Boston College

THE ELEPHANT AND THE RIDER: THE PREFRONTAL CORTEX, ATTENTION REGULATION, AND EUDAEMONIC WELLBEING

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by

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CHAPTER I

Introduction

All human experience is filtered through many lenses, one of which is attention. Like a magnifying glass, attention emphasizes some information with the natural consequence of excluding other information. Human beings have many powerful sensory perceptions including senses of sight, direction, and touch that provide a constant, potentially overwhelming stream of information to the brain, and the attention regulatory system serves to identify the most important information within that stream by strategically shifting or sustaining attention (Arnsten & Castellanos, 2011). Consequently, the system of attention regulation has much power in determining how one interprets and makes meaning of experiences.

The majority of neurological research on attention regulation takes a reductionist approach. Researchers use fMRI techniques to find connections between discrete capacities and isolated brain regions. While this helps to map brain functions and understand the underlying tasks necessary to regulate attention, it prevents researchers from considering the broader system of attention regulation. One task of this review is to synthesize these disparate studies into a unified understanding of the system of attention regulation.

This task is assisted greatly by utilizing Dr. Jonathan Haidt's psychological framework presented in his book, The Happiness Hypothesis (2006). In this text, Haidt presents research suggesting that the Prefrontal Cortex (PFC) and subcortical regions of the brain developed at different times and for different reasons. From this neurological research, he creates a framework for connecting brain functioning to elements of human behavior. This framework, reviewed in the body of this thesis, furthers the task in three major ways: (1) It provides a neurological context for understanding individual neurological studies in a grander scheme of brain function. (2) It introduces the concept of neurological conflict in which various brain regions promote differing and mutually exclusive behaviors. (3) It enables a discussion of neurological functioning to be understood in the larger context of human behavior, pursuit of long-term goals, and potential for eudaemonic wellbeing.

The second task of this thesis is to examine the relationship, if one exists, between attention regulation and eudaemonic wellbeing. Happiness is considered to be one of the most important life aims in the U.S. and many other countries (Diener, 2000). Ancient philosophers made a variety of claims about human happiness. Plato believed that human happiness resulted from bringing desires into alignment. Aristotle argued that eudaemonic wellbeing, today interpreted as thriving or flourishing, is the ultimate good. Modern psychological researchers take a variety of approaches towards studying human happiness, and most of these approaches can be categorized in to three major definitions of wellbeing: Hedonic wellbeing, Eudaemonic wellbeing, and psychological adjustment. Hedonic wellbeing is what Dr. Seligman calls “the Pleasant life” (Seligman, 2002). This form of happiness is defined by the level of positive affect and pleasurable experiences a person has throughout a given period of time. A person who has more positive experiences, whether they arise from seeing the great wonders of the planet or frequenting prostitutes, is considered to be happier than those who do not have as many positive feelings. This is most typically measured with the PANAS (Positive Affect Negative Affect Schedule) scale (Watson, Clark, & Tellegen, 1988). This scale consists of 10 positive (e.g. enthusiastic, excited, and interested) and 10 negative emotions (e.g. afraid, scared, and nervous).

Researchers have investigated eudaemonic wellbeing through the Satisfaction With Life (SWL) measurement (e.g. "In most ways, my life is close to my ideal" and "I am satisfied with my life"), the 7 thriving indicators (e.g. school success, leadership, and valuing diversity) and others (Diener, Emmons, Larsen, & Griffin, 1985; Scales, Benson, Leffert, & Blyth, 2000). These measures are categorized as belonging under the eudaemonic heading because they assess the degree to which an individual is thriving and fulfilling self-perceived potential.

Finally, psychological adjustment is loosely described by Plato's characterization of happiness. Adjustment is defined as maintaining equilibrium, and it is often measured in a particular context such as relationships or in response to the onset of a life trauma such as cancer or disability (Adjustment, 2012; Spanier, 1976; Mundt, Marks, Sheer, & Greist, 2002; Watson et al., 1988). Measures of depression could also be considered to be a measure of adjustment because depression signifies a chronic imbalance.

This review focuses on the flourishing life because this definition of wellbeing best aligns with the aims of education. Transformational educational documents such as A Nation at Risk have emphasized the importance of maximizing the fulfillment of student potential and the role of education in enabling students to thrive in the work setting. This focuses on flourishing in one life domain: work. Some contemporary educational philosophers argue that this is unnecessarily strict and that other life domains should be included within the scope of education (Noddings, 2003). This aligns with the definition of eudaemonic wellbeing which spans all life domains. Therefore, eudaemonic wellbeing will be operationalized in this review as flourishing within many life domains. The second task of this thesis is to understand the relationship, if any, between attention regulation and potential to flourish in a variety of life domains.

In summary, this thesis reviews Haidt's psychological framework, the neurology of attention regulation, and the role that meditation plays in promoting eudaemonic wellbeing through the strengthening of attention regulation. This thesis reviews these fields with the hopes of accomplishing three tasks: (1) reviewing Haidt's framework, (2) establishing a unified understanding of the system of attention regulation, and (3) understanding how that system relates to eudaemonic wellbeing.

CHAPTER II

Review of Literature

The Elephant and the Rider

There is a long history of using metaphor to understand the mind. Buddha described the mind as like an unruly elephant (Mascaro, 1973). Plato described the mind as a chariot with a rational driver, a noble disciplined horse, and a wild stubborn horse (Cooper, 1997). In line with this long tradition and with the help of modern neurological research, Haidt offered a metaphor of the elephant and the rider (Haidt, 2006).

