show high resting state connectivity and an individuals' performance on a variety of face processing tasks can be predicted by the strength of the resting state connectivity between OFA and FFA (Zhu, Zhang, Liu, Dilks & Liu, 2011). However, none of the research thus far has investigated the nature of resting state connectivity between body processing areas. To the best of my knowledge, this is the first study investigating the resting state connectivity between EBA and FBA.

What is background connectivity?

In order to assess the functional connectivity when attention is manipulated to focus on whole bodies versus body parts, a novel approach of background connectivity was used. One problem with functional connectivity measurements during task performance is that spurious correlations might be present due to task-related activations or evoked responses to individual stimuli. In order to examine functional connectivity that result from changes in attention, independent of the evoked responses to individual stimuli, correlations were computed after modeling and removing the mean evoked response from the regions of interest (ROIs). This

approach, known as “background connectivity”, was recently put forth by Norman-Haignere, McCarthy, Chun and Turk-Browne (2012) for examining correlations that occur in the background of stimulus-locked changes by modeling the task-related variance. If a hierarchical architecture exists between EBA and FBA, then functional connectivity between EBA and FBA should increase during attention to whole bodies. On the other hand, functional connectivity between EBA and FBA should not show considerable increase during attention to body parts.

Present study

Functional neuroimaging studies in face processing and object processing have found evidence of hierarchical organization in the respective category specific regions. Category specific regions present on posterior-lateral surface (OFA and lateral occipital) perform the part-based processing and regions on ventro-medial surface (FFA and posterior fusiform) perform the holistic processing of the category specific stimuli: faces and objects (Lerner, Hendler, Ben-Bashat, Harel & Malach, 2001; Lerner, Hendler & Malach, 2002; see Taylor & Downing, 2011 for a review; Yovel & Kanwisher, 2005; Schiltz & Rossion, 2006). However, this hypothesis has not been tested thoroughly for body-selective processing. This study investigates the hierarchical organization between body-selective regions by using a novel approach of functional connectivity. This study is specifically aimed to test three hypotheses: (i) Resting state connectivity between EBA and FBA may be higher than that with a control brain area, (ii) Functional connectivity between EBA and FBA may be higher in the presence of a body related tasks compared to resting state, and (iii) Background connectivity between EBA and FBA during attention to whole body condition may be higher than during attention to body-parts condition.

Experiment 1

Methods

Participants

Seven right-handed adult participants (four females; mean age 27.2) were recruited from within the University of Wales, Bangor community and were paid £15 for their participation. All participants were fully briefed and informed consent was obtained in

compliance with procedures set by the Bangor University School of Psychology Research Ethics Board.

Stimuli and apparatus

Stimuli used for localizers and attention tasks were greyscale images. There were three localizer runs and four attention task runs. For one body-selective EBA and FBA localizer run, the stimuli consisted of 20 images of headless human bodies in a variety of postures; these were compared with 20 different images of chairs as a control. A second body-selective EBA and FBA localizer run compared a variety of body parts (hands, arms, feet, legs etc.) with a variety of common object parts (head of a hammer, cap of a bottle, etc.). A third scene-selective PPA (which served as a control brain area) localizer run, compared a variety of chairs, faces, scenes and scrambled scenes. The stimuli consisted of 16 images of indoor scenes; these were compared with 16 images in each category of faces, chairs and scrambled objects that served as controls (see exemplars in Figure 1). For attention task runs, 18 images of headless bodies were used. There were three body postures (frontal, left facing and right facing) and three hand gestures (palm, fist and 'V'). Each image was a combination of one body posture and one hand gesture, for example a body with frontal body posture and a fist hand gesture or right facing body posture and a palm hand gesture (see exemplars in Figure 2). Participant's attention was maintained and monitored during all localizer and experimental runs using a one-back task. One-back task requires participant to press a button on response pad every time the relevant target (body posture or hand gesture) repeats. Figure 3 shows a design overview of Experiment 1.

All data were acquired using a 1.5-T Philips Intera "Compact Plus" MRI scanner, fitted with a SENSE parallel head coil (Philips, Best, The Netherlands). Stimulus images were presented using a projector focused onto a translucent rear-projection screen. Presentation was controlled using MATLAB (The MathWorks, Natick, MA) and Psychophysics Toolbox (Brainard, 1997; Pelli 1997). One-back responses were recorded using a nonferrous fiber-optic response pad (Current Designs, Philadelphia, PA). Preprocessing and first level statistical analyses were performed using BrainVoyager QX software (Brain Innovation, Maastricht, The Netherlands). Second level statistical analyses were performed using MATLAB.

Scanning parameters

Functional data were obtained using T2*-weighted scans using a single-shot echo planar (EPI) sequence. Twenty-nine axial oblique slices were acquired. Acquisition parameters for all participants were: 64x64 matrix, slice thickness =4 mm, voxel dimensions= 3x3 mm in-plane; echo time (TE) =50 ms; repetition time (TR) =2,000 ms; flip angle= 90°. T1-weighted anatomical scans were also collected for spatial registration and normalization (3D and coplanar).

Resting state run

The first run of the experiment was always a resting state acquisition lasting 6 minutes and 18 seconds. Participants were asked to lie passively in the scanner with open eyes. 189 functional volumes were acquired for the resting scan.

Body-selective EBA and FBA Localizer runs

EBA and FBA ROIs were localized individually in two separate runs: one comparing bodies to chairs and the other comparing body parts to object parts. EBA and FBA were localized bilaterally. One participant did not show left FBA activation. Each localizer run consisted of 21 blocks of 15 s each. Blocks 1, 6, 11, 16 and 21 were fixation-only baseline epochs. In each of the remaining blocks, 20 images of either headless human bodies and images of chairs or human body parts and parts of common objects were presented. Stimuli were each displayed for 300 ms, followed by a blank screen for 450 ms. In total, 168 functional data volumes were acquired for each experimental scan.

Scene-selective PPA Localizer run

A control region, scene-selective PPA, was localized by comparing scenes to faces, chairs and scrambled objects. PPA was localized bilaterally. Length of blocks and trials as well as design was the same as described above for the other two localizer runs.

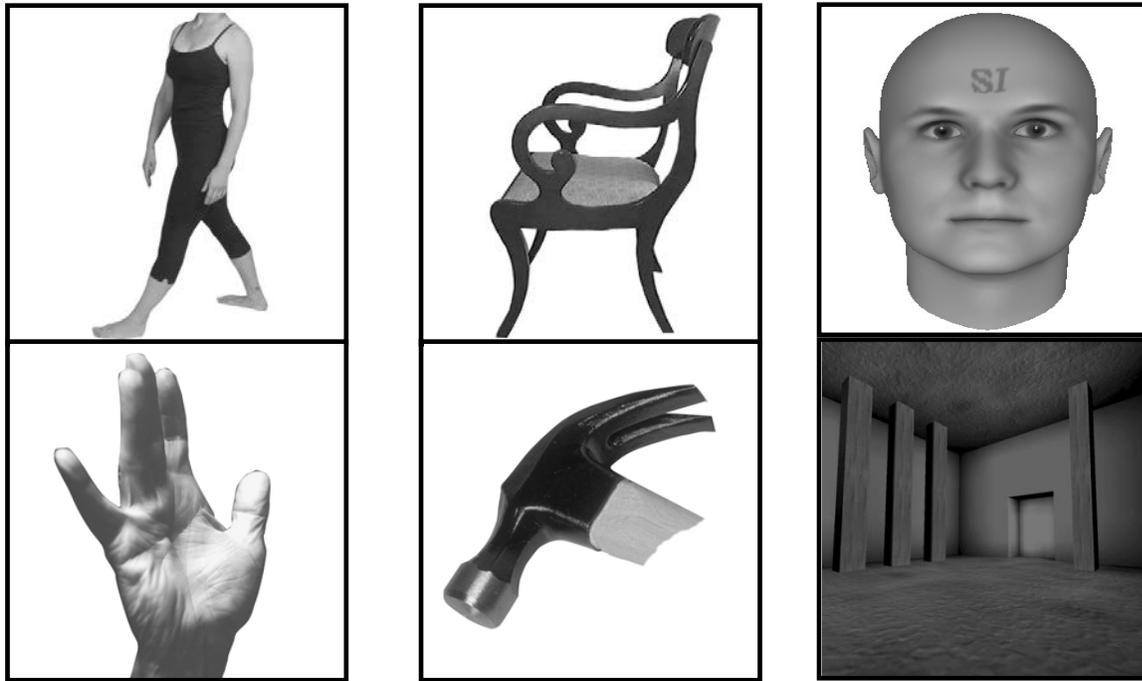


Figure 1 . Exemplar stimuli used in the localizer tasks of Experiment 1



Figure 2. Exemplar stimuli used in the attentional manipulation tasks of Experiment 1

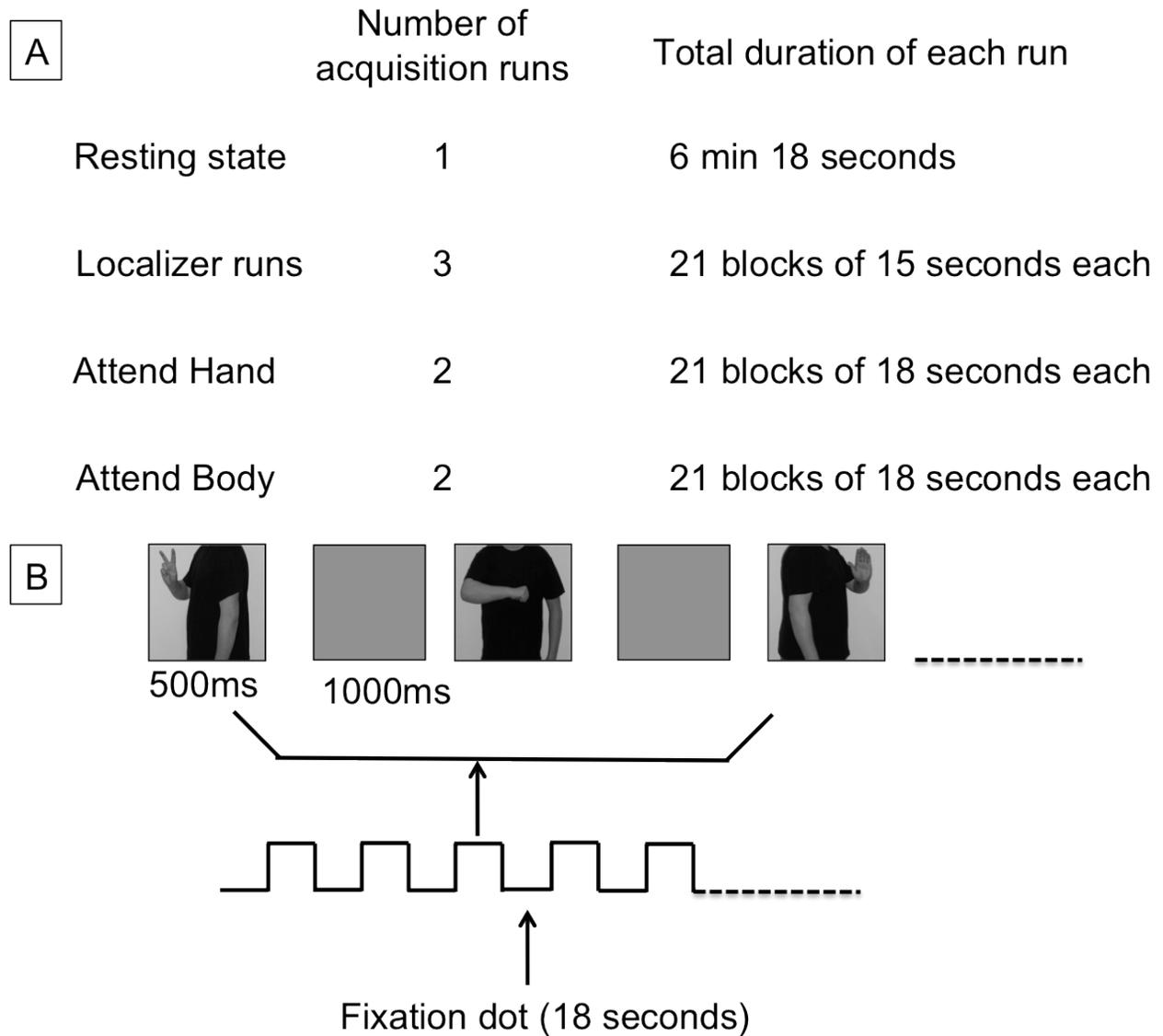


Figure 3: Design overview of Experiment 1: (A) Summary of number and durations of runs. Resting run was always the first. Other runs were counterbalanced between subjects. (B) Design of each Attend Body and Attend Hand runs.

Attention task

Participants were scanned on four blocked design runs. Two runs comprised the ‘Attend Body’ condition and two comprised the ‘Attend Hand’ condition. Block orders within each sequence and the presentation order of items within each block were fully counterbalanced across experimental runs. Each run started with instructions to ‘Attend Body’ or ‘Attend Hand’. Each run consisted of 21 blocks of 18 s each. There were 10 blocks of the attention task. Alternate blocks contained a fixation dot. Participants were asked to perform a 1-back task on hand gesture or body posture, according to the block instructions. Each image was displayed for 500 ms followed by a 1000 ms blank interval. In all, 189 functional data volumes were acquired for each experimental scan.

Data preprocessing

Functional data were slice scan-time corrected and motion-corrected to the first scan of the resting run of each participant. Low-frequency drifts were removed with a temporal high-pass filter (0.006Hz). Spatial smoothing of 4mm kernel size was applied. Functional data were manually coregistered with three-dimensional (3D) anatomical T1 scans (1x1x1.3 mm resolution). The 3D anatomical scans were transformed into Talairach space (Talairach & Tournoux, 1988) and the parameters from this transformation were subsequently applied to the coregistered functional data.

First-level Region of Interest (ROI) analysis

For each ROI in each subject, the most significantly activated voxel was identified within a restricted part of the cortex based on previously reported anatomical locations (Epstein & Kanwisher, 1998; Taylor, Wiggett & Downing, 2007). EBA and FBA localizer runs were fit using a general linear model (GLM) that included boxcar regressors for each block convolved with a hemodynamic response function. z scores were computed from “Bodies > Chairs and “Body parts > Object parts” contrasts. Each ROI was defined by its “peak” voxel and all voxels within a 10 mm³ cube centered on the peak that met a statistical threshold of $p < 0.001$. These contrasts were then used to select body-selective EBA and FBA seeds in each subject. Similarly, scene-selective PPA seeds were selected in each subject from the “Scene > Control

(face/chairs/scrambled objects)” contrasts from PPA localizer run. Figure 4 show bilaterally localized EBA, FBA and PPA in a representative participant.

Second-level Resting State Connectivity (RSC) analysis

The time courses for each ROI were extracted from the resting state run for further analysis. Because functional connectivity networks have been detected in low-frequency ranges (Biswal et al., 1997; Cordes et al., 2001), the timecourses were subjected to a butterworth low-pass filter to retain only the signal less than 0.1 Hz frequencies. The time series of 15 nuisance signals were identified for inclusion in the analyses: global signal, 4 white matter seeds, 4 ventricles seeds and 6 motion parameters. As the global signal is thought to reflect a combination of physiological processes (such as cardiac and respiratory fluctuations) and scanner drift, it was included as a nuisance signal to minimize the influence of such factors (Norman-Haignere et al., 2012). Time courses from ventricles and white matter seeds were also subjected to low pass filtering. Time courses from the resting run were then fitted with a GLM to remove nuisance variables and residuals were obtained to observe the correlations. These correlation coefficients served as measures of RSC, and they were analyzed using a hierarchical combination of repeated-measures analyses of variance (ANOVA) and planned t-tests.

Second level Background connectivity (BC) analysis

The time courses for each ROI were extracted from attention runs for further analysis. Timecourses were low-pass filtered similarly to resting runs. To examine whether attention to whole-bodies versus body parts alters functional connectivity, mean evoked response from attention task runs were modeled and removed, and then residuals of the model were examined to determine the BC (Norman-Haignere et al., 2012). The goal of this approach was to measure changes in functional connectivity that are independent of stimulus-evoked responses and instead depend on a sustained task set (Logan & Gordon, 2001). The timecourses from ROIs were fitted with a finite impulse response (FIR) model with 18 regressors modeling each time point in one stimulus block and fixation. Thus any response that occurred a fixed time period after the onset of a stimulus block was captured by at least one of the 18 regressors. The residuals from these regressions were further fitted with the nuisance model containing global signal, 4 white matter, 4 ventricles and 6 motion parameters. The residuals obtained at this stage were observed for

correlations. Correlation coefficients served as a measure of BC. They were analyzed using a hierarchical combination of repeated-measures ANOVA and planned t-tests just as in resting state analysis.

Results

Bilateral EBA, FBA and PPA were localized by using face and place localizer tasks (for Talairach coordinates, see Table 1). One participant, who did not show FBA activation in body localizer tasks, was excluded from the functional connectivity analysis. Another participant, who did not show left FBA activation in body localizer tasks, was included in the sample for right hemispheric activations. Figure 3 shows bilaterally localized EBA, FBA and PPA in a representative participant.

A repeated-measure mixed ANOVA of RSCs and BCs between all ROI pairs by hemisphere showed no significant difference between right and left hemispheres ($F(1,4)= 2.471$, $p=0.19$); (Figure 5). Given the greater role of the right hemisphere in body-selective processing (Downing et al., 2001), and to simplify the analyses, RSCs and BCs were further analyzed only for right hemisphere.