First it is important to explain the nature of the metaphor, then the research behind it will be reviewed. Haidt argues that, while the experience of the brain is unified, the brain is divided in three important ways. It is divided between left and right with certain functions such as language processing being typical of specific sides. It is divided between new and old where the old portion brain, or limbic system, is characteristic of other closely related animals while the new portion of the brain, or the neocortex, is largely unique to human beings. Finally, it is divided between automatic processes and controlled processes. He argues that the automatic processes (e.g. heart, breathing, balance, etc.) which are continually running are rooted in the older limbic system and make fewer mistakes, have a more powerful reward system, and can run simultaneously. He posits that the controlled processes (e.g. logical reasoning, long-term planning, language) are mostly rooted in the neocortex and make more mistakes, are less powerful, and are limited to one process at a time (Haidt, 2006, 6-17).

He synthesizes these results by claiming that the neocortex and limbic system often act in odds with one another whereby the neocortex tends to favor long-term goals and the limbic system tends to favor short-term rewards. He thereby characterizes the limbic system as a wild elephant and the neocortex as a rider. Because the limbic system is more powerful, it can often override the neocortex in the same way that an elephant can act however it chooses despite the meek disapproval of a human rider. (It is important to note that he is not attributing human characteristics to brain regions. He is arguing that these brain regions have unique functions and that those functions promote behavior either by generating desires for goals or strategies for achieving those goals.) He furthers his analysis by claiming that individuals can gain discipline and strengthen the power of the rider. He argues that this practice promotes eudaemonic wellbeing because the long-term goals and strategic planning pushed by the neocortex is a drive towards flourishing while the reward system of the limbic system is largely a drive towards hedonic wellbeing (Haidt, 2006).

Unfortunately, the research he presents in his text is at times misrepresented and the analysis is at times untethered by empirical data. However, through a review of neurological research, other studies have been found that provide a solid foundation for this metaphor. Haidt cites a study from Olds and Milner (1954) which he interprets by stating "when some regions of the hypothalamus are stimulated directly with a small electric current, rats, cats, and other mammals can be made gluttonous, ferocious, or hypersexual, suggesting that the limbic system underlies many of our basic animal instincts" (Haidt, 2006, 11). However, this study consisted of implanting electrodes in the brains of rats and stimulating the brain when a rat pressed a button. They found that the rats pushed the button most frequently when the electrode was implanted in the septal area of the brain (Olds, & Milner, 1954). Consequently, this study does not report findings on cats or other mammals or on whether or not this compulsive behavior was motivated by gluttonous, ferocious, or hypersexual drives. The finding of Olds and Milner is important to Haidt's framework in that it suggests that an impulsive motivational system exists in the limbic system; however, other studies must be drawn on to support this and explore the extent to which the limbic system "underlies many of our basic animal instincts" as Haidt asserts.

Recent research has supported the position that a region in the human limbic system serves as a wanting system in which desires are generated. In a recent review, authors Berridge & Kringelbach (2008) present evidence of three motivational mechanisms in humans: liking (also defined as pleasure), wanting, and learning. Researchers have combined the findings of numerous studies to map the hedonic hotspots and reward loops of the brain (see Appendix A and B). A variety of neurological studies have linked pleasurable sexual and gustatory experiences to regions of the limbic system, but the presentation of food also corresponded to greater activity in the Orbitofrontal Cortex (Heath, 1972; Gottfried, O'Doherty, & Dolan, 2003;). Interestingly, further fMRI studies have found that participants seeing or smelling food while hungry have especially active amygdalae and Orbitofrontal Cortices, but this activation decreases significantly when sated, particularly when sated on the food being seen or smelled (Kringelbach, O'Doherty, Rolls, & Andrews, 2003; O'Doherty, 2000).

The Orbitofrontal Cortex (OFC) is part of the PFC and found to be critical for making economical decisions (Wallis, 2007; Padoa-Schioppa & Assad, 2006). For example, in a classic study, 4 rhesus monkeys with Orbital Frontal lesions were compared with 4 without lesions (Butter, McDonald, & Snyder, 1969) When presented with food and nonfood objects, the impaired monkeys were more likely to reach for the nonfood items (30 our of 45 trials) while the controls only rarely reached for the nonfood items (10 out of 45 trial). When presented with only food options, both groups demonstrated similar preferences. In a modern replication of this study, researchers found that monkeys with impaired OFCs were equally capable of discerning the objects and did not show signs of learning disability, and they again found that both groups demonstrated similar preferences when presented with only food options (Izquierdo, Suda, & Murray, 1999). These studies, in conjunction with the studies reviewed above, seem to suggest that the OFC is an important part of the reward circuit. It seems to be the center for an economic value assessment across dissimilar objects. In other words, it may allow the brain to compare apples to oranges but is not necessary for comparing apples to apples (as the monkeys demonstrated similar preferences when only food items were presented). The OFC appears to be a center for "wanting," and that wanting seems to be informed by its assessment of the value of the object.

At this point in the review, it is important to analyze these findings to see the extent to which the support Haidt's framework. It is clear from the mapping of the motivational systems of the brain as seen in Appendix A and B as well as the research on the OFC that the motivational system is not rooted entirely and uniquely in the limbic system. However, the framework may still hold if the role of the motivational systems in the PFC is categorically different from the role of the systems in the limbic system. The research on the OFC seems to suggest that these two brain regions serve categorically different roles in the overarching motivational system. The function of the OFC seems to include assessment of value across dissimilar goods, which introduces assignment of value based on rational considerations.

In a recent review of self-control literature, researchers Hofmann, Friese, & Strack (2009) propose a model for more accurate predictions of self-control outcomes. In their review, the authors suggest that previous models have been less accurate because they fail to account for the subtleties of the value assessment process. They argue that the weighting of options is not just between short-term and long-term aims but that there are two independent systems working within the motivational system and that the self-control outcomes depend upon the influence of both of these systems. They call these two systems the "impulsive system" and the "reflective system" (Hofmann, Friese, & Strack, 2009). They argue that the impulsive system in motivated by learned associations between goods and the pleasurable or painful feelings the foster. On the other hand, the reflective system incorporates long-term strategic planning to assess the value of an action. In other words, when presented with a pleasurable but unhealthy food, the impulsive system rates how pleasurable it will be to consume the food while the reflective system compares the pleasure of consuming the food with the long-term goal of losing weight. This model demonstrates one way in which the review of the reward systems can be reconciled with Haidt's framework, but the question becomes, is this the best understanding of the research?

The famous story of Phineas Gage can provide an introduction to the role of the PFC in executive control. In September of 1848, the then 25 year-old construction worker by the name of Phineas Gage survived an accident in which an explosion shot a metal pipe through his skull. Until relatively recently, psychologists could only speculate as to which brain regions were effected by the injury, but researchers recently took measurements of the skull of Phineas Gage to determine the extent of the injury his brain suffered (Damasio, et al., 1994). The researchers found that Gage likely lost both his left and right PFC. The consequences of the injury on Gage's actions and decisions were profound. Previously a responsible and well-mannered citizen, Gage became wildly irresponsible, disrespected social norms, and was soon fired from his job. His doctor described his new behavior as tending towards "animal propensities (Damasio, et al., 1994). This provides further evidence for Haidt's metaphor, but while this is only one example, modern research has replicated this finding.

Researchers conducted a study in which 6 patients with ventromedial prefrontal cortex lesions and 14 controls participated in varients of the gambling task (Bechara, Tranel, & Damasio, 2000). In the gambling task, participants are presented with 4 decks of cards. They win or lose money based on the cards they pick, but they are only told that some of the decks will payout more (or in some cases, will prevent losses) than others. Typically some decks have higher rewards with higher punishments while others have smaller rewards but payoff more in the long-run. Under these conditions, the patients with ventromedial prefrontal cortex lesions were more likely to opt for the decks with high rewards despite the fact that ultimately they would lose more in the end. Seeing this, the authors offered three hypotheses and tested them: impaired patients are (1) highly sensitive to rewards, (2) unresponsive to punishments, or (3) unresponsive to future consequences (Bechara, Tranel, & Damasio, 2000).

In order to test these hypotheses, the researchers conducted a second study in which some decks had high initial punishment but higher future reward and others with low initial punishment but lower future reward (this was the disadvantageous deck). The impaired patients again opted for the disadvantageous deck. The authors then ran a third version similar to the first study, but in this instance the tested whether increased punishment for the disadvantageous deck or decreased reward in the disadvantageous deck would alter the decisions of the patients with ventromedial prefrontal cortex lesions. In all cases, the patients preferred to draw from the deck with the best initial result: the higher reward or the smaller punishment. This suggests that the patients were not unusually sensitive to reward (as they preferred the deck with low immediate punishment to the one with high immediate punishment despite the fact that it had lower future rewards) or unresponsive to punishment (because they preferred the decks with lower immediate punishment. Therefore, of the three hypotheses, the one that remained in-tact was (3); the patients were unresponsive to future consequences (Bechara, Tranel, & Damasio, 2000). The authors argue that the patients were "primarily guided by immediate prospects." This further supports the framework of Haidt suggesting that the limbic system creates impulses and the PFC attempts to inhibit them.

Finally, the field of executive function gives further support to Haidt's theory. Executive function is an umbrella concept including several mental capacities such as the ability to inhibit behavior, regulate attention, and prepare for the future. Using a go/no-go task where adolescent boys were required to inhibit impulses in order to follow rules, researchers found that errors (failures to inhibit impulses) corresponded to activation of the ventrolateral prefrontal cortex and to diagnosis of ADHD, which is characterized by deficits in executive functioning (Schulz, 2005). Therefore, this research suggests that the PFC is important to executive function and the inhibition of impulse.

To return to the question being addressed, is Haidt's theory the best explanation for the research reviewed here? It seems that the information is incomplete to make the judgment that it is the best theory, but it does appear to be a reasonably well-supported theory. The research suggests that various brain regions have differing functions, and that those functions can be in conflict. The limbic system may recognize the possibility of a large monetary reward and generate desire for the reward while the PFC may processes the risks associated with the reward generating a countering desire in alignment with long term goals. As the first task of reviewing Haidt's theory ends and the second task of establishing a unified understanding of attention regulation begins, it will become evident that the attention regulation literature suggests a similar dual-systems model between the PFC and limbic system providing further evidence for Haidt's theory.

Neurology of Attention Regulation

In the introduction, it was argued that the use of Haidt's theory as a framework for this thesis will provide three primary benefits: (1) It can contextualize individual findings within an understanding of the general roles of brain regions. (2) It introduces neurological conflict. (3) It can connect an understanding of the general roles of brain regions with human behavior. If the above review of Haidt's theory was successful, and if the attention regulation literature further supports his theory, then it will be possible to make meaning of individual findings as being a component of the rider (the PFC) or the elephant (the limbic system). Moreover, understanding the PFC as supporting long-term strategic thinking and the limbic system as short-term impulsive thinking, it will be possible to see how attention regulation can relate to behavior and therefore eudaemonic wellbeing. Consequently, the next task is to understand attention regulation.

Attention regulation is a highly sophisticated neurological system comprised of several underlying functions. Attention regulation is an umbrella concept that unifies various mechanisms that help to direct and organize attention. In a recently published chapter on the neurobiology of attention regulation, authors Arnsten and Castellanos (2011) identified elemental capacities of attention regulation such as the capacity to process stimulus features, inhibit distractions, and sustain attention. Moreover, Arnsten and Castellanos mapped these functions onto brain regions (see Appendix C). This empirical research underlying this chapter will be reviewed below, but it is important to note the similarities between this model and Haidt's theory. In both cases, the functions associated with the limbic system seem to be associated with reaction to external stimuli while the functions of the PFC seem to be associated with control or moderation of those reactions.