Importantly, the RSC, (i.e. mean correlation) between two body-selective regions (EBA/FBA RSC: $r= 0.41$), was slightly larger than the mean correlation between body-selective regions and a scene-selective region (EBA/PPA RSC: $r= 0.37$; FBA/PPA RSC: $r= 0.38$). This demonstrates that functionally related body specific brain areas tend to communicate more with each other than a scene specific control region. However, there was no significant difference between the EBA/FBA RSC and EBA/PPA RSC or FBA/PPA RSC ($F(2,4) = 0.04$, $p=0.95$). BC, i.e. mean correlation between two body-selective regions during the ‘Attend Body’ condition (EBA/ FBA BC: $r= 0.47$) was significantly larger than the correlation between body-selective regions and a scene-selective region (EBA/PPA BC: $r= 0.34$; FBA/PPA BC: $r= 0.36$) ($F(2,4)=13.501$, $p<0.01$; $\eta_p^2=.89$). Interestingly, EBA showed much higher BC with FBA than PPA in the ‘Attend Body’ condition ($t(1,5)=5.15$, $p<0.004$). This demonstrates that when participants attended to bodies, the communication between EBA and FBA enhanced as compared to the communication between EBA and PPA. BC between two body-selective regions during the ‘Attend Hand’ condition (EBA/ FBA BC: $r= 0.48$) was also larger than the correlation

between body-selective regions and a scene-selective region but this effect was not significant (EBA/PPA BC: $r=0.33$; FBA/PPA BC: $r=0.34$) ($F(2,4) = 2.08, p=0.24$). EBA showed slightly higher BC with FBA than PPA in ‘Attend Hand’ condition ($t(1,5)=2.05, p<0.095$ (Figure 6). Therefore, the communication between EBA and FBA was enhanced in ‘Attend Hand’ condition too.

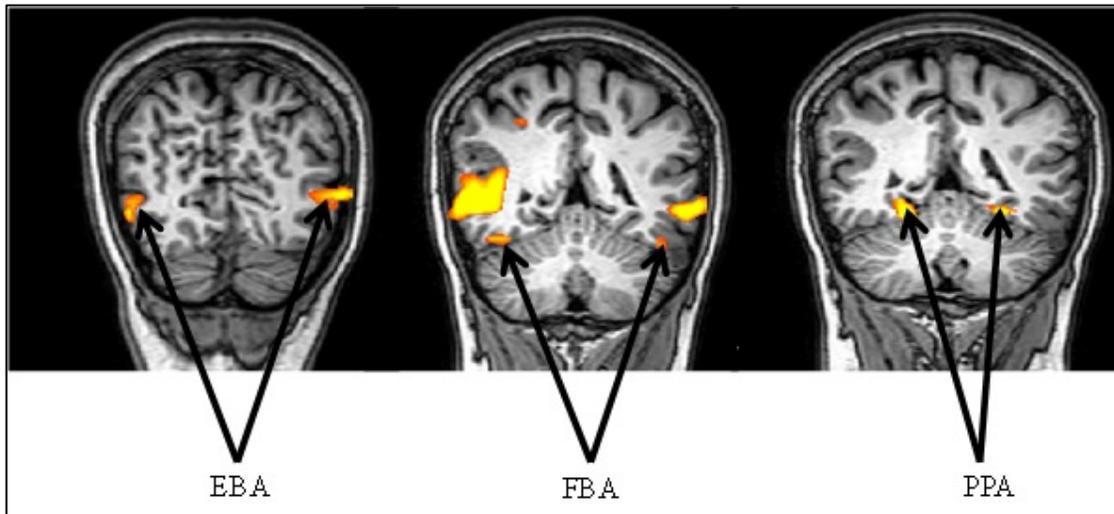


Figure 4. Bilaterally localized EBA, FBA and PPA in a representative participant

Table 1. Peak Talairach coordinates for ROIs

Participant	rEBA	lEBA	rFBA	lFBA	rPPA	lPPA
1	44,-60,-8	-57,-68,-7	39,-41,-27	-46,-32,-33	20,-40,-14	-28,-41,-22
2	42,-59,-4	-53,-51,1	34,-43,-13	No activation	22,-38,-10	-30,-38,-7
3	46,-62,-6	-41,-78,-13	39,-44,-21	-41,-44,-27	19,-32,-13	-25,-44,-12
4	45,-63,-1	-47,-68,-4	35,-38,-23	-40,-40,-17	22,-38,-12	-25,-42,-10
5	37,-62,-1	-45,-80,-10	31,-43,-12	-39,-40,-26	19,-41,-12	-25,-47,-6
6	46,-65,-4	-47,-77,-1	37,-41,-18	-38,-34,-24	28,-41,-10	-30,-43,-14

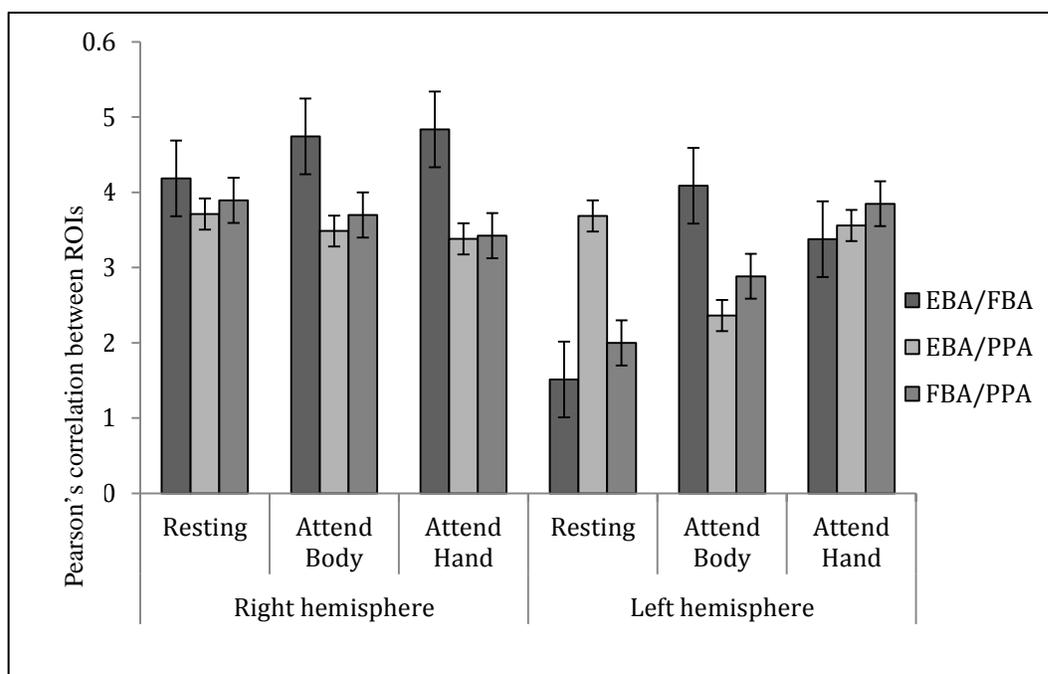


Figure 5. Mean functional connectivity for resting and attention task runs in right and left hemisphere. Error bars reflect standard error of means.

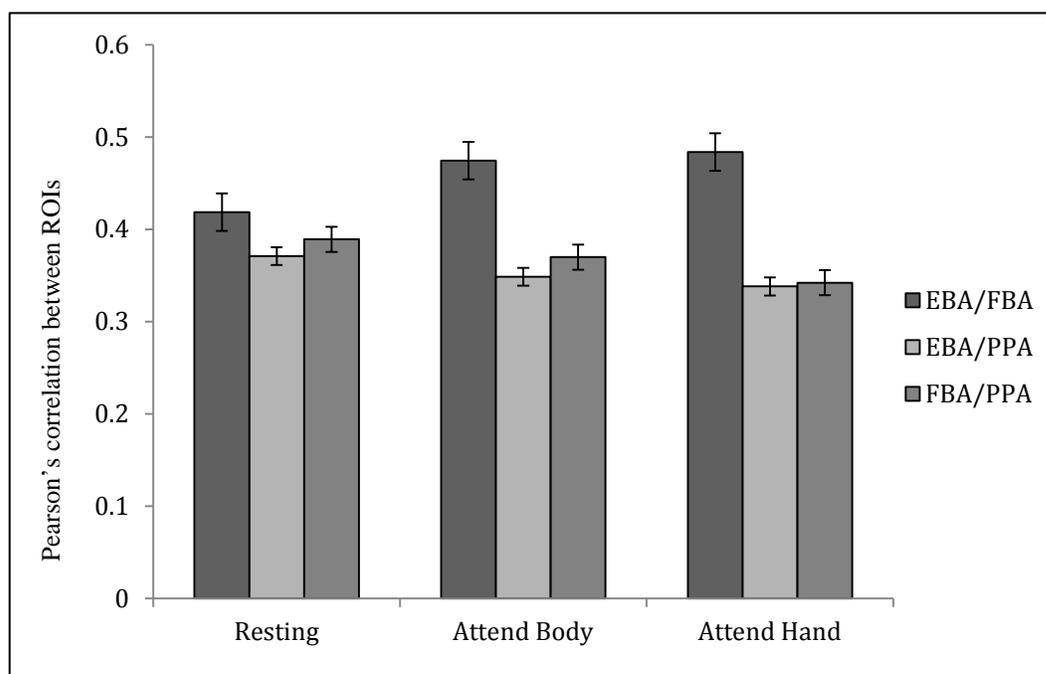


Figure 6. Mean functional connectivity for resting and attention task runs in right hemisphere. Error bars reflect standard error of means.

Repeated measure ANOVA between mean correlations between EBA and FBA in resting, attend body, and attend hand conditions was conducted to assess the effect of the task on the functional connectivity between the body-selective regions. Functional connectivity was higher in attend body and attend hand conditions compared to the resting state but the effect was not significant ($F(2,4)=0.519, p=0.63$). This effect hinted at an increase in functional connectivity when engaged in body processing (both ‘Attend Body’ and ‘Attend Hand’ conditions) compared to the rest. Importantly, the expected increase of functional connectivity between EBA and FBA during ‘Attend Body’ condition versus ‘Attend Hand’ condition was not observed. Thus, there was no conclusive evidence of a hierarchical architecture between EBA and FBA.

Discussion

The main objective of this experiment was to examine the intrinsic and attention-related changes in functional connectivity between the body-selective brain areas by examining the resting state and background connectivity between EBA and FBA. In particular, the effect of attentional manipulation on functional connectivity was used as a tool to assess the influence of attentional manipulations on visual recognition and hierarchical organization in the occipito-temporal cortex. Resting state connectivity between body-selective brain areas has not been investigated by previous research. This study was aimed at determining whether intrinsic activations in the brain provide an underlying substrate for body-selective processing even in absence of a body-related task. Furthermore, it was hypothesized that attention to bodies and body parts will enhance the functional connectivity between brain areas involved in body processing, compared to resting state connectivity. It was also hypothesized that if body-selective brain areas demonstrate a hierarchical organization, whereby posterior-lateral EBA performs the part-based processing and ventro-medial FBA performs the holistic processing of bodies, functional connectivity will increase in ‘Attend Body’ condition compared to resting state and ‘Attend Hand’ condition.

The data from only six participants have shown the desired trend but due to less power, strong conclusions cannot be made. The results from the resting state show that body-selective areas, EBA and FBA, possess higher temporal correlations with each other than with the scene-specific area, PPA. This effect is enhanced when participants attend to bodies and hands.

Specifically, in the ‘Attend Body’ condition, the background connectivity between EBA and FBA is very high compared to EBA and PPA. This supports the idea that functional connectivity between brain areas involved in body processing increases in the ‘Attend Body’ condition compared to that between brain areas involved in body and scene processing. Background connectivity between EBA and FBA in both the ‘Attend Hand’ and ‘Attend Body’ conditions were slightly increased compared to resting state connectivity. This shows more functional integration between these two body processing areas when attention was engaged to their preferred category of stimuli compared to integration at rest. Contrary to the prediction, functional connectivity between EBA and FBA in ‘Attend Body’ condition did not show significant enhancement compared to the ‘Attend Hand’ condition. Thus, the data did not provide statistically significant evidence of the proposed hierarchical architecture between EBA and FBA.

Resting state connectivity between two brain areas involved in body processing was slightly higher than that between brain areas involved in body processing and scene processing, providing evidence that intrinsic brain activity reflects the functional architecture of the brain. This finding is consistent with the research that suggests that brain areas involved in similar cognitive functions show correlations in intrinsic activations, even in absence of their preferred task (Biswal et al., 1997). Traditional approaches to studying brain function by neuroimaging methods were strongly driven by the conceptualization of the brain as a system primarily responding to task demands. Numerous studies have focused on such techniques of localization of task-related activations (Downing et al., 2001; Epstein & Kanwisher, 1998). However, recent research has adopted an alternative perspective of resting state that suggests that the brain is active even at rest and is primarily driven by intrinsic activity, with external events modulating the activity of the system (Fox et al., 2005; Kenet, Bibitchkov, Tsodyks, Grinvald & Arieli, 2003). Resting state connectivity has received an immense response from the neuroimaging community over the last two decades, after Biswal and colleagues showed that low frequency BOLD signal can be used to characterize brain functions (Biswal et al., 1995). This study used a seed voxel correlation analysis and found that high temporal correlations exist in low frequency resting state BOLD signals originating from the left motor cortex and other regions that are involved in motor functions (including thalamus and contralateral motor cortex). Not surprisingly, this alternative view gained the interest of various researchers since most of the

brain's energy consumption is in support of intrinsic functional activity (Raichle & Mintun, 2006). Blood flow to the brain during rest is typically just 5–10% lower than during task-based experiments. Thus, resting state connectivity emerged as a powerful tool to provide insight into the function of neural systems, even in the absence of a task that depends on that neural system, and can be observed to infer the functional organization of the brain.

Another question that has intrigued cognitive neuroscientists is that of how functional connectivity is influenced by a cognitive function. In Experiment 1, I explored a similar question: how do attentional manipulations to body parts versus whole bodies influence functional connectivity between EBA and FBA? One problem that is encountered while examining functional connectivity is that the onset of a stimulus tends to correlate the responses of different brain areas even if they do not directly interact. Such spurious correlations cannot be correctly interpreted as functional connectivity. In this study, I used FIR modeling to account for any task-related responses as used in Norman-Haignere et al. (2012). By examining the residuals after modeling task-related responses and other nuisance variables, the background connectivity approach directly probes the relationship between functional connectivity and cognitive processes. This technique gave an insight as to how attention influences functional connectivity in the background of stimulus locked task-related changes. It is to be noted that other techniques that have examined functional connectivity without modeling task-related responses have received criticism (see Poldrack et al., 2011). For example, in the psychophysiological interaction technique (PPI; Friston et al., 1997), in addition to standard general linear model task and seed voxel regressors, additional PPI regressors modeling the interaction between task and timecourse of seed voxels are included. However, highly correlated task and PPI regressors may result in multicollinearity and therefore should be interpreted with caution (see Poldrack et al., 2011). Another problem with PPI is that it assumes that the fit of the hemodynamic function is exact. In case of any misspecification of model, correlation reflects activation-induced effects instead of functional connectivity. Considering these shortcomings, in the background connectivity technique evoked responses were fitted with an FIR model, which makes no assumption of the shape of hemodynamic response function. Thus, the background connectivity technique can be effectively used to investigate functional connectivity in the presence of a cognitive task.

Although research in past twenty years has informed us a great extent about category-selective processing in the human brain, very little attention has been given to the question of how attentional changes can modulate category-selective processing. Most researchers have used face perception as an efficient tool to help investigate this question. Faces are visually complex objects of primary social importance, and humans possess a remarkable ability to encode and remember a large number of different faces. Infants show attention bias to look at faces more than other complex objects (Johnson & Morton, 1991) and perception of faces reveals unique effects, such as the inversion effect (upside-down faces are more difficult to recognize than other complex inverted stimuli; see Farah, Tanaka & Drain, 1995). ERP studies show that faces elicit a higher N170 component compared to objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996), an evidence of enhanced attention to face stimuli. Thus, there is ample evidence consistent with the idea that faces are special and attract attention. Furthermore, neuroimaging studies have found evidence that distinct brain areas respond specifically to faces, and that attention modulates the activity in different areas of the ‘extended face network’ (Fairhall & Ishai, 2007; Haxby et al., 2001). Fairhall and Ishai (2007) used dynamic causal modeling (DCM; Friston, Harrison, & Penny, 2003) to investigate the hierarchical structure between face-selective posterior-lateral and ventro-medial areas, (i.e. OFA and FFA respectively). They found a unidirectional influence of OFA on FFA (see also Pitcher et al., 2011). Similarly, Rotshtein, Vuilleumier, Winston, Driver, and Dolan (2007) also found that several occipital areas, including OFA, send projections to FFA for holistic face processing. Although the focus on functional connectivity studies to investigate the hierarchical organization of the occipital cortex has used the face network profoundly, one recent study has examined functional connectivity in body-selective regions as well. The main objective of this study (Ewbank et al., 2011) was to assess the nature of neural underpinnings of repetition suppression, but their results can also be interpreted in terms of the hierarchical organization between EBA and FBA. Ewbank and colleagues found evidence for differences in the directional influence (effective connectivity) between EBA and FBA; the EBA to FBA connection was modulated only by exact stimulus repetition, whereas the FBA to EBA connection was modulated by repetitions across changes in size and viewpoint. This study hints at a similar cortical architecture as present in face processing but does not provide direct evidence of a hierarchical structure between posterior-lateral EBA and ventro-medial FBA.

Body perception holds an important position in visual processing because human beings are continuously involved in interacting with their own and other bodies. Our own movements are visually guided according to our bodies and we need to process a lot of information about others bodies, such as who they are, what they are doing and how they are feeling. Various researchers have speculated that EBA and FBA extend their role of body perception to additional body-related roles, such as representation of identities, perception of others' emotion, body movements, etc. (Ewbank et al., 2011; Sugiura et al., 2006; Van de Riet, Grezes & de Gelder, 2009). Contrary to this view, Downing and Peelen (2011) suggested that EBA and FBA together create a detailed but unelaborated visual representation of human bodies without determining high level information related to their identities, emotions, body movements, etc. It is likely that EBA and FBA provide the basic perceptual information about the bodies to other areas of the brain that are directly involved in processing identity, emotion and body movements (see Downing & Peelen, 2011). Further research is needed to investigate such an 'extended network' that facilitates such body-related processing. Note that this extended network has been a topic of much research in face processing (see Fairhall & Ishai, 2007). It is likely that functional connectivity between EBA/FBA and areas specific to identity processing (anterior temporal lobes), emotion processing (vmPFC, amygdala, OFC), and body movements (hMT+) might be influenced by attention to the respective aspect of the body. For example, background connectivity between body selective regions and anterior temporal lobes and amygdala might be selectively modulated by attention to identity and emotions of the bodies respectively. Such studies will give a complete view of how body perception and other related processes are accomplished.

In summary, this study was novel in terms of use of resting state and background connectivity to examine the hierarchical architecture of occipito-temporal cortex. Although strong conclusions cannot be made because of a small sample size, the trends support the intrinsic architecture to accomplish body-selective processing and influence of attention on the functional connectivity between body-selective brain areas.

Chapter 3: Attention and Mood

Until the last two decades, attention was typically considered to be a cognitive process that was strictly perceptual and did not have any consequences related to emotion or motivation processes. Traditional approaches to studying cognition emphasized the information processing view of attentional processing which generally excluded emotion. But recent research has proven that attention has emotional and motivational consequences. This part of the thesis focuses on how attention influences the intermediate stages of cognition when it interacts with emotional information and results in mood-related changes. Mood has a crucial role in determining human behavior. It impacts the way human beings attend to and interact with the surroundings. Yet, the cognitive mechanisms that can affect mood are less understood. Given the importance of mood on overall health and wellbeing and the potential role of attention in enhancing mood, this section of the thesis investigates the effects of manipulations of attention on mood.

Mood and its impact on cognition

Mood influences almost all aspects of cognitive processing. Positive mood has shown to improve cognitive flexibility, inclusive categorization, creativity, openness to information, and facilitation of unusual word associations (Isen, 2004). Individuals in positive moods, compared with those in negative moods, describe autobiographical events using more abstract, global representations (Beukeboom & Semin, 2005). It has been found that positive mood broadens the scopes of attention, cognition and action (Fredrickson & Branigan, 2005; Gasper & Clore, 2002). Mood not only affects cognition but also promotes well-being. High levels of positive mood states are associated with higher income, more successful social interactions, and a longer life span (Lyubomirsky, King, & Diener, 2005). Mood influences both mental and physical health. Mood dysfunctions are directly related to depression, anxiety, cardiovascular diseases and addiction. Given the importance of mood for healthy cognitive functioning and overall well-being, it is important to understand how mood changes influence cognitive processing, and how cognitive processing can be manipulated to enhance mood.

Research in the last two decades has provided ample evidence about the influence of mood states on the focus of attention (Derryberry & Reed, 1998; Easterbrook, 1959; Fredrickson, 2001; Fredrickson & Branigan, 2005; Gable & Harmon-Jones, 2008; Rowe, Hirsh, & Anderson,

2007). Effects of positive and negative mood states on the focus of attention have been examined by using a global–local visual processing paradigm (Kimchi & Palmer, 1982; Navon, 1977) or an Eriksen flanker task (Eriksen & Eriksen, 1974). Participants in a positive mood state tend to make similarity judgments based on global information, whereas participants in negative mood states tend to make similarity judgments based on local information (Basso et al., 1996; Gasper & Clore, 2002). Positive mood also results in greater flanker interference, compared to both sad and neutral mood states, indicating more interference from flankers due to broad focus of attention in induced positive mood (Rowe, Hirsch & Anderson, 2007). Researchers have also stressed the effect of negative mood states on the focus of attention (see reviews, Easterbrook, 1959; Wells & Matthews, 1994). Negative mood states, such as anxiety and fear, result in narrow focus of attention, popularly known as “weapon focus” (Loftus, Loftus & Messo, 1987). Thus, positive and negative mood states have been related with an opposing effect on the focus of attention.

Mood states are usually described using the dimensions of valence and arousal. Researchers differ in their view of labeling the dimensions. While Barrett and Russell (1999) used "pleasure-misery" and "sleep-arousal" labels, Russell, Weiss, and Mendelsohn (1989) used "pleasant-unpleasant" and "sleepiness-high arousal" labels. But almost all researchers agree that an interaction of valence and arousal govern mood states and mood can be described in terms of valence (positive and negative), and arousal (low and high). Valence refers to positive or negative affect and arousal refers to feeling activated or deactivated. While sadness is considered to be negative and low arousal, happiness is considered to be positive and low arousal. On the other extreme is anger, which is negative and high arousal and ecstasy, which is positive and high arousal. Interestingly, the interaction of valence and arousal has different impacts on focus of attention. Individuals who are sad or depressed tend to process the finer details of a scene at the expense of gist, while individuals in happy mood tend to focus on the gist at the expense of details (Gaspar & Clore, 2002; Huber, Beckmann, & Herrmann, 2004).

Neuroimaging studies have also supported the behavioral results (Moriya & Nittono, 2011; Schmitz, Rosa & Anderson, 2009). Positive, neutral, or negative mood state was induced by presentation of affective pictures and scope of attention was assessed with a flanker task. The participants' task was to respond to the central target letter by pressing a button. Spacing

between each letter was manipulated so that it appeared either near or far. Reaction time data showed that the effect of spacing on the flanker compatibility effect was absent under positive mood state. ERP data provided additional support to the behavioral data where evoked P1 component, which reflects early sensory processing, was found to be larger in the positive mood state than in the neutral and negative mood states (Moriya & Nittono, 2011). Schmitz, Rosa and Anderson (2009) performed an fMRI study to investigate the interaction between mood states and scope of attention. Positive, neutral, and negative states were induced on alternating blocks of trials. Participants then viewed pictures of face/place concentric center/surround stimuli on alternate blocks. Central faces were attended, rendering the surrounding place unattended. Face and place information was presented at different visual eccentricities and place processing in the parahippocampal place area (PPA) was recorded as an index of scope of attention. Results showed that positive affective states increased and negative states decreased PPA response, thus strengthening the view that positive and negative affective states have opposing effects on focus of attention.

Although there is ample research evidence that mood state affects the focus of attention, and the bidirectionality between attention and mood has been implied in several psychological literatures, none of the research, to the best of my knowledge, has measured the influence of broad versus narrow focus of attention on mood state. This direction of influence (broad focus of attention resulting in improved mood) could have profound implications for the treatment of mood disorders. The next section will outline the cognitive neuroscience findings that hint at the bidirectionality of this effects and predictions about how attention can play a role in improving mood.

Cognitive neuroscience underlying the interaction between mood and attention

Over the last two decade there has been a rapid advancement in neuroimaging techniques that have provided information about the cognitive neuroscience of mood disorders. Studies in patients with mood disorders, such as major depression, have identified structural and functional abnormalities in various brain regions (Drevets, 2003; Holthoff et al., 2004; Sheline, 2003). These regions include the hippocampus, amygdala, anterior cingulate, thalamus, ventromedial- and dorsomedial- prefrontal cortex and subgenual cingulate cortex. Interestingly,

some of these areas are part of the default mode network (DMN) – task negative brain areas that are activated at rest and deactivated in the presence of cognitively demanding tasks (Greicius, Krasnow, Reiss & Menon, 2003; Raichle et al., 2001). The discovery of this brain network was a result of meta-analyses that investigated the functional anatomy at resting state. Mazoyer and colleagues (2001) and Raichle and colleagues (2001) independently conducted meta analyses of several studies to explicitly determine if there were common brain regions active during rest or passive mental states. These meta-analyses revealed a remarkably consistent set of brain regions that were more active during rest as compared to during numerous cognitive tasks. The DMN consists of hubs in the ventromedial and dorsomedial prefrontal cortex, posterior cingulate cortex, and inferior parietal and lateral temporal regions, including hippocampal formation (Buckner et al., 2008). Note that hyperactivation of these areas have been reported in mood disorders (Drevets, 2003; Sheline, 2003).

Conversely, attention-demanding tasks activate a task-positive network that is also found to be active during rest in an anti-correlated manner with the DMN (Fox et al., 2005; Fransson, 2005). During performance of attention-demanding cognitive tasks, two opposite types of responses are commonly observed. A specific set of frontal and parietal cortical areas demonstrate increased activation (Cabeza & Nyberg, 2000; Corbetta & Schulman, 2002), whereas activity in DMN decreases (Gusnard & Raichle, 2001; Simpson, Snyder, Gusnard & Raichle, 2001). As the attentional demands of the task increase, this dichotomy becomes more pronounced; activity in task-positive regions is further increased (Wojciulik & Kanwisher, 1999), whereas activity in negative regions is further decreased (McKiernan, Kaufman, Kucera-Thompson & Binder, 2003). Reduction of activity in the DMN during cognitively demanding tasks can be interpreted as reflecting the need to attenuate the brain's self-referential activity as a means of more effectively focusing on the task. Buckner et al. (2008) suggested that these anti-correlated networks compete with one another for control of information processing within the brain. A failure to appropriately engage in attention processing might lead to interference in task performance from internal emotional states, as seen in patients with depression. Additionally, attention-based meditation has been shown to increase left-sided anterior activations associated with increase in positive mood and reduction in anxiety and negative mood state (Davidson et al., 2003). Thus, improving attentional processing might be the key to better mood. Attentional processing has been traditionally seen as a cold cognitive process, which is distant from any

emotional and motivational consequence, but recent evidence from psychological studies have hinted at affective consequences of attentional processing. The next section will provide further evidence of such a relationship.

Reciprocal interactions between attention and emotion

Research in the past decade has shown a rapid growth of literature providing evidence of a reciprocal relationship between attention and emotion processing (Fenske & Eastwood 2003; Gasper & Clore, 2002; Raymond, Fenske & Tavassoli, 2003; Srinivasan & Hanif, 2010). Emotional information influences focus of attention. Fenske and Eastwood (2003) used a flanker task to investigate the influence of happy and sad emotional information on the focus of attention. They found flanker interference with schematic happy faces but not with schematic sad faces suggesting that happy and sad faces are associated with broad and narrow scope of attention respectively, thus demonstrating that emotional information influences the scope of attention. Interestingly, not only emotion affects attention, but attention also influences emotion (Raymond, Fenske & Tavassoli, 2003; Srinivasan & Hanif, 2010). Raymond, Fenske, and Tavassoli (2003) showed that selectively attending or ignoring an affectively neutral visual stimulus influences its subsequent affective evaluation. Recent work from our lab has provided evidence that applying attentional inhibition can even decrease the affective evaluation for highly salient stimuli (Ferrey, 2012). My Masters-thesis research (Srinivasan & Hanif, 2010) also demonstrated that broad and narrow attentional focus results in faster recognition of happy and sad faces, respectively. Thus, ample research evidence shows that attentional manipulations influence emotion processing. But are these effects of attentional manipulation confined to emotion processing of particular stimuli or can this effect extend to influence the mood as well? Given the anti-correlated attention and default mode networks and affective consequences of attention, it seems likely that attention should impact mood.

Broad focus of attention has been shown to be related with adaptive attentional functioning, cognitive flexibility, and positive emotion (Oliver & Nieuwenhuis, 2005). Recent work from Moshe Bar's lab (Bar, 2009; Mason & Bar, 2012) also support the view that mood dysfunctions are a result of narrow thought processing and engaging in broad associative processing might lead to improvements in mood. It is expected that a broad focus of attention

will result in improvement in mood. Interestingly, mood-related attentional bias manipulations have been shown to improve mood. For example, depressed patients show attentional preference to negative information and reduced attention to positive information. Recent studies used attentional training to reduce attention to negative information and increase attention to positive information (Baert, De Raedt, Schacht & Koster, 2010; Siegle, Ghinassi & Thase, 2007). Such attentional training showed mild improvements of mood in patients at risk of developing depression. It is to be noted that these attentional manipulations tasks used emotional information and were not purely cognitive in nature. But in order to investigate the role of attention in improving mood, it is essential that we employ attentional manipulations in cognitive domain and observe its influence on mood. To the best of my knowledge, no study has experimentally manipulated the focus of attention in purely cognitive domain to observe its effects on mood. One experiment was conducted to provide a novel investigation of attention mechanisms to enhance mood. It was predicted that inducing a broad focus of attention will improve mood.

Experiment 2

This experiment manipulated the focus of attention to broad-, narrow- and neutral-focus using hierarchical stimuli (see Figure 7). A within-subject design was used where baseline mood was assessed using an affect grid (see Figure 8; Russell, Weis & Mendelsohn, 1989) and individual differences in attentional focus were assessed using a global precedence task (Navon, 1977). Participants performed attentional manipulation tasks and the order was counterbalanced for each participant. Participants were given mood assessment at the end of each attentional manipulation task. It was expected that participants will have a better mood after performing a broad-focus task as compared to baseline, narrow- and neutral-focus.

Methods

Participants

Forty-three (26 women; mean age 20.1) University of Guelph introductory psychology students took part in the experiment in exchange for course credit. All participants had normal or corrected to normal vision. Informed consent forms were obtained in compliance with procedures set by the University of Guelph Research Ethics Board.

Stimuli

For the global precedence task, which served as a measure of individual differences in attentional focus or dispositional biases to attend to global or local information, hierarchical Navon-type letter stimuli were used. The global and local levels of these stimuli were either congruent (e.g., a big 'H' composed of small 'H's) or incongruent (e.g., big 'H' made of small 'S's). A different set of hierarchical stimuli was used to induce a broad or narrow focus of attention in the attentional manipulation task. These stimuli were shapes (triangle, square, circle, diamond) instead of letters, and they were always incongruent (e.g., a large triangle composed of small squares). For all hierarchical stimuli, the global level of the stimuli measured approximately 7.2cm X 7.2cm and the local level approximately 0.9cm x 0.9cm. Two separate pilot studies were conducted to ensure that these stimuli lacked global or local precedence and were equivalent in terms of task difficulty. For a neutral-focus control condition, a set of non-hierarchical shapes measuring approximately 2.94cm X 2.94cm in size were used. Compared to the hierarchical stimuli, these control items were smaller than the global dimension, larger than the local dimension, and lacked any global-local interference (Figure 7 (Note that the same stimuli will be used in Experiments 3 and 4)). All stimuli were black presented on a white background at a viewing distance of 60 cm.

Design & Procedure

Participants first completed the global precedence task. There were four alternating blocks (24 trials each) in which participants identified either the big letter (requiring global processing), or the small letter (requiring local processing) of the hierarchical stimuli. In each block, congruent and incongruent stimuli were presented with equal probability, for 200 ms each, followed by a blank screen until response. Participants made speeded key presses (H or S) to identify the target letter. Participants were then asked to rate their mood at that point in time. An affect grid (Russell, Weis & Mendelsohn, 1989) was used to assess the mood of the participants. It was a 9X9 grid. The x-axis of the grid was labeled for valence, from unpleasant to pleasant. The y-axis was labeled for arousal, from high arousal to low arousal or sleepiness. Participants were also asked to rate their overall mood on a scale of 0 to 100. Zero represented extremely negative, and one hundred represented an extremely positive mood.

Participants were then given a Broad-focus, Neutral-focus or Narrow-focus attentional manipulation task. The order of this task was counterbalanced between subjects. Each trial started with a fixation cross for 500ms, followed by the hierarchical stimuli for 200ms, followed by blank screen. The participants were asked to identify either the big shape (for Broad-focus task), or the small shape (for Narrow-focus task), or to identify the shape (for Neutral-focus task). Participants identified the target shapes by pressing keys 'N' or 'M' (labeled as 'circle' and 'triangle': Broad-focus task), keys 'V' or 'B' (labeled as 'square' and 'diamond': Narrow-focus task), or keys 'N', 'M', 'V' or 'B' (labeled as 'circle', 'triangle', 'square' and 'diamond': Neutral-focus control group). In the neutral-focus task, each participant identified either between circle and triangles or between squares and diamonds.

Participants completed the mood ratings at four time points: After the global precedence task, Broad-focus, Neutral-focus or Narrow-focus attentional manipulation task.