Bottom-up and Top-down Attention Regulation

Attention regulation is described as coming in two forms: bottom-up and top-down. In a neurological study of Macaca Mulatta monkeys, researchers presented the monkeys with a stimulus (a slanted green bar), and then after a 500ms delay, they were presented with 4 bars (Buschman and Miller, 2007). There were two conditions. In the first condition (bottom-up), the top left bar was the same slanted green bar while the other three were purple and slanted uniformly in a direction different than that of the original green bar. After the delay in the second condition (top-down), the monkeys were presented with 4 bars where the top left bar was the original, two other bars were green but slanted in other directions, and one bar was blue and slanted in the same direction as the original (See Appendix D). Buschman and Miller measured the time gap between the presentation of the 4 bars and the beginning of the saccade towards the original stimulus as well as neural activity of the monkeys' lateral intraparietal areas, parietal cortices, and lateral prefrontal cortices. The authors found that in the first condition (bottom-up), the monkey's saccade towards the stimulus was faster (233ms) and initiated activity first in the lateral intraparietal area, while in the second condition (top-down), the monkey's took slightly longer (272ms) and initiated activity first in the lateral PFC. In the bottom-up condition, the stimulus is highly salient and "pops-out," while the top-down condition relies on intentional searching for the stimulus. This finding suggests that elements of a stimulus makes it more or less salient and that monkeys may still regulate attention towards a stimulus when there is reason to do so.

Salience of Stimuli

Much research has been conducted on influences on the salience of stimuli. Dr. William Champlin Lewis observed the importance of novelty, and he described the reaction of attending to new or surprising stimuli as the orienting reflex (1972). Since then, researchers have further explored this mechanism. Researchers Downar, Crawley, Mikulis, and Davis (2002) habituated participants in an fMRI machine to a specific symbol by showing it to them repeatedly. After ten repetitions of the same symbol, the participants would see novel symbols interspersed with the habituated symbols. The researchers found that the participants displayed greater activity in the temporo-parietal junction (TPJ), the right inferior frontal gyrus, the right anterior insula, and the left anterior cingulate cortex when the novel symbols were displayed. Because these regions are primarily in the parietal and temporal lobes or their borders, this finding seems to support the mapping created by Arnsten and Castellanos (2011) and displayed in Appendix C.

It is important to note that the TPJ has been found to be active in other tasks related to responding to salient stimuli. In an EEG study of participants with impaired TPJs, researchers found that participants failed to generate P3-waves when hearing distracting sounds (Knight, Scabini, Woods, & Clayworth, 1989). Typically, P3-waves are generated when attention is drawn to environmental events; therefore, the lack of P3-waves in these participants, but the presence in controls suggest that the lesions are impairing some element of the attention regulation process. Interpreted in concert with the Downar et al. (2002) study, it seems that the TPJ is important for bottom-up attention regulation. Moreover, it seems that novelty is an important element of salience.

Another important factor for stimulus salience seems to be the relevance of that stimulus to behavior. For example, a $100 bill on the ground is likely to command greater attention than a $100 receipt because that bill is valuable while the receipt is not. This bill is relevant to future behavior in a way that the receipt is not. Likewise, moneys demonstrated increased activity in inferotemporal neurons when they saw colors relevant to completing a task (Fuster & Jervey, 1981). Because the monkeys responded in this way to this color only when it was behaviorally relevant and because past research with lesion studies have associated this region to visual attention, it seems that the behavioral relevance of the stimulus makes it more salient to the attentional systems.

In summary, it appears that stimuli are particularly salient when they are novel and behaviorally relevant. Moreover, because the regions active during these studies were in the parietal and temporal lobes, it suggests that salience effects bottom-up attention regulation.

Inhibiting Distractions and Sustaining Attention

Without the ability to inhibit distractions or sustain attention, attention could be continually jumping to the most novel or behaviorally relevant stimulus in one's present environment. These top-down mechanisms introduce an element of control and intentionality. While the bottom-up system seems to act as a receiver meant to filter out irrelevant stimuli and attend to valuable stimuli, the top-down system seems to be one of control in which intentions can largely manipulate attention.

Sustaining attention is the ability to continually attend to a stimulus despite a delay. In a study of patients with right frontal lobe lesions were presented with stimuli at varying rates and asked to count them (Wilkins, Shallice, & McCarthy, 1987). The authors found that the patients were unable to count the stimuli when they were presented at a rate of 1 every second; however, the patients were able to count the stimuli when they were presented at a faster rate of 7 every second. This suggests that at 1 per second the delay was long enough to disrupt the attentional network whereas the faster pace of 7 per second acted as one continual stimulus. Therefore, it appears that the right frontal lobe may be important for sustaining attention in-between stimuli.

In an fMRI study, researchers were either asked to remember 1, 4, or 6 digits while unknowingly being subjected to extra irrelevant stimuli (Bunge, et al., 2001). The researchers found a negative correlation between susceptibility to the interference and activation of the right dorsolateral PFC. The authors interpret this to mean that the area contributes to the ability to resolve the interference, presumably because the region would no longer remain active if the interference had been resolved.

These findings seem to suggest (a) that Arnsten and Castellanos (2011) were accurate in mapping these capacities onto the PFC, and (b) the functions located in the PFC seem to regulate attention according to goal-directed intentions whereas the bottom-up attention regulation seems to be driven primarily by the salience of the stimulus.

Neurology of Attention Regulation and Haidt's theory

Dr. Jonathan Haidt proposed a theory in which the PFC and the limbic system generate countering goals and thereby work against each other in order to determine behavioral outcomes. This theory seemed to be reasonably supported by the research on reward systems; however, it only seems to be supported by the attention regulation literature with a major revision to the theory. While both top-down and bottom-up neural circuits seem to be driven by differing purposes to influence one outcome, the limbic system does not stand out as playing a significant and direct role in the regulation of attention.

Still, there are interesting parallels between Haidt's depiction of the PFC and limbic system and the picture emerging from the attention regulation literature of the PFC and the parietal and temporal lobes. In both cases the PFC seems to be directed towards overcoming immediate reaction to environmental cues. In the case of the reward systems, the PFC demonstrates the capacity to economically analyze various options to determine the advantageous solution in the long-term, overcoming the allure of short-term, impulsive rewards. In the case of attention regulation, the PFC is capable of retaining attention over a delay and resolve interference thereby inhibiting and ignoring salient environmental cues. In the case of the limbic system, parietal, and temporal lobes, there is a pattern of presenting the stimuli that are time-sensitive and emergent from the environment. The limbic system processes and generates desire for immediate rewards without regard to future consequences. The parietal and temporal lobes process and identify the most relevant and novel stimuli in the environment. In both cases there is an element of conflict between reaction to the environment and control of intentions.

These elements are perhaps what is best described by the metaphor of the rider and the elephant. Presumably the rider has intentions in a way that the elephant does not. That is to say that the framework appears to maintain explanatory power so long as the "elephant" can be defined as inclusive also of the temporal and parietal lobes.

The Benefits of Haidt's Framework

Now that the area of attention regulation has been reviewed, it is possible to return to the three proposed benefits of applying Haidt's framework. (1) It can contextualize individual findings. (2) It introduces neurological conflict. (3) It can connect the general roles of brain regions with human behavior.

It is clear that the complicated nature of the brain makes it impossible to assume that certain regions are devoted specifically and exclusively to one overarching goal; however, knowledge about general guiding principles such as those described by Haidt's framework can provide valuable insight when it is discovered that a discrete mechanism is associated with a specific region. When an fMRI study finds that sustaining attention is related to the PFC, one can consider how this particular function might fit in with the general trend of functions in that region. The fact that the functions in the PFC were generally supportive of Haidt's depiction of the PFC should add credibility that the first benefit. Because all of the functions seated in the PFC seem to serve reasoned and long-term goals, it seems informative to know that a particular function is seated in the PFC. In other words, the consistency with which the findings support Haidt's depiction of the PFC supports the notion that future findings can continue to be contextualized and that contextualizing a finding can provide increased insight into the understanding of both the function and the region involved in the finding.

The topic of conflict between top-down and bottom-up neural circuits was not discussed in the attention regulation literature; however, Haidt's framework raises the question, is there conflict between the attentional circuits in the same way that there is conflict between short-term and long-term goals? That is likely a question with an empirical answer, and the benefit of applying Haidt's framework is that it raises the question and creates a suggestion for future research.

Finally, Haidt's metaphor of the rider and the elephant has implications for behavioral outcomes, namely that the resultant behavior is a consequence of which goals were more influential. However, this topic brings the thesis to its third and final task: how does the system of attention regulation relate to eudaemonic wellbeing?

Attention Regulation and Eudaemonic Wellbeing

As discussed above, eudaemonic wellbeing is operationalized as fulfillment of potential across life domains. This could conceivable be measured in three ways: (1) measuring self-perceived fulfillment of potential in each life domain through self-reported surveys, (2) gathering more objective information for each domain, for example: G.P.A. for academics, salary and career stability for work, regularity of smiles for the intrapersonal domain, and number of friendships for the interpersonal domain, or (3) combining the two. The objective measures are strong because multiple data sources can be drawn on for any one domain, and much research has already been conducted on the relationship between attention regulation and objective measures indicative of success in various life domains.

Attention Regulation and Objective Measures of Success

First, it is important to note that there seems to be a common resource that fuels attention regulation, self-control, and logical reasoning (Schmeichel, Vohs, & Baumeister, 2003). These researchers found that participants who had been tasked with regulating attention or emotion for a period of time before taking tests of logical reasoning or reading comprehension did significantly worse than controls who did not regulate attention or emotion beforehand. Moreover, regulation attention or emotion did not similarly suppress performance for the experimental group on tests of memory. This suggests that there is a common resource that fuels attention regulation, self-control, and logical reasoning. This is especially important to note because this shared relationship could suggest a common dependence. In this section, research will be reviewed that relates attention regulation to eudaemonic wellbeing, and in many cases it is possible that attention regulation acts as a third variable. In other words, if a relationship is found between attention regulation and success in a particular life domain, it is possible that one of these other capacities such as emotion regulation, self-control, or logical reasoning are the driving factors.

In a one year longitudinal study, researchers Blair & Razza (2007) found a relationship between self-regulation (including inhibitory control and attention shifting) of preschoolers predicted academic success a year later even after controlling for intelligence. Because self-control is not controlled for as well, it is not clear if this effect is driven by self-control, attention regulation, or some other variable. However, in another study drawing from 6 data sets, analysis of longitudinal data found a significant relationship between attention regulation and later academic success after controlling for academic skills, social emotional skills, and other socioeconomic factors (Duncan, et al., 2007). Unfortunately, this study does not control for self-control, and therefore it still remains a question as to whether attention regulation is driving the effect. The best way to counter this problem is to use an experimental design in which attention regulation skills are improved. Research suggests that this can be done through meditation.