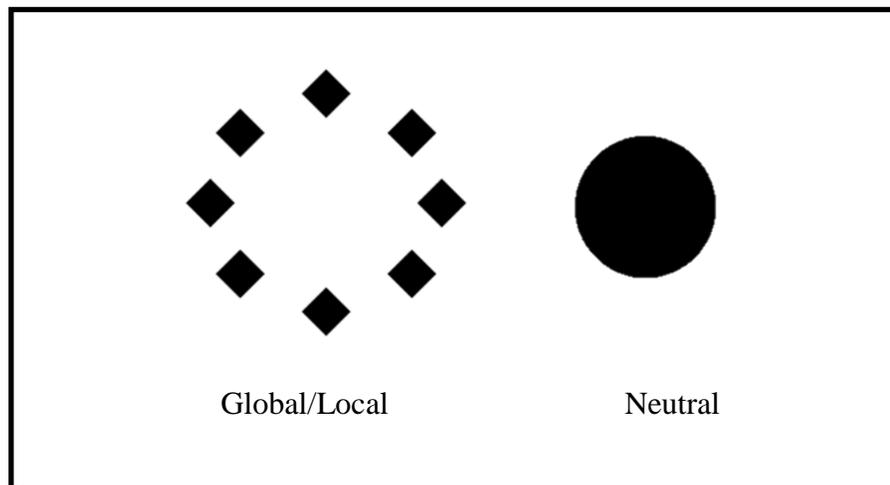


Figure 7. Hierarchical stimuli used in Experiments 2, 3 and 4

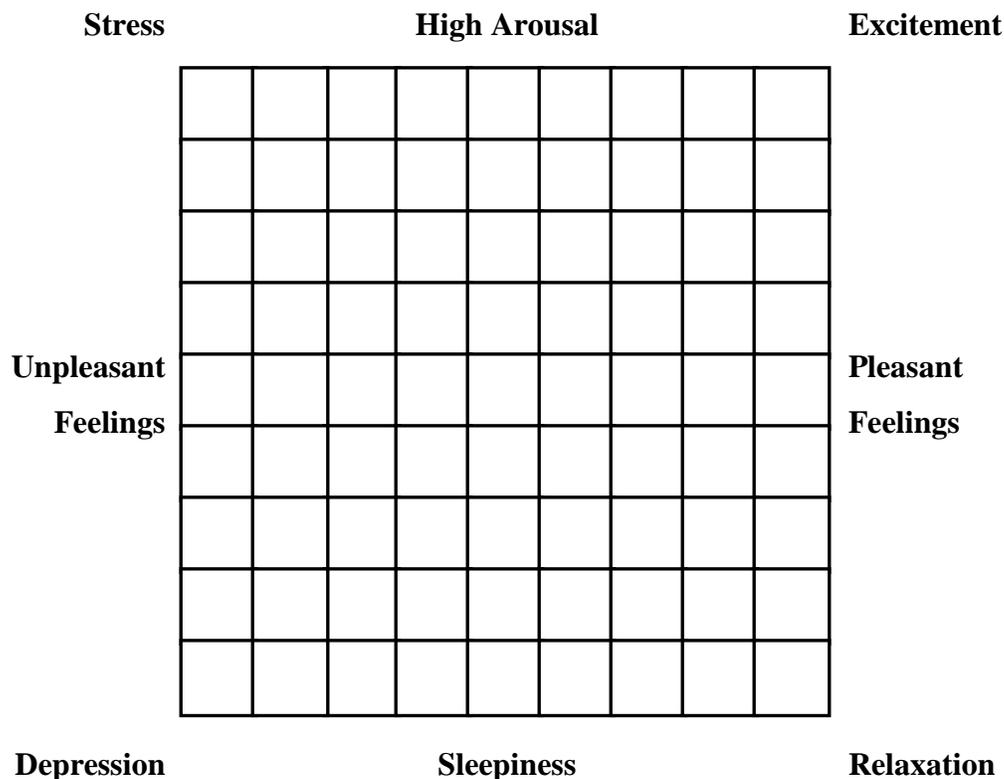


Figure 8. Affect grid. Horizontal scale represents valence and vertical scale represent arousal

Results

Mean reaction time (RT) and accuracy to identify the target served as dependent measures for the attentional manipulation tasks; the affect grid provided valence and arousal scores before and after the attentional manipulation tasks, which served as a measure of change in mood.

For the global precedence task, global precedence scores were computed by subtracting local interference scores (i.e., global-congruent RT minus global-incongruent RT) from global interference scores (i.e., local-congruent RT minus local-incongruent RT). There was no significant correlation between global precedence scores and baseline valence, and arousal, and overall mood ratings, respectively (i.e. individual differences in global/local processing did not

influence baseline mood). To rule out the influence of task difficulty on mood, reaction time and accuracy performance on Broad-, Narrow-, or Control- attentional manipulation tasks were analyzed. There was no significant difference between RT ($F(2,43)=1.49$; $p= 0.23$) and accuracy ($F(2,43)=1.68$; $p= 0.19$) for identifying global and local targets (See Table 2). The main dependent measures were the valence scores, arousal scores, and overall mood ratings before and after attentional manipulation tasks, referred to as baseline and post-task mood respectively. Valence score was calculated by counting the column checked from left side. Lesser values indicated ‘Unpleasant valence’ and higher values indicated ‘Pleasant valence’. Arousal score was calculated by counting the row checked from bottom. Lesser values indicated ‘Less activated or sleepiness’ and higher values indicated ‘Highly activated or aroused’. Overall mood rating was the self-report measure on a scale from 0 to 100. Although there was no significant enhancement by Broad-focus task, as revealed by the post-task measures of valence, arousal and overall rating as compared to the baseline (all p 's >0.05), Broad-focus resulted in enhancement in post-task valence and arousal when compared with Narrow-focus task (both p 's $<.01$). However, the overall mood rating did not show a significant effect ($t(43)=1.79$; $p=.07$). See Figures 9, 10 and 11. Valence score after performing the Broad-focus task was slightly better than after performing the Neutral-focus task ($t(43)=1.79$; $p=.08$). The arousal score after performing the Broad-focus task was significantly better than after performing the Neutral-focus task ($t(43)=2.22$; $p=.03$). Overall mood rating after performing the Broad-focus task was also significantly better than after performing the Neutral-focus task ($t(43)=2.97$; $p=.005$).

Discussion

This experiment was conducted to investigate the influence of attentional manipulations on mood. Consistent with the expectations, Broad-focus induced by global processing resulted in a better mood as compared to Narrow- and Neutral-focus. Although there was no significant enhancement of valence and arousal by Broad-focus task as compared to the baseline mood, Broad-focus indeed resulted in enhancement when compared with Narrow-focus and Neutral-focus task. On the other hand, Narrow-focus of attention seemed to impair mood. It is important to note that most of the cognitive experiments that involve a certain amount of self-sustained attention to be engaged in task results in boredom in participants and lead to a slightly negative

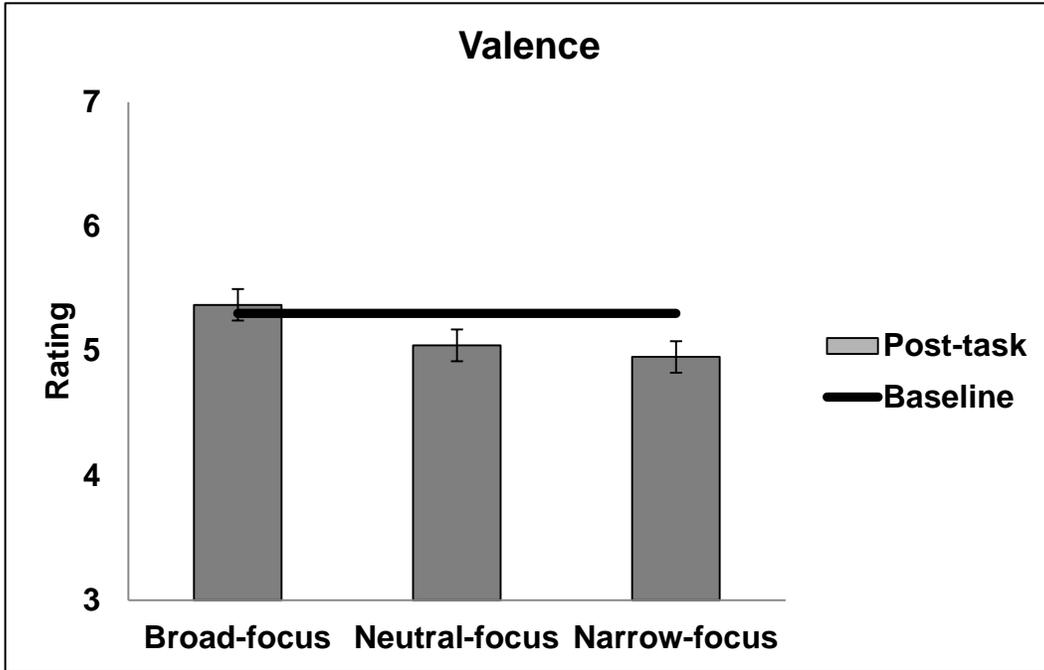


Figure 9. Valence ratings in Experiment 2. The rating scale was 1 to 9 with higher ratings indicating higher positive valence and better mood.

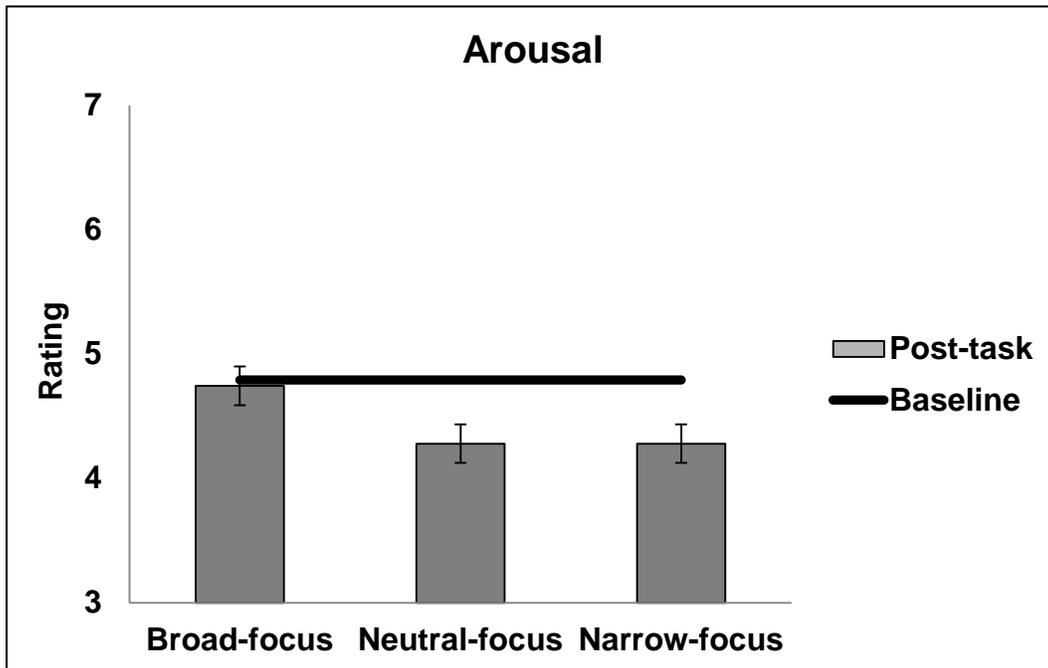


Figure 10. Arousal ratings in Experiment 2. The rating scale was 1 to 9 with higher ratings indicating higher arousal and better mood.

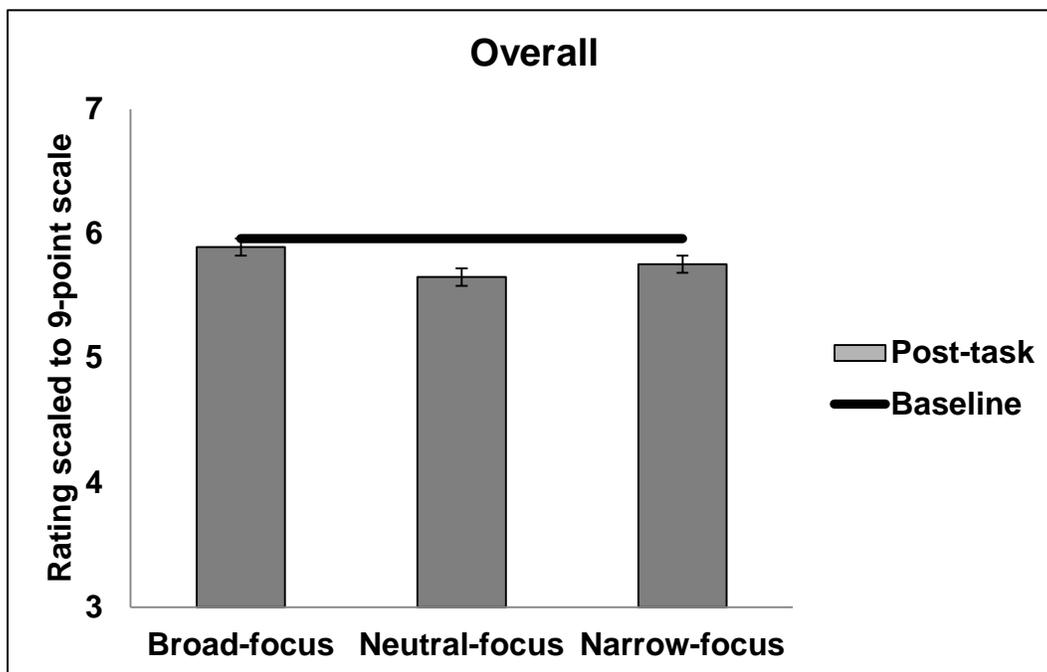


Figure 11. Overall ratings in Experiment 2. The rating scale was 0 to 100 with higher ratings indicating better mood. Here the ratings are scaled to a 1 to 9 scale for comparison with other graphs.

Table 2. Means and standard deviations (in parentheses) for the mood and attention task in Experiment 2.

		Baseline	Broad-focus		Neutral-focus		Narrow-focus	
Mood	Valence	5.3(1.83)	5.37(1.36)		5.05(1.66)		4.95(1.52)	
	Arousal	4.79(1.71)	4.74(1.74)		4.28(1.62)		4.28(1.66)	
	Overall rating	66.21(15.71)	65.47(15.1)		62.79(16.12)		63.93(15.47)	
Attention task			RT	Accuracy	RT	Accuracy	RT	Accuracy
			690.19(68.38)	96.23(2.77)	674.97(93.75)	95.28(4.17)	667.43(84.55)	95.72(2.97)

mood (Eastwood, Frischen, Fenske & Smilek, 2012), which is seen in Neutral- and Narrow-focus tasks. Boredom is caused by a failure of attentional processes to focus and engage attention and is associated with negative mood. It is likely that when participants engage in Neutral- and Narrow-focus tasks, the demands of being engaged in a task that requires self-sustained attention and internal motivation caused negative mood. Interestingly, the Broad-focus task surpassed this impact and resulted in a better mood. The results support the earlier findings linking positive mood and broad focus of attention as well as negative mood and narrow focus of attention (Frederickson, 2001; Frederickson & Branigan, 2005; Gasper & Clore, 2002). These findings provide the first evidence of enhancement of mood with changes in focus of attention. It is to be noted that most studies on mood and attention have shown that mood states influence the focus of attention, but to the best of my knowledge this is the first study that has shown a reciprocal effect. The results show that inducing a broad or narrow focus of attention impacts the mood state. Both valence and arousal are influenced by manipulation of focus of attention. The results provide a novel finding that efficiently distributing attention in a broad focus might enhance mood.

The levels-of-focus hypothesis (Clore & Gasper, 2000) showed that in task situations, cues from happy and sad moods might be experienced as information that promotes attention to global and local information, respectively. I propose that a reciprocal effect also exist, wherein global and local information might also act as affective information, resulting in changes in mood. Attention networks and DMN are anti-correlated and compete with each other to influence information processing (Buckner et al., 2008). Efficient attentional processing achieved by broad scope of attentional focus will decrease activity in DMN. Additionally, hyperactivity of DMN is associated with mood dysfunctions (Sheline, 2003). Thus, efficient attentional processing enhances mood state by attenuating the activity of DMN.

Successful allocation of attention by global processing yields fluent information processing by reducing interference from local information. As Navon's (1977) classic work demonstrated, people have a default tendency to perceive and rely upon global information rather than local information. Global information tends to be naturally dominant both perceptually (Navon, 2000) as well as conceptually (Fiske & Taylor, 1991). In impression formation studies, individuals have a predispositional tendency to rely on categorical information as a basis for their

judgments (Brewer, 1988; Fiske & Neuberg, 1990). Such a tendency increases with better mood states and individuals in a sad mood rely on more detailed behavioral information (Isbell, 2004). Thus, inducing a broad focus of attention with global processing put individuals in a more naturally dominant or 'fluent' state that might induce ease of processing of incoming information. Furthermore, fluency of information processing has been shown to induce positive mood states. Studies suggest that easier and faster information processing elicits a more positive mood, as indicated by self-report, and by signs of smiling in the zygomatic muscle (Winkielman & Cacioppo, 2001). Thus, a broad focus of attention induced by global processing puts an individual in a fluent state that results in positive mood.

Global processing is accompanied with less inhibition from the non-dominant local dimension. On the other hand, local processing is accompanied with more inhibition exerted by the dominant global dimension. Inhibition is related to negative affect. It is to be noted that impaired inhibition of negative emotional information is an important cognitive component of depression (Goeleven, De Raedt, Baert & Koster, 2006) and depressed individuals show reduced activations in ACC, the brain area responsible for inhibition (Rogers et al., 2004). Thus, a narrow focus of attention leads to worse mood than broad focus of attention due to high inhibition induced by local processing. Broad attentional focus also prevents narrow attention or "rumination", a hallmark of mood disorders, by directing attention away from narrow negative thought processing and helps to gain a broader perspective.

The relationship between attention and mood has been implicated in various fields of research, but few studies have investigated the impact of attentional manipulations on mood in the laboratory settings. Studies on clinical populations with mood dysfunctions have indicated that negative mood states in such populations are a result of poor attentional processing. Depressed individuals show high self-directed attention and persistent narrow attention on negative thoughts or "rumination" (Gross, 1998). They are also slower to disengage their attention from any stimuli while engaged in a stress task (Ellenbogen et al., 2006). A deficit in inhibition of irrelevant information is considered as a "cognitive vulnerability factor" for causing depression (Joormann, 2007). Mood disorders are accompanied with deficits in the brain regions associated with attentional control and hyperactivations in the brain regions associated with emotion processing. PET and fMRI studies have reported decreased activation of cortical regions responsible for attentional control (dorsolateral prefrontal cortex and anterior cingulate cortex) in

depression (Drevets et al., 1997; Ketter, George, Kimbrell, Benson & Post, 1996). Conversely, increased activation of emotion related limbic regions such as the medial thalamus, pallidostriatum and amygdala (Drevets 2000; Mayberg et al 1999; Sheline et al., 2001; Siegle et al., 2002) have been reported in depression. Depression may be caused by the disruption of the cortical-subcortical pathway resulting in decreased attentional control on the limbic areas (Mayberg et al., 1999). These studies support the idea that successful engagement of attention related brain areas might be a key to healthy emotional functioning and positive mood. Wells (1990) developed the attentional training (ATT) program for patients with mood dysfunctions. This task trains individuals to reallocate their attention from emotional to neutral information processing through the use of three auditory tasks. By training selective attention, divided attention, and attention shifting mechanisms, participants with depression and anxiety showed improvements in their mood states (Papageorgiou & Wells, 2000; Siegle, Ghinassi, & Thase, 2007). Interestingly, these attentional training tasks are 'cue-specific' i.e. training to draw attention away from negative cues and towards positive cues results in enhancement of positive mood but the results of experiment 2 show that fundamental and cue-invariant attentional processes may be useful in enhancing mood. Additionally, mindfulness-based cognitive therapy which combines cognitive therapy with mindfulness techniques, has also been successfully used as an intervention to reduce relapses in recurrent major depression (Segal, Williams & Teasdale, 2002). Bishop et al. (2004) explained that mindfulness involves components of sustained attention, attentional switching, and cognitive control. Thus, efficient attentional mechanisms can be used as means of improving mood states in clinical population. This study lays a promising foundation for testing the possibility that simple attention-based interventions that enhance the focus of attention may be useful for enhancing mood.

Chapter 4: Attention and self-regulation

How do human beings manage to act in line with their high priority goals when faced with tempting yet conflicting alternatives? How do we make a decision of passing an offer of chocolate cake to stay on a diet plan? Self-regulation is the ability to override such competing urges or behaviors and focus on the goal relevant behavior (Baumeister & Heatherton, 1996). Self-regulation has a wide range of behavioral implications and is related to success in many aspects of life. Failure of self-regulation results in various maladaptive behaviors, including drug abuse, obesity and academic underachievement (Muraven, Collins, & Nienhaus, 2002). Additionally, children who show higher self-regulation abilities deal with stress better as adolescents and receive higher SAT scores when applying to college (Shoda, Mischel, & Peake, 1990). Self-regulation is typically described in abstract terms regarding the application of willpower or balancing the cost of short-term gratification against the benefit of achieving long-term goals. Emerging evidence, however, suggests that attention may provide specific cognitive mechanisms that mediate self-regulation (e.g., Baumeister & Heatherton, 1996; Rueda, Posner & Rothbart, 2005). The main objective of this section of the thesis is to investigate the effects of manipulations of attentional processing on self-regulation.

What is self-regulation?

Self-regulation is the ability to deal with conflicting situations by focusing on the goal relevant behavior and inhibit any cues related to the goal irrelevant and maladaptive behavior (Baumeister, Heatherton & Tice, 1994). In a series of experiments, popularly known as “the marshmallow test”, Mischel and colleagues demonstrated the phenomenon of self-regulation in pre-school kids (Metcalf & Mischel, 1999; Mischel, Shoda, & Rodriguez, 1989). In this paradigm, a young child is shown a desired treat, such as a marshmallow, but asked to wait until the experimenter returns and get two of the desired treats. Children are also given an option to ring a bell, in which case the experimenter comes back immediately– but then only one treat will be obtained. Findings from such experiments have shown that attention to the motivational stimuli drives an individual to immediate goal response. On the other hand driving attention to long-term benefits or distraction serve as a better self-regulatory strategy. For example, priming children to think about pleasant, distracting thoughts while waiting (i.e., “if you want, while

you're waiting, you can think about Mommy pushing you on a swing'') increased children's ability to self-regulate greatly. In contrast, cuing children to think about the maladaptive rewards (i.e., "think about how sweet and chewy the marshmallows would be in your mouth") made it almost impossible for most preschoolers to wait (Mischel et al., 1989). Another related phenomenon, known as "delay discounting", is found in behavioral economic studies (Rachlin, Ranieri & Cross, 1991). People discard big future rewards, for example \$4000 in four years, and choose less valuable immediate rewards, for example, \$1000 now. A common feature of these studies is that people respond to maladaptive short-term goals and disregard adaptive long-term goals.

Various researchers have proposed different theories about the nature of self-regulation. One of the most influential models of self-regulation is the strength or limited resource model (Baumeister & Heatherton, 1996). The strength model suggests that all acts of self-regulation depend on a limited mental resource and consecutive exertions of self-regulation are characterized by deteriorating performance. For example, suppressing forbidden thoughts about a 'white bear' leads to a tendency to give up quickly on a task that requires persisting on unsolvable anagrams (Muraven, Tice & Baumeister, 1998). Likewise, people who had to resist the temptation to eat chocolates and cookies and were asked to eat radishes subsequently gave up faster on difficult puzzles (Baumeister, Bratslavsky, Muraven, & Tice, 1998). This decrease in self-regulation performance is known as 'ego depletion'. Additionally, the strength model also suggests that the resource can be restored with rest and possibly other mechanisms, and that regular exercise can increase strength over the long term. Thus, it is suggested that although exercising self-regulation results in reduction of the person's capacity for more self-regulation, it is beneficial in the long run. Muraven, Baumeister, and Tice (1999) found that individuals who exerted self-control over their eating habits or who regulated their posture for two weeks performed better on a task that required overriding physical discomfort. Recently, Muraven (2010) also found that participants who were trained to exert self-regulation by cutting back on sweets or squeezing a handgrip exerciser exhibited significant improvement in another task assessing self-regulation relative to those who practiced tasks that did not require self-regulation. These results suggest that self-regulation is dependent on a limited mental resource that can be diminished by immediate acts of self-regulation but replenished by practicing small acts of self-regulation over time.

Another theory of self-regulation is the willpower theory. According to the willpower theory, the abilities to self-regulate can be compared with the abilities of willpower, a strength or energy that people use to bring about the changes that they seek in their behavior (Mischel & Ayduk, 2004). The “hot/cool model of willpower” (Metcalf & Mischel, 1999) suggests that motivational “hot” cues about a desired object activate arousal, driving individuals to the immediate goal response and informational “cool” cognitive cues about the stimulus, on the other hand, serve to direct attention to maladaptive aspects of the situation, thus facilitate self-regulation. Additionally, Construal level theory for self-regulation (Fujita & Han, 2009) suggests that high-level construals (subjective mental representations that capture the abstract features of events or situations) lead to greater self-regulation than low-level construals (representations that capture concrete features of events or situations). Goal-directed signals can be mentally represented, or construed, in numerous ways. Given a question about “why” one engages in a behavior activates more abstract representations or high-level construals. Conversely, questions about “how” one engages in a behavior activate concrete or low-level construals. These mental representations or construals can have different implications on behavior. Fujita and Han (2009) found that promoting high-level construals enhance self-regulation, as compared to low-level construals, i.e. answering questions about “why” one should maintain a healthy diet keeps one focused on a diet plan rather than answering questions about “how” one should maintain a healthy diet.

These social psychology theories of self-regulation have greatly overlooked the cognitive processes that might influence self-regulation. Little is known about the specific cognitive processes that impact self-regulation. The next section will cover the proposed role that attention might play in enhancing self-regulation.

What role might attention play in enhancing self-regulation?

Self-regulation can be considered as a “battle in the brain” that arises due to competing representations that contest with each other to influence behavior. Recent evidence suggests that such a “battle” between goal-relevant and goal-irrelevant information results in goal directed or self-regulatory behavior (Hofman, Schmeichel & Baddeley, 2012; Knudsen, 2007). Increase in potential reward associated with a particular stimulus or response option results in increased

activity in brain regions such as the ventral striatum and ventral-medial prefrontal cortex (Botvinick, Huffstetler, & McGuire, 2009; Leotti & Delgado, 2011). The likelihood that behavior will be directed toward the associated stimulus increases with an increase in the reward associated with it (Iketmoto & Panksepp, 1999). Meanwhile, activity in other brain regions, such as areas of the dorsal anterior cingulate and dorsal striatum, varies with the anticipated effort and other costs associated with the pursuit of such a stimulus (Kurniawan et al., 2010). Such competing neural representations have been shown to have mutually suppressive effects, (i.e. activity associated with effort and cost decreases with the increases in relative salience of potential reward) (Walton, Kennerley, Bannerman, Phillips & Rushworth, 2006). Thus, any cognitive mechanism that can enhance the strength of a behavioral signal can effectively bias the competition in its favour, making it more likely to ultimately guide behavior.

Attention is a leading candidate for this role. Attention biases the flow of information so that salient and relevant information is prioritized while processing of irrelevant or distracting information is reduced (Desimone & Duncan, 1995). Attention is believed to channelize strategic, goal-directed neural signals originating in regions such as lateral prefrontal cortex to bias the competition in other brain regions to favour, and thereby enhance the activation of, task-relevant representations (Desimone & Duncan, 1995). As goal-relevant neural activity is enhanced, activity related to distracting and potentially conflicting representations is reduced (Kastner & Ungerleider, 2000; Tsotsos et al., 1995). Likewise, self-regulation also involves focusing on accomplishing the goal behavior while overriding competing urges or behaviors (Baumeister & Heatherton, 1996). It can only be successful if representations relevant to maintaining the strategic goal win the neural competition over those that would otherwise undermine self-regulatory efforts. Biasing the competition between these conflicting signals in favour of strategic goals can therefore increase the likelihood that adaptive cues guide behavior. Hare, Malmaud, and Rangel (2011) showed that when participants focus their attention on the health aspects of food choices, they improve their dietary choices. It is also associated with the modulation of stimulus-value signals in the ventral-medial prefrontal cortex by activity in the dorsolateral prefrontal cortex. Additionally, Cohen and Lieberman (2010) provided evidence that ventro-lateral PFC is involved in different forms of self-regulation, such as motor inhibition, memory inhibition, temporal discounting, emotional regulation, risk taking etc. It is to be noted that ventro-lateral PFC is a key region involved in attentional control and inhibition (Garavan,

Ross, Murphy, Roche & Stein, 2002). These findings suggest that attentional control is essential in mediating the success of self-regulatory efforts.

Empirical evidence for a relationship between attention and self-regulation also comes from a number of recent studies showing that attentional control is correlated with self-regulation (Rueda et al., 2005). Conversely, breakdowns of self-regulating behavior are often associated with limited attentional abilities. For example, adolescents with limited attentional abilities are found to be at risk for developing problematic alcohol and drug abuse (Tapert, Baratta, Abrantes, & Brown, 2005). Furthermore, activity in the anterior cingulate cortex (ACC), which engages attentional control mechanisms, interacts with brain structures involved in evaluating the emotional-motivational significance of stimuli, including the insula, amygdala, and nucleus accumbens. This integration of emotionally significant signals with attentional control signals in prefrontal cortex thus facilitates emotional regulation, one of the processes involved in successful self-regulation (Pessoa, 2009). Heatherton and Wagner (2011) also proposed that a disconnection in such cortical-subcortical interaction results in self-regulation failure. Thus, the ability to effectively control attention (i.e., selectively allocating one's attention to task-relevant concerns and inhibiting irrelevant information and inappropriate responses) may be a key factor for successful self-regulation. However, very little is known about the specific mechanisms through which attention influences self-regulation. In the next section, I propose two cognitive mechanisms that might be important in biasing neural competition in a manner that might influence self-regulation. Broad focus of attention allows for greater cognitive flexibility than a narrow focus locked on salient but goal-irrelevant information, and response inhibition diminishes the contribution of goal-irrelevant information to behavior and primes the suppression of inappropriate responses.

Broad focus of attention and Inhibition

Diffuse and focused deployments of attention are linked with distinct neurophysiological states and uniquely influence behavior (Lutz, Slagter, Dunne, & Davidson, 2008). Broad attentional focus is associated with cognitive flexibility, which results in effective allocation of resources (Olivers & Nieuwenhuis, 2005). For example, persisting in a healthy diet plan would be considerably more difficult to achieve if one were to narrow the focus attention to

the delicious aroma of chocolate cake instead of broadening the focus to allow influences from other relevant factors, such as the summer dress that one bought as an incentive. Broadening of attention is further associated with positive affect (Fenske & Eastwood, 2003; Srinivasan & Hanif, 2009), which in turn has been shown to enhance self-regulation (Aspinwall, 1998). Thus, it is expected that broadening one's attention will facilitate cognitive flexibility and thus enhance efficient allocation of resources needed for self-regulation. This reasoning is in line with Construal Level Theory, according to which activation of broad, high-level concepts results in better self-control than activation of narrow, low-level concerns that can conflict with the requirement to self-regulate (Fujita & Han, 2009). A recent study showed that dieters exhibited an attentional bias towards (maladaptive) food cues, but were less likely to do so when primed with diet-related concepts (Papies, Stroebe, & Aarts, 2008).

Secondly, successful self-regulation entails the ability to suppress actions that arise from maladaptive impulses (Baumeister & Heatherton, 1996). A substantial body of research has demonstrated that inhibitory processes of attention are integral to goal-directed, adaptive behavior (e.g., Loach, Frischen, Bruce, & Tsotsos, 2008). With regard to self-regulation, von Hippel and Gonsalkorale (2005) showed that individuals with stronger inhibitory skills were less likely to make socially inappropriate actions that require self-regulation. Moreover, participants were more likely to make socially inappropriate responses if their ability to inhibit was limited as compared to performance with undivided attention. Additionally, predispositional response inhibition and impulsive food preference predicts long-term weight gain (Nederkoorn et al., 2010). A number of studies across diverse domains have demonstrated that individuals with low response inhibition are more strongly influenced by impulses than those high in inhibition (Houben & Wiers, 2009; Payne, 2005). It is therefore proposed that practicing response inhibition will enhance self-regulation by making suppression of unwanted thoughts and actions easier.

Although attentional biasing has been implicated in successful self-regulation, previous research is largely correlational in nature and does therefore not allow for firm conclusions regarding a causal relationship between attention and self-regulation. Furthermore, no study has aimed to manipulate attentional mechanisms in an effort to enhance self-regulation. Four experiments were conducted to provide a novel investigation of attentional mechanisms for

enhancements in self-regulatory behavior. It was predicted that improving one's ability to (i) broaden the focus of attention (experiments 3 and 4), and (ii) make response inhibition more efficient (experiments 5 and 6), will facilitate self-regulation performance.

Experiment 3

This experiment manipulated the breadth of attentional focus. Participants identified either the global form or local detail of hierarchical stimuli to induce a broad or narrow focus, respectively (see Navon, 1977). A neutral-focus was used as a control condition, whereby participants performed an object recognition task on non-hierarchical shapes. The different processing styles associated with broad and narrow focus of attention carry over to subsequent unrelated tasks (Förster & Dannenberg, 2010). It was expected that the cognitive flexibility associated with broad attention would be beneficial for subsequent self-regulation performance. Capacity for self-regulation was assessed before and after the attentional manipulation by measuring the length of time participants were willing to squeeze a handgrip exerciser. This is a commonly used measure of self-regulation as it requires a great deal of effortful-persistence and is unrelated to grip strength *per se* (e.g., Alberts, et al., 2007; Ciarocco, Sommer, & Baumeister, 2001; Hejak, 1989; Muraven et al., 1998). Distributing attention broadly should help to prevent maladaptive over-investment of attention to any particular goal-irrelevant process (such as the awareness of muscle fatigue) that might otherwise consume mental resources contributing to self-regulation. It was predicted that participants with a broad focus of attention would improve self-regulation performance compared to those with a narrow or neutral focus.

Methods

Participants

Ninety-two University of Guelph introductory psychology students took part in exchange for course credit. Eight participants were eliminated because they failed to complete some aspect of the task or their baseline handgrip squeeze-duration was more than 2.5 standard deviations from their group mean. The final sample comprised 84 participants (51 women; mean age 19.9). All participants had normal or corrected to normal vision. Informed consent forms were obtained in compliance with procedures set by the University of Guelph Research Ethics Board.

Stimuli

For the global precedence task, which served as a measure of dispositional biases to attend to global or local information, we presented hierarchical Navon-type letter stimuli. The global and local levels of these stimuli were either congruent (e.g., a big ‘H’ composed of small ‘H’s) or incongruent (e.g., big ‘H’ made of small ‘S’s). A different set of hierarchical stimuli was used to induce a broad or narrow focus of attention in the attentional manipulation task. These stimuli were shapes (triangle, square, circle, diamond) instead of letters, and they were always incongruent (e.g., a large triangle composed of small squares). For all hierarchical stimuli, the global level of the stimuli measured approximately 7.2 cm X 7.2 cm and the local level approximately 0.9cm x 0.9cm. A set of non-hierarchical shapes, measuring approximately 2.94cm X 2.94cm in size, was used for a neutral-focus control condition. Compared to the hierarchical stimuli, these control items were smaller than the global dimension, larger than the local dimension, and lacked any global-local interference. All stimuli were black presented on a white background at a viewing distance of 60cm (see Figure 7, same stimuli as Experiment 2).