Meditation

Meditation is often confused for either relaxation or spiritual prayer. In fact, it is neither. Jon Kabat-Zinn, founder of Mindfulness-Based Stress Reduction (MBSR), defines meditation as “the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience” (Kabat-Zinn, 2003, p. 145). Many meditation exercises are highly similar in that they all depend upon the mental exercise of continually regulating attention back to the present. Thus meditation is more akin to a cognitive exercise as meditators focus on the present, inevitably drift into thoughts of the future or past, and then regulate their attention back to the present. The frequent regulation of attention to the present raises the question, does meditation improve one’s ability to regulate attention?

In a test comparing long-term meditators to controls who have never meditated, the meditators demonstrated significantly better attention regulation abilities on a Stroup task as well as a variety of other attention, concentration, and cognitive flexibility tasks (Moore & Malinowski, 2009). Certainly meditation can be stressful, and those who are able to succeed in sustaining the habit of meditation for many years may begin the process with greater executive functioning and attention regulation than the general population. Therefore, it is necessary to consider a study in which participants were randomly assigned to a meditation group. In another study, researchers conducted fMRI scans of 16 individuals who had never meditated before and after an 8-week MBSR program and found significant changes in gray matter density in brain regions associated with emotion regulation and perspective taking (Holzel et al., 2011). While there are still some questions to be answered, it seems that meditation may have a significant impact at a neurological level.

Using another meditation practice known as Integrative Mind-Body Training, researchers randomly assigned 40 males to a meditation group and 40 to a relaxation therapy control (Tang, et al., 2007). After just five days of 20 minutes a day, the experimental group demonstrated improved efficiency in executive attention. Because this study used attention relaxation as the control, it demonstrates that the mental exercise of regulating attention is likely to be driving the effect. Consequently, it seems that the attention regulation may improve through meditation. Moreover, this study found that participants assigned to the meditation group experienced great vigor, improved conflict scores on the Attention Network Test, lower anxiety, depression, anger, fatigue, and stress-related cortisol over their relaxation trained counterparts. Finally, mediation seemed to improve their immunoreactivity scores suggesting they experienced health benefits as well. The results of this study provide a variety of objective measures to suggest that meditators may experience significant boosts in the intrapersonal domain, which may come as a result of boosting attention regulation.

In another study focusing on interpersonal relationships, researchers Carson, Carson, Gill, and Baucom (2004) found that couples randomly assigned to a meditation group significantly higher relationship satisfaction, closeness, and acceptance of one another, and these findings were maintained at a 3-month follow-up. This suggests that attention regulation may relate to positive interpersonal outcomes.

Finally, a meditation program in an elementary school with 64 students aged 7-9 participated in an 8-week meditation program (Flook et al., 2010). The researchers found significant increases in executive functioning in all the students but found especially strong improvements in students who began the program with executive functioning deficits. Because executive functioning is important for academic and career success, it is possible that this could be a link between attention and success in other life domains.

It is important to interpret these results with caution as it is possible that the positive results are being driven by some effect other than attention regulation. More research is necessary to follow-up on these promising findings.

Haidt's Framework and Behavioral Outcomes

Although not conclusive, the research presented above draws possible connections between attention regulation and positive outcomes in various life domains. Until this point, no mechanism has been described that could explain why attention regulation might lead to such positive outcomes. However, Haidt's framework can help to connect attention regulation to positive behavioral outcomes. Because the PFC processes long-term goals and strategic thinking, the success of the PFC in influencing behavioral outcomes will likely mean success of the individual in reaching long-term goals. If the limbic system is generating desire for cheesecake and the PFC is processing the long-term health benefits of maintaining a diet and the PFC overrides the limbic system, then the individual is more likely to experience positive health outcomes. Likewise, if the limbic system is generating a strong impulse to lay in bed and the PFC is creating plans to land the dream job, the success of the PFC is more likely to translate into eudaemonic wellbeing in the domain of work.

Translating this to attention regulation, if the mechanism for sustaining attention is weak, then the individual will likely struggle to study for long enough periods of time to experience academic success. If the mechanism for inhibiting distractions is too weak to drown out the conversations, ringing phones, and chirping birds outside, then time that was supposed to be devoted to study will be wasted. Haidt's framework lays the groundwork for understanding how the system of attention regulation could potentially promote success across a variety of life domains.

CHAPTER III

Conclusion

This thesis began with three tasks: (1) Review the empirical support of Haidt's framework. (2) Understand the system of attention regulation. (3) Understand the relationship between attention regulation and eudaemonic wellbeing. With these tasks complete, Haidt's framework was found to be reasonably well supported, attention regulation was found to map onto the brain in a way that is supportive of Haidt's framework, and attention regulation was found to hold promise for promoting eudaemonic wellbeing, but at this point the research is inconclusive.

Haidt's framework was found to be beneficial to the analysis of attention regulation and eudaemonic wellbeing in three primary ways: (1) It provided a framework through which discrete neurological studies in attention regulation could be synthesized to form a systematic understanding of the literature. (2) It introduced the concept of neurological conflict in which various brain regions promote differing behavioral outcomes and therefore work in competition for influencing behavioral outcomes. (3) It provided a framework for understanding how brain regions could relate to behavioral outcomes.

Attention regulation was found to hold promise for promoting eudaemonic wellbeing; however, much research needs to be done to test this hypothesis. It is necessary to conduct longitudinal studies in which other important functions of the PFC are controlled for, such as logical reasoning and self-control. Future meditation studies should also take into account boosts to self-control, logical reasoning, or other possible effects that could be promoting eudaemonic wellbeing in order to test the role that attention regulation plays in these positive outcomes. Finally, researchers should identify other mechanisms for boosting attention regulation.