Trait self-report measures

Participants completed the Attentional Control Scale (ACS) (Derryberry & Reed, 2002), Self-Regulation Scale (SRS) (Schwarzer, Diehl, & Schmitz, 1999) and Social Desirability Questionnaire (SDQ) (Crowne & Marlowe, 1960). These measures allowed us to ensure that any between-group differences in self-regulation performance were not due to pre-existing differences in individuals’ capacity for attentional control, self-regulation, or tendency to respond in a manner that conforms to others’ expectations. Given the established interaction between mood and scope of attention (Gasper & Clore, 2002), broadening the focus of attention might induce a positive mood, which in turn can influence the capacity for self-regulation. We therefore administered the Positive and Negative Affect Schedule (PANAS; Watson, Clark & Tellegen, 1988) in order to account for possible influences of mood on self-regulation.

Apparatus

In order to measure self-regulation, we installed a USB micro-switch in the handles of a standard handgrip exerciser. The micro-switch was connected to an Intel Core2Duo computer running Windows XP and E-Prime 1.1 software (Schneider, Eschman, & Zuccolotto, 2002) to

provide millisecond timing of the duration during which the exerciser handles were fully squeezed together. All other tasks were also run in E-Prime.

Design & Procedure

Participants began the session by squeezing the handgrip exerciser for as long as possible. This served as the baseline self-regulation measure and allowed us to control for individual differences in grip strength. Participants then completed the trait self-report measures, which were followed by the global precedence task. There were four alternating blocks (24 trials each) in which participants identified either the big letter (requiring global processing) or the small letter (requiring local processing) of the hierarchical stimuli. In each block, congruent and incongruent stimuli were presented with equal probability, for 200 ms each, followed by a blank screen until response. Participants made speeded key presses (H or S) to identify the target letter.

Participants were then randomly assigned to the Broad-focus (N=30) Narrow-focus (N=31) or Neutral-focus control (N=23) groups. Participants in the Broad-focus and Narrow-focus groups viewed the same sets of hierarchical shape stimuli and were asked to identify only the global shape (Broad-focus) or only the local shape (Narrow-focus). Participants in the Neutral-focus control group viewed the set of non-hierarchical stimuli and were asked simply to identify the shape. Stimuli were presented in a random order across 160 trials, for 200 ms each, followed by a blank screen until response. Participants identified the target shapes by pressing keys 'N' or 'M' (labeled as 'circle' and 'triangle': Broad-focus group), keys 'V' or 'B' (labeled as 'square' and 'diamond': Narrow-focus group), or keys 'N', 'M', 'V' or 'B' (labeled as 'circle', 'triangle', 'square' and 'diamond': Neutral-focus control group). The neutral-focus task had alternating blocks of trials where participants had to identify either between circle and triangles or between squares and diamonds.

All participants then completed the PANAS before squeezing the handgrip exerciser again for as long as they could to measure their self-regulation ability following the attentional manipulation. The experimenter who oversaw the pre- and post-attentional manipulation self-regulation measures was blind to the attentional manipulation condition (Broad-, Neutral-, or Narrow-focus) in order to avoid unintentional variations in the manner in which the handgrip task was administered.

Results

Mean reaction time (RT) and accuracy to identify the global/local target served as dependent measures for the global precedence and attentional manipulation tasks; handgrip-squeeze duration provided the critical dependent measure of self-regulation.

For the global precedence task, global precedence scores were computed by subtracting local interference scores (i.e., global-congruent RT minus global-incongruent RT) from global interference scores (i.e., local-congruent RT minus local-incongruent RT). There was no significant difference in global precedence between the Broad-, Neutral- and Narrow-focus groups ($p > .05$), confirming that they did not differ in their dispositional tendency to attend to the global or local level of hierarchical stimuli. Furthermore, they did not differ on any of the trait self-report measures (all $ps > 0.05$), or the baseline handgrip task ($F < 1$) confirming that all the groups were equivalent in terms of their predisposition for attention control, self-regulation capacity, social desirability, and in terms of their initial self-regulation performance (see Table 3).

A 2 (Handgrip: baseline vs. post-attention) x 3 (Group: Broad-focus vs. Neutral-focus vs. Narrow-focus) mixed ANOVA revealed that the groups differed in their self-regulation performance as a function of the attentional manipulation ($F[2,81]=4.64$, $p=0.012$; $\eta_p^2=.103$; see Figure 12). After the attentional manipulation, participants in the Broad-focus group were able to squeeze the handgrip for longer than their own baseline duration that had been measured before the manipulation (Mean_{before}= 29.16 sec; $MSE_{before}=5.92$ sec; Mean_{after}=38.25 sec; $MSE_{after}=5.34$ sec; $t[29]=-2.16$, $p=0.03$). In contrast, participants in the Narrow-focus group tended to squeeze the handgrip for a shorter time than their own baseline duration (Mean_{before}= 40.28 sec; $MSE_{before}=6.57$; Mean_{after}=32.30 seconds; $MSE_{after}=4.45$; $t[30]=1.87$, $p=0.07$). The neutral-focus group did not show any significant difference in handgrip squeezing duration (Mean_{before}=34.09 sec; $MSE_{before}=6.43$; Mean_{after}=36.60 sec; $MSE_{after}=5.17$; $t[22]=-0.66$, $p=0.51$). Analyses of the RT and accuracy data for the attentional manipulation tasks revealed no significant group differences (all $ps > 0.05$), except for the Neutral-focus group, which showed faster RTs than the other two groups (both $ps < .05$). This suggests that the Neutral-focus task was easier than the other two tasks, yet it did not result in any changes in self-regulation. Only the Broad-focus task resulted in improvement while Narrow-focus resulted in impairment of self-regulation performance.

Handgrip performance after the attention manipulation did not correlate with PANAS scores for any group (all $ps > 0.05$), ruling out the possibility that this critical measure of self-regulation was influenced by mood.

Table 3. Means and standard deviations (in parentheses) for the predisposition task, attentional manipulation task and mood data of Experiment 3.

		Broad-focus	Neutral-focus	Narrow-focus
Predisposition	Attention Control	51.90 (7.51)	50.26 (7.47)	49.16 (8.01)
	Self-regulation	25.83 (4.37)	26.22 (3.95)	25.41 (5.00)
	Social Desirability	19.60 (3.23)	18.87 (3.19)	19.87 (2.41)
	Global Precedence	-31.19 (113.09)	-69.9 (171.64)	39.05 (318.50)
Attention Task	Accuracy (%)	97.50 (2.68)	96.0 (.04)	98.1 (2.71)
	Mean RT (ms)	649.20 (119.20)	300.85 (92.1)	692.9 (279.20)
PANAS	Positive Affect	2.80 (0.52)	2.79 (0.64)	3.11 (0.75)
	Negative Affect	1.40 (0.63)	1.30 (0.42)	1.70 (0.53)

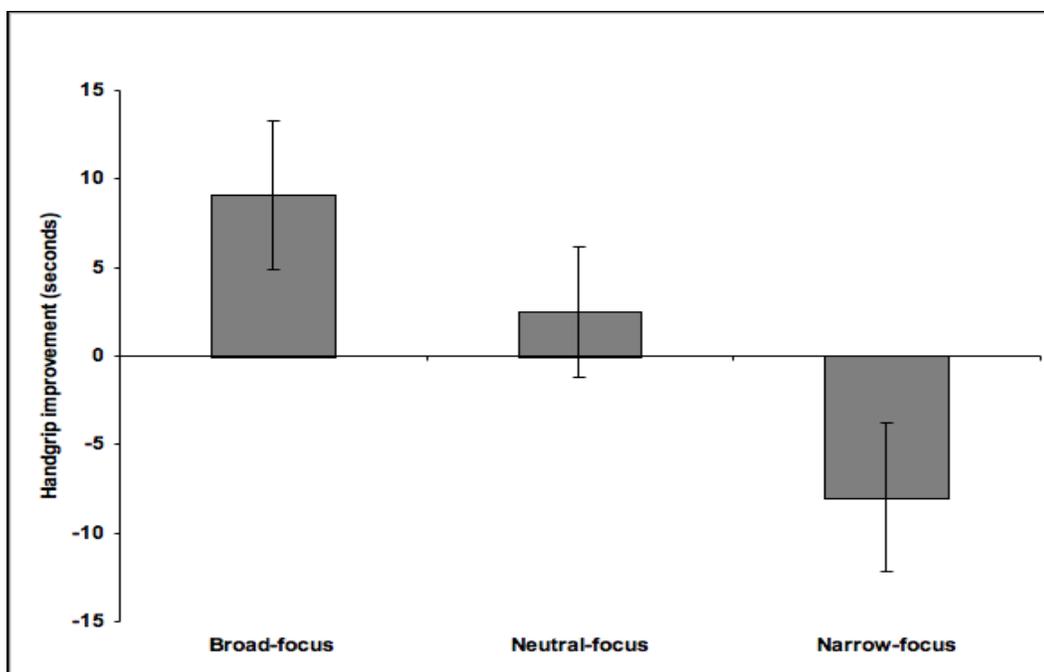


Figure 12. Self-regulation performance results for Experiment 3

Experiment 4

The results of experiment 3 showed that broad focus of attention, as compared to neutral and narrow focus of attention, resulted in an improvement on hand grip exerciser time as an index of self-regulation performance. The main objective of experiment 4 was to provide converging evidence using a different task to assess self-regulation; namely, time spent on an anagram task in which some of the anagrams were unsolvable. Unsolvable anagrams are frustrating and discouraging, and people may often be inclined to quit trying. Effective self-regulation would be needed to override the impulse to quit and instead force them to keep trying for a longer period of time. This has been used as a measure of self-regulation in many previous studies (for example, Muraven, Tice, & Baumeister, 1998). The handgrip exerciser was also used to assess the baseline self-regulation performance. The attentional manipulation task was the same as experiment 3. It was predicted that irrespective of the performance on the handgrip exerciser and predisposition questionnaires (also used in experiment 3), participants in Broad-focus group will spend more time in persisting on the unsolvable anagram task as compared to those in Narrow- or Neutral-focus groups.

Methods

Participants

Sixty-five University of Guelph introductory psychology students took part in exchange for course credit. Four participants were eliminated because they had performed below par on the solvable anagrams. These participants were unable to solve at least two out of the first three solvable anagrams and reach 50% overall accuracy on solvable anagrams. Two participants who reported having learning disability were also eliminated from the final sample because their persistence on the anagrams task might be directly influenced by their learning disability. The final sample comprised 59 participants (47 women; mean age 18.4). All participants had normal or corrected to normal vision. Informed consent forms were obtained in compliance with procedures set by the University of Guelph Research Ethics Board.

Stimuli and Trait self-report measures

For global/local predisposition task and attentional manipulation task, the same hierarchical stimuli were used as those in Experiment 3. Participants were also asked to complete ACS, SRS and SDQ questionnaires. For anagram task, twenty-five anagrams were created. The anagrams were 4-7 letters that were to be rearranged to form a word. A pilot test was done to control for difficulty level of the anagrams where 6 participants rated for difficulty level of solving the anagrams on a scale of 1 to 5. All the solvable anagrams were of intermediate difficulty level (mean score 1.8). Unsolvable anagrams were created by letters that cannot be arranged to form a word. The list of anagrams is shown in the Appendix.

Design & Procedure

The procedure was same as in Experiment 3 except for the post-task self-regulation assessment. Participants began the session by squeezing the handgrip exerciser for as long as possible. This served as the baseline self-regulation measure and acted as a control for individual differences in grip strength. Participants then completed the trait self-report measures, which were followed by the global precedence task. Participants were then randomly assigned to the Broad-focus (N=19) Narrow-focus (N=18) or Neutral-focus control (N=22) groups. All participants then completed the PANAS before starting the anagram task. In the anagram task,

twenty-five anagrams were presented one-by-one on the computer screen. Stimuli were presented in black Courier New Bold 25-point font on a white background. Participants were instructed to try to solve all the anagrams. Participants were stopped at the maximum time of 40 minutes.

Results

Mean reaction time (RT) and accuracy to identify the global/local target served as dependent measures for the global precedence and attentional manipulation tasks; handgrip-squeeze duration provided the dependent measure of baseline self-regulation.

For the global precedence task, global precedence scores were computed just as in experiment 3. There was no significant difference in global precedence between the Broad-, Neutral- and Narrow-focus groups ($p > .05$), confirming that they did not differ in their dispositional tendency to attend to the global or local level of hierarchical stimuli. Furthermore, they did not differ on any of the trait self-report measures (all $p_s > 0.05$), or the baseline handgrip task ($F < 1$) confirming that all the groups were equivalent in terms of their predisposition for attention control, self-regulation capacity, social desirability, and in terms of their initial self-regulation performance (see Table 4).

A one-way ANOVA was conducted to test the difference in time spent on unsolvable anagrams by three groups (Broad-focus vs. Neutral-focus vs. Narrow-focus). It was revealed that the groups differed in their self-regulation performance as a function of the attentional manipulation ($F[2,58]=3.69, p = 0.031; \eta_p^2 = .117$; see Figure 11). After the attentional manipulation, participants in the Broad-focus group spent more time in persisting on unsolvable anagrams as compared to participants in Neutral ($p < 0.02$) and Narrow-focus ($p < 0.024$). There was no significant difference between Neutral and Narrow focus groups in terms of time spent at persisting on unsolvable anagrams ($p = 0.97$). Analyses of the RT and accuracy data for the attentional manipulation tasks revealed no significant group differences (all $p_s > 0.05$), except for the Neutral-focus group, which showed faster RTs than the other two groups (both $p_s < .05$). This suggests that the Neutral-focus task was easier than the other two tasks, yet it did not result in any changes in self-regulation. Only the Broad-focus task resulted in improvement while Narrow-focus resulted in impairment of self-regulation performance. Performance on the

anagram task after the attention manipulation did not correlate with PANAS scores for any group (all $ps > 0.05$), ruling out the possibility that this critical measure of self-regulation was influenced by mood. Thus, results of experiment 3 and 4 demonstrated that broad focus of attention leads to enhanced self-regulation.

Experiment 5

In this experiment, participants' efficiency at inhibiting inappropriate responses was manipulated. Participants performed a Go/No-go task which required inhibiting habitual responses on a subset of trials, or they performed a version of the same task that did not require any response inhibition. It is important to note that the Go/No-go task poses different inhibitory demands than the inhibition tasks that are sometimes used to exhaust mental resources in ego depletion paradigms. For example, Muraven et al. (1998) showed that thought suppression (participants were instructed to avoid thinking about a white bear while performing an unrelated task) results in self-regulation impairment. Instructing participants not to think about a particular and unusual thing makes that thought paradoxically more salient (Eastwood, Gaskovski & Bowers, 1998). Effortful controlled inhibition is therefore required to suppress such thoughts, which consumes resources thus impairing self-regulation. In contrast, the Go/No-go task engages more automatic inhibition processes (Verbruggen & Logan, 2008) and may therefore prime inhibitory processes required for self-regulation, making them more efficient. Pre-engaging these processes to yield more efficient inhibition could aid self-regulation in two ways: first, complementing the benefits of broadly distributed attention, it should decrease the extent to which factors that are detrimental to the task at hand (e.g., awareness of fatigue) receive higher-level processing and consume mental resources, which would conserve resources to be used for self-regulation; second, priming the effectiveness of response inhibition should facilitate the suppression of impulses to abandon self-regulatory efforts (e.g., the urge to let go of the handgrip). It was predicted that participants who practiced withholding inappropriate responses would be subsequently more capable of self-regulation than those who did not pre-engage such processes of response inhibition.

Table 4. Means and standard deviations (in parentheses) for the predisposition task, attentional manipulation task and mood data of Experiment 4.

		Broad-focus	Neutral-focus	Narrow-focus
Predisposition	Attention Control	53.37 (6.89)	48.95 (1.6)	52.33 (1.03)
	Self-regulation	26.74(4.45)	25.68(8.84)	25.5 (5.26)
	Social Desirability	17.31 (6.37)	17.33 (5.91)	17.11 (9.52)
	Global Precedence	116.59 (390.29)	56.22 (211.61)	20.67 (245.73)
Attention Task	Accuracy (%)	96.0 (2.0)	96.0 (2.0)	95 (4.0)
	Mean RT (ms)	563.60 (138.97)	305.41 (82.13)	646.45 (134.69)
PANAS	Positive Affect	2.81 (0.81)	2.68 (0.71)	2.55 (0.66)
	Negative Affect	1.47 (0.33)	1.76 (0.75)	1.58 (0.54)

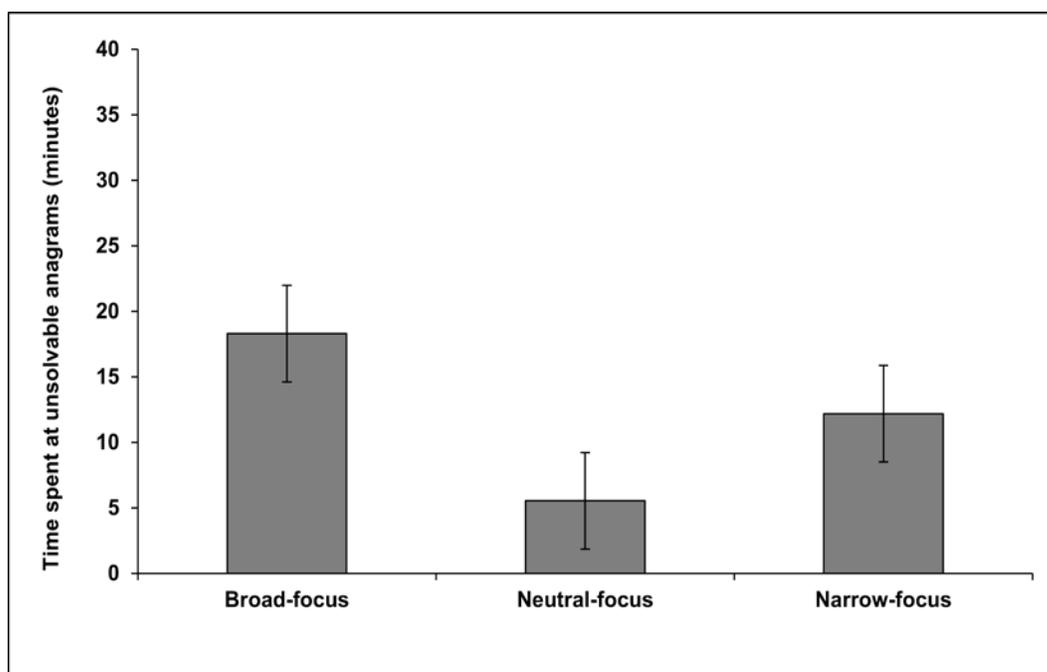


Figure 13. Self-regulation performance results for Experiment 4

Methods

Participants

Fifty-six University of Guelph introductory psychology participants took part in exchange for course credit. Four participants were eliminated from the dataset because their baseline handgrip reaction times were more than 2.5 standard deviations from their group mean. The final sample comprised 52 participants (44 women; mean age 20.44). All participants had normal or corrected to normal vision. Informed consent forms were obtained in compliance with procedures set by the University of Guelph Research Ethics Board.

Stimuli

The attentional manipulation task used digits (0-9) as stimuli. Participants were given a predisposition task that was designed to assess potential pre-existing group differences in

response inhibition. The stimuli used in this predisposition task were letters ('D' to 'N', omitting the letter 'I' as it resembled the digit '1', which was used in the attentional manipulation task). All stimuli were presented in white Times New Roman font on a black background and measured approximately 2 cm (height) X 1.5 cm (width). Two white concentric circles (1.3 cm and 3.3 cm) were used as a mask. Stimuli were presented at a viewing distance of 60 cm.

Design & Procedure

All other aspects of the methods were identical to Experiment 3, except that instead of global/local identification tasks, participants performed versions of a Go/No-go task. In the predisposition task, 100 backwards-masked letters appeared for 200ms each in rapid succession (800ms inter-stimulus interval). Participants pressed the 'G'-key on the keyboard as quickly as possible in response to each letter ('Go' stimuli) except for the letter 'F' ('No-go' stimulus), in which case they had to withhold their response. Go and No-go stimuli appeared with equal probability. Participants were then randomly assigned to either Response-inhibition (N=26) or Non-inhibitory-control (N=26) groups to perform another version of this task that presented digits instead of letters. Participants in the Non-inhibitory-control group pressed the 'H'-key for the digit '3' (dummy-coded as the "No-go" stimulus) and the 'G'-key for every other digit (dummy-coded as "Go" stimuli). The dummy 'Go' and 'No-go' stimuli appeared with equal probability in each block. Thus, there was no requirement to withhold from responding on any trial, and both (dummy) "Go" and "No-go" responses were equally habitual. Participants in the Response-inhibition group viewed the same stimuli but pressed the 'G'-key for every digit except the digit '3', in which case they had to withhold their response. Thus, in contrast to the Non-inhibitory-control group, this task required response inhibition. In order to further enhance the demands for response inhibition in the Response-inhibition group, the probability of the No-go stimulus appearance decreased across 3 blocks (Block 1:25%; Block 2:18%; Block 3:10%) in order to increase the habituation of the response on 'Go' trials and the degree of inhibition required for withholding responses on 'No-go' trials. In both groups, participants performed a minimum of 100 trials per block, moving on to the next block once their overall accuracy reached 95% or after 200 trials had elapsed to ensure that participants received sufficient practice. The PANAS was not administered in this experiment.

Results

For the Go/No-go tasks, the dependent measures were mean RTs on Go trials, as well as mean Go and No-go accuracy. In the inhibitory predisposition task, the two experimental groups did not differ on any of these measures (all p s>0.05), showing that both groups were equally effective at response inhibition prior to the attentional manipulation. They also did not differ on any of the questionnaires (all p s>0.05) or the baseline handgrip task (t <1), confirming that both groups were equivalent in terms of their predisposition regarding attention control, self-regulation capacity, social desirability, and initial self-regulation performance (see Table 5).

Analyses of the attentional manipulation data with 3 (Block: 1 vs. 2. vs. 3) x 2 (Group: Response-inhibition vs. Non-inhibitory-control) mixed ANOVAs on the RT and accuracy data confirmed that the task posed different demands on inhibitory processing for the two groups. The Go response became more habitual for the Response-inhibition group, as evidenced by decreasing Go RTs across blocks for the Response-inhibition group ($F[2,50]=42.5$, $MSE=662.82$, $p<.001$, $\eta_p^2=.63$), but not for the Non-inhibitory-control group ($F < 1$; Group x Block interaction: $F[2,100]=18.28$, $MSE=737.23$, $p<0.001$, $\eta_p^2=.27$). Go accuracy remained consistent across the three blocks for both groups, as did the dummy-coded No-go accuracy for the Non-inhibitory-control group (all F s<1). However, No-go accuracy declined across blocks for the Response-inhibition group ($F[2,50]=20.16$, $MSE=.011$, $p<0.001$, $\eta_p^2=.45$; Block x Group interaction: $F[2,100]=16.54$, $MSE=.007$, $p<0.001$, $\eta_p^2=.25$), confirming that the demand for inhibitory processing progressively increased in this group. The critical 2 (Handgrip: baseline vs. post-attention) x 2 (Group: Response-inhibition vs. Non-inhibitory-control) mixed ANOVA revealed that participants in the Response-inhibition group squeezed the handgrip significantly longer after performing the task ($t[25]=3.57$, $p=0.002$), whereas the Non-inhibitory-control group did not improve their own baseline performance ($t < 1$; see Figure 14); Handgrip x Group interaction: $F[1,50]=4.64$, $MSE=7.71$, $p=0.036$, $\eta_p^2=.09$. These findings show that participants who recently recruited automatic response inhibition processes improved self-regulation.

Table 5. Means and standard deviations (in parentheses) for the predisposition task and the attentional manipulation task of Experiment 5. Note that ‘Go’ vs. ‘No-go’ is a dummy-coded variable for the Non-inhibitory-control group.

			Response-inhibition	Non-inhibitory-control
Predisposition		Attention Control	50.88 (7.68)	49.96 (7.27)
		Self-regulation	26.38 (4.37)	25.73 (0.03)
		Social Desirability	16.65 (4.32)	14.0 (5.33)
		Go Accuracy (%)	98.08 (2.23)	97.96 (2.97)
		No-go Accuracy	90.92 (6.46)	88.38 (10.25)
		Go RT (ms)	476.62	466.62 (62.91)
Attention	Block 1	Go Accuracy (%)	98.81 (2.06)	91.77 (7.07)
		No-go Accuracy	80.46 (13.34)	89.5 (9.95)
		Go RT (ms)	414.54	492.71 (62.17)
	Block 2	Go Accuracy (%)	99.08 (1.09)	91.23 (8.82)
		No-go Accuracy	68.23 (17.08)	87.19 (9.91)
		Go RT (ms)	388.62 (59.5)	485.98 (62.61)
	Block 3	Go Accuracy (%)	99.08 (1.98)	91.96 (8.72)
		No-go Accuracy	62.5 (18.77)	90.08 (7.47)
		Go RT (ms)	349.17	490.17 (57.12)

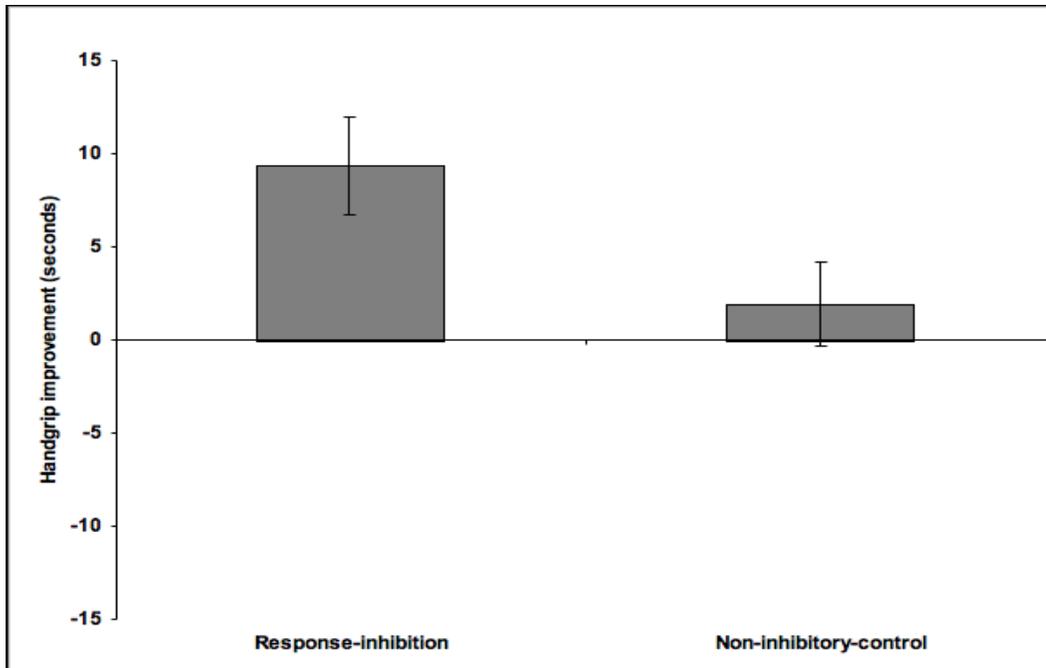


Figure 14. Self-regulation performance results for Experiment 5

Experiment 6

Experiment 5 showed that self-regulation was improved in participants who recently recruited automatic response inhibition processes. The main objective of experiment 6 was to provide converging evidence using a different task to assess self-regulation, time spent on an anagram task. The self-regulation assessment was identical to that used in experiment 4. The handgrip exerciser was used to assess the baseline self-regulation performance and post-task self-regulation was measured by the anagram task. The attentional manipulation task was the same as experiment 5. It was predicted that irrespective of the performance on the handgrip exerciser and predisposition questionnaires, participants in Response-inhibition group would spend more time in persisting on the unsolvable anagram task as compared to those in Non-inhibitory-control group.

Methods

Participants

Forty-three University of Guelph introductory psychology students took part in exchange for course credit. Four participants were eliminated because they had performed below par on the solvable anagrams. These participants were unable to solve at least two out of the first three solvable anagrams and reach 50% overall accuracy on solvable anagrams. The final sample comprised 39 participants (27 women; mean age 20.1). All participants had normal or corrected to normal vision. Informed consent forms were obtained in compliance with procedures set by the University of Guelph Research Ethics Board.

Results

For the Go/No-go tasks, the dependent measures were mean RTs on Go trials, as well as mean Go and No-go accuracy. In the inhibitory predisposition task, the two experimental groups did not differ on any of these measures (all $ps > 0.05$), showing that both groups were equally effective at response inhibition prior to the attentional manipulation. They also did not differ on any of the questionnaires (all $ps > 0.05$) or the baseline handgrip task ($t < 1$), confirming that both groups were equivalent in terms of their predisposition regarding attention control, self-regulation capacity, social desirability, and initial self-regulation performance (see Table 6).

Analyses of the attentional manipulation data with 3 (Block: 1 vs. 2. vs. 3) x 2 (Group: Response-inhibition vs. Non-inhibitory-control) mixed ANOVAs on the RT and accuracy data confirmed that the task posed different demands on inhibitory processing for the two groups. The Go response became more habitual for the Response-inhibition group, as evidenced by decreasing Go RTs across blocks for the Response-inhibition group ($F[2,36]=22.12, p < .001, \eta_p^2 = .55$), but not for the Non-inhibitory-control group ($F[2,36]=2.14, p = .132$); Group x Block interaction: $F[2,36]=10.96, MSE=737.23, p < 0.01, \eta_p^2 = .379$). Go accuracy remained consistent across the three blocks for both groups ($F[2,36]=1.2, p = .31$). The dummy-coded No-go accuracy for the Non-inhibitory-control group also remained consistent across the three blocks for both groups ($F[2,17]=0.25, p = .77$). However, No-go accuracy declined across blocks for the

Response-inhibition group ($F[2,36]=22.28, p < 0.001, \eta_p^2 = .553$; Block x Group interaction: $F[2,36] = 11.85, p < 0.001, \eta_p^2 = .39$), confirming that the demand for inhibitory processing progressively increased in this group.

An independent sample t-test was conducted to test the difference in time spent on unsolvable anagrams by the two groups (Response-inhibition vs. Non-inhibitory-control). It was revealed that the groups differed in their self-regulation performance as a function of the attentional manipulation ($t(36)=3.97, p = 0.001; \eta_p^2 = 1.28$; see Figure 15). After the attentional manipulation, participants in the Response-inhibition group (Mean=16.79 minutes; $MSE=1.39$) spent more time in persisting on unsolvable anagrams as compared to participants in Non-inhibitory-control group (Mean=9.4 minutes; $MSE=1.1$).

Discussion

Four experiments demonstrated that the capacity for self-regulation could be enhanced by simple manipulations of attentional mechanisms. Participants improved their own self-regulation performance- assessed by squeezing time of a handgrip exerciser- after they were induced into a broad focus of attention (Experiment 3) or after recently inhibiting inappropriate responses (Experiment 5). This effect was replicated using a different measure of self-regulation performance – an unsolvable anagram task (Experiments 4 and 6). These findings indicate a causal relationship in which mechanisms of attention influence self-regulation. It can be concluded that improving the degree to which attention selectively favors processing of goal-relevant information and inhibits inappropriate responses enhances self-regulation. Accordingly, broadening the focus of attention facilitates cognitive flexibility and distribution of attention across a broad range of factors, preventing the over-investment of attention in maladaptive processes or thoughts. Efficient inhibitory control likewise decreases the extent to which such goal-irrelevant factors receive higher-level processing. As a result, the maintenance of goal-directed processes in the brain would be more efficient.

Table 6. Means and standard deviations (in parentheses) for the predisposition task and the attentional manipulation task of Experiment 6. Note that ‘Go’ vs. ‘No-go’ is a dummy-coded variable for the Non-inhibitory-control group.

			Response-inhibition	Non-inhibitory-control
Predisposition		Attention Control	51.2 (9.24)	52.36 (7.79)
		Self-regulation	27.35 (4.08)	25.89 (5.17)
		Social	17.06 (2.56)	16.84 (2.6)
		Go Accuracy (%)	98.2 (1.8)	97.47 (4.2)
		No-go Accuracy	88.7(9.3)	87.26 (5.24)
		Go RT (ms)	472.6(51.35)	463.1(53.16)
Attention Task	Block 1	Go Accuracy (%)	98.6 (1.81)	95.1(3.9)
		No-go Accuracy	75.4 (15.87)	89.94 (5.76)
		Go RT (ms)	431.97	486.44 (54.87)
	Block 2	Go Accuracy (%)	97.75(3.38)	92.94 (5.4)
		No-go Accuracy	64 (21.4)	90.89 (6.4)
		Go RT (ms)	397.32	502.13 (68.15)
	Block 3	Go Accuracy (%)	96.55(6.7)	92.57(5.17)
		No-go Accuracy	51.25 (24.16)	90.84 (6.16)
		Go RT (ms)	355.52(100.8)	487.13 (65.96)

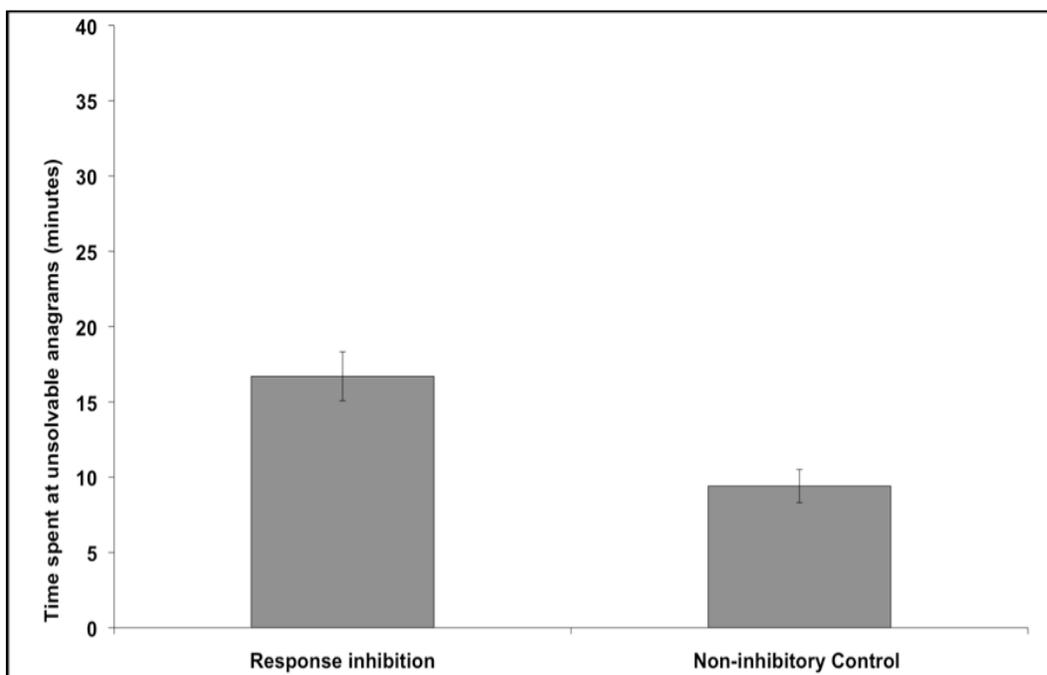


Figure 15. Self-regulation performance results for Experiment 6

Attention influences every level of information processing in the brain, from early sensory processing to action planning and execution (Loach et al., 2008), ensuring that salient and relevant information is prioritized, thus circumventing potential bottlenecks in information processing such as access to working memory and awareness (Luck & Vogel, 1997). Likewise, by regulating the degree of processing that is devoted to a given cognitive operation, attention regulates the amount of mental resources that would otherwise be consumed by task-irrelevant activity. Efficient attentional processing may thus result in more mental resources remaining available for continued self-regulation. These results are in line with evidence that effective attentional processing underlies healthy mental functioning. Eastern meditation practices that focus on drawing one's attention to present thoughts and actions result in improved attention and reduced stress (Tang et al., 2007), improved brain-resource allocation (Slagter et al., 2007), and enhanced self-regulation (Tang & Posner, 2010). Attention restoration theory (Kaplan & Berman, 2010) also suggests that reducing the demands that busy, over-stimulating environments

pose on selective attention enhances self-regulation. The results reported here critically build upon these lines of research by experimentally demonstrating specific attentional mechanisms that may underlie such restorative efforts. An increasing number of studies examine the potential of attention-based training techniques for improving psychological well-being (e.g., Wadlinger & Isaacowitz, 2011). These findings contribute to this development, laying a promising foundation for testing the possibility that simple attention-based interventions may be useful for helping individuals with deficits in self-regulation.