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Appendix A

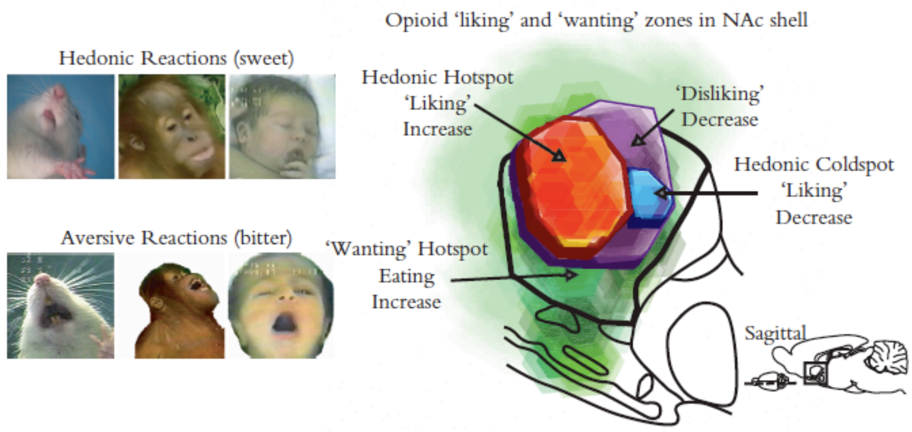


Figure 1.1 Taste 'liking' reactions and contrast map of nucleus accumbens hotspots. Positive 'liking' reactions to pleasant sweet tastes shared by human newborn, young orangutan, and adult rat (tongue protrusion; left top), and aversive 'disliking' reactions to unpleasant bitter tastes (gape; left bottom). Affective facial expressions like these provide an objective index of 'liking' and 'disliking' reactions to the hedonic impact of tastes. Opioid hotspots and coldspots for hedonic 'liking.' 'disliking,' and motivational 'wanting' are mapped and stacked within the nucleus accumbens (medial shell region shown in sagittal view; right). Virtually the entire medial shell stimulates 'wanting' for reward (e.g., increased food intake) in response to opioid stimulation (green hexagons represent individual microinjection Fos plumes) and so do other nearby structures including the core of nucleus accumbens as well as parts of the ventral neostriatum above the accumbens, and the olfactory tubercle beneath the accumbens. The much smaller hedonic hotspot for 'liking,' where opioid stimulation actually increases positive hedonic reactions to sucrose taste (red), is contained within the anterior and dorsal quarter of shell. 'Liking' reactions to sucrose are reduced by opioid stimulation in a small posterior hedonic coldspot (though still stimulating 'wanting'; blue), whereas an intermediate region that contains both hotspot and coldspot mediates opioid suppression of aversive 'disliking' for bitter quinine (purple). The hotspot zone map is modified from Peciña and Berridge (2005).

Source: Smith, K.S., Mahler, S.V., Pecina, S. & Berridge, K.C. (2010). Hedonic hotspots: Generating sensory pleasure in the brain. In Pleasures of the Brain. M.L. Kringelbach & K.C. Berridge (Eds.), Oxford University Press, pp. 27-49.

Appendix B

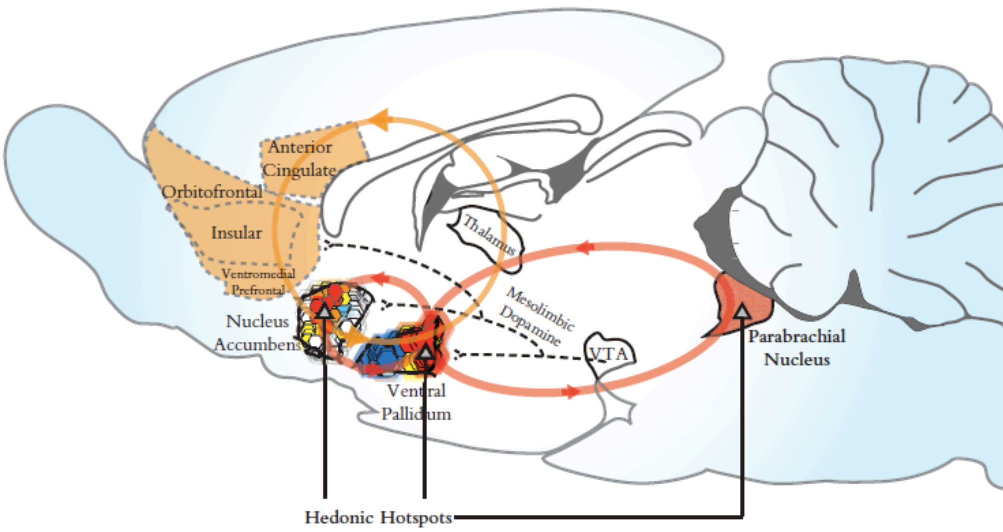


Figure 1.4 Hedonic hotspots and hedonic circuits of the brain. Opioid hedonic hotspots are shown in nucleus accumbens, ventral pallidum, and brainstem parabrachial nucleus. Neurochemical signals in each hedonic hotspot can cause amplification of core 'liking' reactions to sweetness. Hedonic circuits connect hotspots (red) into integrated loops for causation of 'liking' (orange and red loops). Additional forebrain loops relay 'liking' signals to limbic regions of prefrontal cortex and back to hotspots, perhaps for translation of core 'liking' into conscious feelings of pleasure and cognitive representations (dotted, orange cortex). Dashed, black subcortical lines show mesolimbic dopamine projections, which we suggest fail to cause 'liking' after all.

Source: Smith, K.S., Mahler, S.V., Pecina, S. & Berridge, K.C. (2010). Hedonic hotspots: Generating sensory pleasure in the brain. In Pleasures of the Brain. M.L. Kringelbach & K.C. Berridge (Eds.), Oxford University Press, pp. 27-49.