A few researchers have also claimed that self-regulation relies on glucose as a limited energy source (Gailliot et al., 2007, but also see Kurzban, 2010). Future research can investigate the role of attentional processing in the interplay between self-regulation and glucose metabolism. Further research is also needed to elucidate the generalizability of these findings to other self-regulation measures and real-world tasks. For example, would attention manipulations like those utilized here help dieters to avoid focusing on unhealthy foods and improve their restraint when confronted with temptation? It will also be important to investigate the longevity of the improvements in self-regulation in order to develop practical, real-world interventions for people with self-regulatory problems. The current experiments provide the first steps along these exciting new avenues of inquiry.

Chapter 5: General Discussion

The main objective of this thesis was to investigate the influence of attentional manipulations on the different stages of cognition and emotion resulting in goal-directed behavior: early visual recognition, interaction with affective state, and behavioral output stage. At visual recognition stages, attention to bodies increases functional connectivity between body-selective occipito-temporal regions - EBA and FBA. In other words, attention prioritizes recognition of goal-relevant information by strengthening communication between category-specific brain areas and thus facilitating visual recognition. Resting state connectivity indicates that body-selective cortical areas communicate more with each other compared to other category-selective areas; attention enhances this communication. Attention is thought to modulate visual recognition by modulating the neural activity of the visual areas that are involved in category-specific processing. For example, body-selective EBA and FBA show enhanced neural activity during recognition of human bodies compared to activity during recognition of a range of stimuli. Recently developed fMRI techniques allow us to investigate how attention can modulate interactions between these areas. Using a functional connectivity technique in Experiment 1, I found that body-selective EBA and FBA tend to have higher functional connectivity, even in the absence of a body-related task, and that attention to bodies tends to enhance this connectivity.

Attention also affects interaction with affective state. Induction of a broad focus of attention results in greater processing fluency and less attentional inhibition, resulting in a better mood. Interestingly, all accounts of attention-mood interactions in the current literature have only looked at the influence of mood on attention. But here I have investigated the opposite direction of this interaction and have found that attention also influences mood state. Traditional studies within cognitive science have distanced the concepts of cognition and emotion, but recent evidence has bolstered the view that cognition-emotion interactions exist and are important for healthy cognitive functioning. The results of Experiments 2 build on the view that cognition and emotion interact reciprocally. It is found that inducing a broad focus of attention enhances mood. Mood dysfunction results from poor attentional abilities. Depressed individuals show high self-directed attention or rumination (Gross, 1998) and are slower to disengage their attention from any stimuli while engaged in a stress-related task (Ellenbogen et al., 2006). Wadlinger &

Isaacowitz (2011) advocated the role of the attentional training to enhance emotion processing and mood. Results from this study contribute to this development, laying a promising foundation for testing the possibility that simple attention-based interventions that involve broadening of attention may be useful for enhancing mood.

Attention is also found to enhance the output stage of goal-directed behavior and self-regulation. Broad focus of attention enhances the salience of goal-relevant representations and efficient response inhibition reduces the salience of goal-irrelevant representations, resulting in successful self-regulation. Results of experiments 3-6 are in line with evidence that effective attentional processing underlies healthy mental functioning. Eastern meditation practices that focus on drawing one's attention to present thoughts and actions result in improved attention and reduced stress (Tang et al., 2007), improved brain-resource allocation (Slagter et al., 2007), and enhanced self-regulation (Tang & Posner, 2010). Attention restoration theory (Kaplan & Berman, 2010) also suggests that reducing the demands that busy, over-stimulating environments pose on attention enhances self-regulation. The results reported here critically build upon these lines of research by experimentally demonstrating specific attentional mechanisms that may underlie such restorative efforts. An increasing number of studies examine the potential of attention-based training techniques for improving self-regulation (see Tang & Posner, 2009 for a review). My findings contribute to this development, laying a promising foundation for testing the possibility that simple attention-based interventions may be useful for helping individuals with deficits in self-regulation.

Role of attentional training in mood and self-regulation

Research on resting state connectivity is helping neuroscientists to map the brain's intrinsic connections by showing which areas of the brain prefer to communicate with which other areas, and how those patterns might differ in mental disorders and maladaptive behavior. One of the major discoveries in the field of Cognitive neuroscience is that of the DMN or task negative network (Raichle et al., 2001). DMN shows greater activity during the resting state than during any cognitive task (Gusnard and Raichle 2001; Mayer, et al. 2010), and has been proposed to be preferentially involved in the neuropathology of psychiatric disorders (Greicius, et al. 2004). Interestingly, hyperactivity of DMN network has been attributed to mood

dysfunctions, such as depression. Anand et al. (2005) found increased activity in some areas of DMN in depressed patients. Grimm et al. (2008) reported hyperactivation in midline DMN regions, which is correlated with increased depression severity and feelings of hopelessness. Greicius et al. (2007) found abnormally increased resting state connectivity of subgenual anterior cingulate. The attention control network or task positive network is more active during tasks requiring attention to external stimuli (Corbetta & Shulman 2002). An intriguing finding is that resting state connectivity or spontaneous activity tends to be anti-correlated, even when no stimulus is presented and no task is being performed (Fox et al., 2005; Fukunaga et al., 2006). Buckner, Andrews-Hanna & Schachter (2008) suggested that anti-correlated DMN and attentional networks compete with one another for control of information processing within the brain. A failure to appropriately engage in attention processing might thus lead to interference in task performance from internal emotional states, as seen in patients with depression, or maladaptive motivational cues, as seen in the case of self-regulatory failure. By engaging attentional mechanisms efficiently and enhancing the activity of attentional network, such patients may overcome the negative affect associated with depression and maladaptive cues related to self-regulation failure. Additionally, recent research supports the view that efficient attentional processing in experienced meditators is accompanied by deactivation of the main nodes of the DMN (medial prefrontal and posterior cingulate cortices) (Brewer et al., 2011; cf. Jang et al., 2011). Here, I argue that efficient engagement of attentional processes results in the activation of attentional network and reduces the activation of DMN, resulting in better mood and self-regulation. Further studies are needed to ascertain the role of attentional network and DMN in mood and self-regulation.

Although cognitive (neuro)science research has been investigating the underlying cognitive mechanisms through which attention can enhance mood and self-regulation, growing research indicates that attentional training can be used to enhance mood and self-regulation (Wadlinger & Isaacowitz, 2011; Tang & Posner, 2009). Regulating attentional control is a critical component of emotion regulation and can be successfully trained through repeated practice. Participants can be experimentally trained to attend less to negative information and demonstrate better emotion regulation after undergoing attentional training to selectively attend to positive information (Wadlinger & Isaacowitz, 2008). ATT, a technique developed by Adrian

Wells, involves placing repetitive sound sources at similar sound levels in four corners of a room and having the participants focus their attention on a spot in front of them and shifting their attention only from one sound to another in a randomized fashion, gradually increasing the speed of the shifts from one sound to the next (Wells, 1990). By employing better attentional control and training attention, ATT has resulted in attenuated symptoms in various special populations, such as depression, anxiety, obsessive-compulsive disorder etc., and has resulted in enhanced mood and self-regulation (Wells, 2008).

Apart from selective attention, attentional control practice in tasks involving working memory and executive functions have proven to be useful in training attention in children (Posner & Rothbart, 2007). Curriculum designs that involve higher use of executive functions have been shown to improve self-regulation, inhibition and working memory in children (Diamond et al., 2007). Recently it has been shown that working memory training in adults can improve general cognitive ability of fluid intelligence (Jaeggi et al., 2008). Additionally, there is an increasing interest among neuroscientists to study the eastern meditation practices that involve attentional training, which have been shown to be effective ways to improve mood, self-regulation and psychological well-being (Green & Turner, 2010; Rubia, 2009). Hasenkamp and Barsalou (2012) recently found that experienced meditators show greater resting state connectivity within attention network and between attention network and DMN. With increased coherence between the two networks, experienced meditators may have improved capacity for disengagement of internally-directed thought content mediated by the DMN. This bolsters the view presented here that attentional training is the key to improved psychological well-being.

Experiments 2-6 have examined how attentional manipulations may enhance mood and self-regulation. But in order to use these tasks for improving mood and self-regulation in vulnerable populations, such as the depressed, obese, drug addicts etc., longevity and generalizability of these tasks need to be investigated thoroughly. Further research can investigate the longevity and generalizability of the attentional mechanisms used in Experiments 2-6 to ascertain their role in using these tasks in training protocols for improving mood and self-regulation. A multiple-session attentional training program, including broad-focus tasks and response inhibition tasks, can be used to ascertain proper attentional training. Improvement in different tasks measuring mood and self-regulation can be assessed by pre- and post-training and

a week-later follow up assessment. Such experiments will provide evidence of the longevity and generalizability of the attentional mechanisms used here.

Other cognitive mechanisms that might enhance mood

Growing research in mood disorders has indicated the role of executive functions in mood. Executive functions (also known as frontal lobe functions) mainly consist of three cognitive processes: mental set shifting, working memory and attentional inhibition (Miyake et al., 2000). Patients with mood disorders possess lack of ability to shift their thought processes from negative to positive information resulting in “a vicious cycle of negative thoughts” or rumination. Rumination also reflects an inability to inhibit maladaptive negative thoughts (Papageorgiou & Wells, 1990; Bar, 2009). Recent research has highlighted that cognitive deficits, independent of mood-specific deficits, also play a role in mood dysfunctions. Grant, Thase, and Sweeney (2001) administered a number of cognitive tasks to depressed outpatients and noted a surprising absence of cognitive deficits in their sample except for executive function task: Wisconsin Card Sorting task (WCST). WCST is a widely used measure of set switching and cognitive flexibility. These results suggest that depression is associated with deficits in set switching. Additionally, Davis and Nolen-Hoeksema (2000) administered the WCST to normal participants with varying amount of ruminative style and reported that high-ruminators made more errors than low- and non-ruminators. Additionally, Bar (2009) proposed that promoting broad associative processing- making thought processes advance from one context to another smoothly and promptly- will promote better mood. Linville (1996) examined performance of individuals with depression on a *negative priming* response inhibition task. It was found that depressed individuals were less likely to inhibit distracting information. Thus, it can be concluded that dysfunctions of set-shifting and inhibition may play a role in mood disorders. Another aspect of executive functioning is working memory, which is commonly described as a system for the active maintenance and manipulation of information and for the control of attention (Baddeley, 1986). However, there are conflicting findings on the relationship between working memory capacity and mood dysfunctions. Breslow, Kocsis, and Belkin (1980) found differences between depressed and non-depressed participants on the digit span task, a measure of working memory, while other studies could not replicate this effect (Colby & Gotlib, 1988; Gray, Dean, Rattan & Cramer, 1987; Harvey et al., 2004). Thus, it is important to examine

whether training to induce efficient set-shifting, inhibition, and working memory and promoting broad associative processing might play an important role in enhancing mood.

Role of attention in other domains- boredom, social interactions

In addition to negative mood and self-regulation failures, inefficient attentional processing is also linked with boredom (Eastwood et al., 2012). Eastwood and colleagues defined boredom as “the aversive state of wanting, but being unable, to engage in satisfying activity”. They reviewed previous literature to conclude that boredom is a result of inadequate orientation and engagement of attentional processing, and failure of executive functions. It is to be noted that boredom is a common problem and has been associated with a range of maladaptive behaviours and health problems. For example, boredom is correlated with depression, anxiety, problem gambling, somatization complaints etc. Although failure of attentional processes such as attentional inhibition and executive functions has been pointed out as a cause of boredom, existing literature does not provide enough information about how manipulation of these attentional processes may enhance or impair boredom in laboratory settings. Further research is needed to investigate the effects of manipulation of attentional processes on boredom.

My research has indicated that manipulations of attention impact self-regulation. Successful self-regulation can be achieved by enhancing the salience of goal-relevant representations and reducing the salience of goal-irrelevant representations. Additionally, self-regulation is itself an important component of successful social interactions and social skills. Furthermore, the capacity for self-regulation is considered to be an important precursor for pro-social behavior (altruism and empathy) (DeWall, Baumeister, Gailliot & Maner, 2008). Further research can investigate whether the impact of efficient attentional processing on improved self-regulation extends to result in successful social interactions and pro-social behavior.

Cortico-subcortical functional connectivity for mood and self-regulation

Successful self-regulation and positive mood (as a result of successful emotion-regulation) tend to rely on efficient control signals (originating in prefrontal cortex) on maladaptive and emotion-related cues (generating in the sub-cortical areas). Volkow and colleagues (Volkow et al., 2010) found that when cocaine users exert self-regulation to reduce

their craving in response to cocaine cues, they show reduced activity in the nucleus accumbens and ventral striatum and the magnitude of this reduction is correlated with an increase in activity in dorsolateral prefrontal cortex. Additionally, depressed participants show increased and sustained amygdala activity in response to negative words while showing decreased dorsolateral prefrontal cortex activity (Siegle, Thompson, Carter, Steinhauer & Thase, 2007). Thus, investigation of cortico-subcortical functional connectivity will be helpful in elucidating the role of efficient attentional processing in improving mood and self-regulation. It is also important to investigate whether attentional training can enhance functional connectivity to manifest behavioral outcomes in terms of improved mood and self-regulation. Further research is also needed to investigate the individual differences in susceptibility to self-regulatory and mood failures and its relationship with prefrontal–subcortical connectivity.

Limitations

Limitations of the current research also need to be acknowledged while interpreting the findings. Two limitations of Experiment 1 are worth discussing. Recent research from Turk-Browne's lab (Norman-Haignere et al., 2012; Al-Aidroos, Said & Turk-Browne, 2012) has provided similar results as Experiment 1 where they found that functional coupling between early visual areas and category-selective areas in occipito-temporal regions is modulated by attentional mechanisms. In my experiment, I used seed-voxel based functional connectivity where I extracted time courses from particular VOIs only which can be seen as a limitation of the study. In line with Al-Aidroos et al.'s (2012) research, further analysis of the current dataset can look into a whole brain connectivity approach. I expect that attentional modulation will influence the functional connectivity with early visual areas as well. Interestingly, Al-Aidroos et al. (2012) found significant attentional modulation (background connectivity) in higher frequencies between 0.2 and 0.3 Hz that were discarded in my experiment. I filtered out the upper frequencies in order to maintain the analysis protocol similar to that of resting state and because of interference due to respiratory artifacts (Cordes et al., 2001). Cordes et al. (2001) found that the major frequency contributions to resting-state functional connectivity come from fluctuations less than 0.1 Hz, respiratory interference occur between 0.1 and 0.5 Hz and cardiac interference occur between 0.6 and 1.1 Hz. Given the latest research indicating the presence of meaningful

information in higher frequencies, further analysis of the current dataset can look into the discarded frequencies for evidence of background connectivity.

In Experiment 2, the baseline mood was assessed after the participants performed the global predisposition task and before the attentional manipulation task. Engaging in the global predisposition task could have influenced mood. Thus, a true baseline mood measurement was missing. In Experiments 3 and 4, PANAS scores did not show any group differences between Broad-focus and Narrow-focus groups. In line with the results of Experiment 2, I expected that mood changes would be observed between different groups. Since there was no pre-task assessment of mood in Experiments 3 and 4, the pre-existing group differences in mood cannot be ruled out. Further research can look at the role of mood in modulating the effect of attentional manipulations on self-regulation.

Conclusion

The research reported here focused on one central question: how do attentional manipulations influence various stages of cognition and emotion to result in goal-directed behavior? The results showed that attention influences functional connectivity between body-selective visual processing areas in occipito-temporal cortex. Changes in the scope of attention were also found to influence mood and self-regulation. Broadening attentional focus improves mood and self-regulation. Narrowing attentional focus impairs mood and self-regulation. Self-regulation was also aided through the pre-engagement of attentional inhibition. In summary, attention plays a crucial role in influencing cognition at three stages- input of visual information, interaction with affective state and output of behavior. Using a diverse range of methodologies and paradigms, my doctoral research has provided evidence that attention influences the goal-relevant functional connections to facilitate visual processing, promotes fluency of information to result in better mood and prioritize goal-relevant representations to result in successful self-regulation.

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Appendix

List of Anagrams used in Experiment 4 and 6

aglo	kabigs
ngieb	rgwno
talehh	estat
rsitlne	ofts
cmhtael	nidrk
ygnid	gehnc
gehnc	kieclh
ngmroin	fisrda
caligr	eahsdn
ghreda	nakgib
ourtnm	ttossir
rhttyis	ekrab
schmeal	