Appendix C

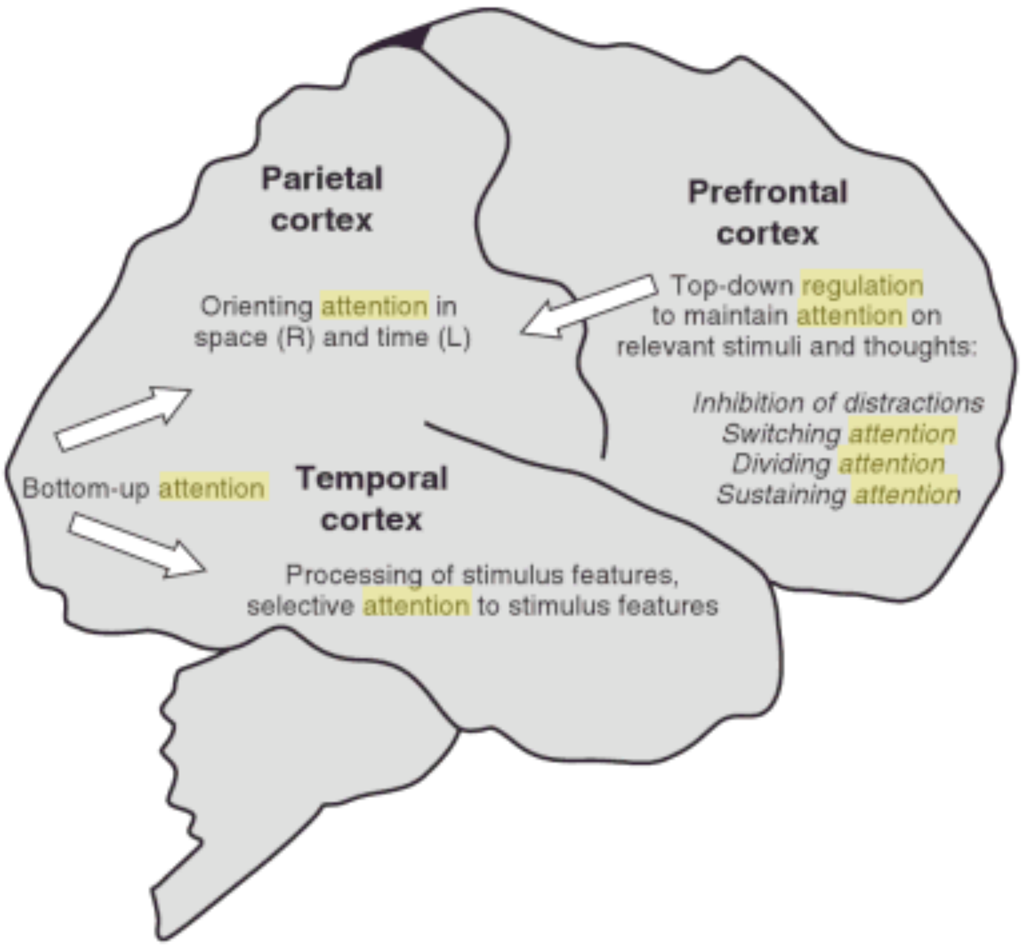
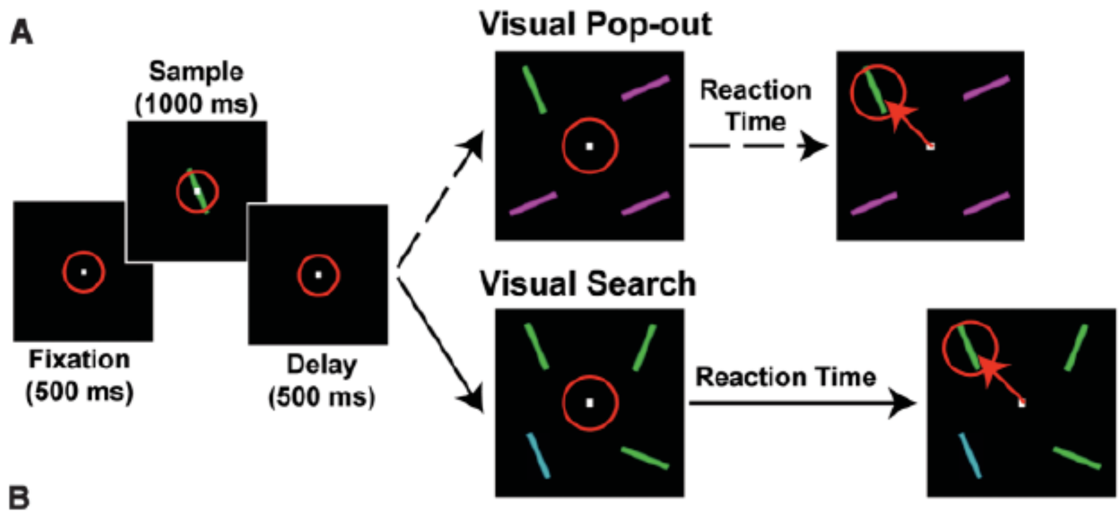


FIGURE 7.1 The prefrontal, parietal, and temporal association cortices. These cortices form interconnected networks that play complementary roles in attentional processing.

Source: Arnsten, A. F. T., & Castellanos, F. X. (2011). Neurobiology of attention regulation and its disorders. In A. Martin, L. Scahill, & C. J. Kratochvil (Eds.), Pediatric psychopharmacology: principles and practice (95-111). New York: Oxford University Press.

Appendix D



Source: Buschman, T. J., & Miller, E. K. (2012). Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices. Science, 1860(2007), 10-13. doi:10.1126/science.1138071