Medictation: Analysis of Attentional Control in Regards to Medication and Meditation

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Abstract

[From the introduction]

Side effects of some Attention Deficit Hyperactivity Disorder (ADHD) medications (like Adderall) include rapid euphoria onset, decreased appetite, insomnia, abdomen pain, and headache. The nature and intensity of the effects range from drug to drug, with some having no reported effects, some having a “market level acceptable” degree, and some having mild to severe effects. No study reviewed lasted longer than four months (Hodgkins, et al., 2012).

Around the world the prescription and usage of ADHD medications rose threefold in the ten years between 1993 and 2003 and the amount of capital flowing into that market has risen nine-fold (Scheffler, Hinshaw, Modrek, & Levine, 2007). Along with this, the frequency of cases filed by the American Association of Poison Control Centers relating to abuse of ADHD medications rose by 76% between 1998-2005 for teenagers (Setlik, Bond, & Ho, 2009).

The aim of this thesis is to analyze the mechanisms of action for leading prescription ADHD drugs and meditative practice through the intersected lens of neuroscience, clinical, and cognitive psychology research. Central to this goal will be the analysis of how these topics shed light on the development and behavior of attentional control. Science makes a promise to use its outcomes to build a better society and future. The progress from these research fields and the current clinical treatment of ADD/ADHD demand matching.

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Medication: Analysis of Attentional Control in Regards to Medication and Meditation

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The aim of this thesis is to analyze the mechanisms of action for leading prescription ADHD drugs and meditative practice through the intersected lens of neuroscience, clinical, and cognitive psychology research. Central to this goal will be the analysis of how these topics shed light on the development and behavior of attentional control. Science makes a promise to use its outcomes to build a better society and future. The progress from these research fields and the current clinical treatment of ADD/ADHD demand matching.

The Presented Analysis

Several outcomes can be expected of the presented analysis. A refined understanding of the current state of academic perspectives on attentional control and the progress of research is the first. Second is a cost/benefit analysis of endogenous and exogenous solutions to ADHD. Finally, a list of key factors that concern attentional control improvement will be produced and made available for application.
The foundation of this analysis will be built by examining the evolution-based function of attentional control. Development of attentional control processes over the lifespan reflects the evolutionary development and sheds light on the physiological affordances and limitations. These characteristics, like fatigue and processing time, frame how deficits and improvements of attentional control are defined. The completed analysis of the development and characteristics of attentional control will prime the comparison between endogenous (internally administered mechanisms, in this case personal meditative practice) and exogenous (externally administered mechanisms, medical substances) methods of attention deficit solutions.

Comparing pharmaceutical and meditative methods is structured to support both the analysis and the synthesis of information at the same time. Three research areas, neuroscience, cognitive psychology, and clinical research, that are each individually disciplined and highly interrelated, compose a framing lens. In the first step, the underlying assumptions and the states of research for neuroscience and cognitive psychology will be addressed and integrated. Applying research from the combined fields to focused meditation and psychostimulants, individually, marks the beginning of the comparison. Then I will introduce case study research of clients with ADHD and make sense of the cognitive and nervous conceptualizations of it.

The sequence of discussion was crafted to provide an opportunity to step back from the constraints of treatment and craft a model of meditation and amphetamines before the applications must be considered. That point will be the apex of the comparisons between the two. The ultimate goal here is to produce the necessary knowledge about a structured activity, or schedule of activities, that excels at improving attentional control and can be prescribed as not only a viable but also a competitive treatment.

**Brief Overview of Attentional Control**
“Attentional control” broadly describes the ability to concentrate and direct available working memory and complimentary mental components through internal and external stimuli by excluding other stimuli. Framed within this discussion, attentional control is the primary skill children and adults diagnosed with ADHD face difficulties with. Current treatments to alleviate these difficulties are typically centered on prescription stimulants/amphetamines like methylphenidate (e.g., Ritalin, Concerta, Adderall). Because the long-term effects of these substances have yet to be completely determined, it is risky to rely on them as heavily as several cultures across the globe do.

Therapy and lifestyle solutions usually supplement substance-based treatment schedules for individuals with ADHD. Meditation practice is a broad term and refers to many different styles and traditions of mental activity. One meditation strain focuses solely on sustaining attention to one and only one stimulus. This has been determined to hone attentional control and improve other cognitive skills, as well (Xue, Tang, and Posner, 2011).

Working Memory & Executive Functions

The Working Memory Model established by Baddely (2011) describes a mechanism that connects experience to long-term memory. Key components to the model include the phonological loop, the visuo-spatial sketchpad, the episodic buffer, the central executive, and the interactions that operate among those systems and with long-term memory stores are described, as well. Lack from the model is the proper description of how attending to other modalities like olfaction, proprioception, temperature sensation, and gustation fit. The central executive is the coordinating and planning system, it fills the symbolic role of the homunculus, and it houses attentional control.
Executive functions, though almost universally accepted, are open to debate in terms of specific components and definition. Juaredo and Roselli (2012) formally review the controversies in explanation and measurement that surround contemporary studies of executive control. As is often the case with acts of definition, whether executive function means a set of all unified features or separable ones, which operations are explicitly executive, and what can be considered appropriate or insufficient measurement and operationalization are salient questions. The authors never directly state it, but every function that is considered a prospective candidate for an executive function involves the manipulation and control of other cognitive and neural functions (e.g., attentional control, verbal fluency, goal-setting, action initiation).

The scientific community broadly, but not unanimously, agrees that the frontal lobes are the neural substrate for executive function. Dysexecutive syndrome is seen consistently in patients with exclusive frontal lobe damage, and it involves symptoms like difficulty coordinating complex tasks, frequent distraction, struggles with organization, and inability to form multifaceted plans. Three circuits starting separately in the dorsolateral prefrontal lobes, lateral orbitofrontal lobes, and anterior cingulate cortex and interacting with the subcortical basal ganglia and thalamus demonstrate the production of differentiated executive tasks (summarized as planning, risk/inhibition, and monitoring/correction respectively).

The amount of working memory that can be engaged at one moment is a person’s “operation span.” Holding a procedural rule task steady, while attending to the different characteristics of the task is an example of allocating working memory. If the operation span is insufficient, the procedural rule may be dropped (Baddeley, Chap.3). This limit on resources demonstrates the need for effective attentional guidance.
There is a transition from a “fluid” state to a “crystal” state of memory that appears to be marked by the binding of meaning to objects or stimuli in relation to current long-term memory. Speech would be an example of a fluid phonological process where language is the crystal component (Baddeley, Chap.3). This categorization highlights the primary role of working memory for converting fluid experience into stably memorized information.

**Dual Mechanisms**

An organism’s net attention, the finite amount of working memory, has two major sources of control. They could be looked at as the customers and the manager of a business. Customers in this comparison are the environmental or bodily stimuli that draw attention. Berthoud (2011) terms this category “metabolic and hedonic drives.” These drives are stimulus-driven and are known as “bottom-up” processes.

The manager represents attentional control faculties in the business comparison. She or he has the authority to coordinate, trigger, and stop the actions of the work staff as “top-down” mechanisms facilitate attentional processes. It is through top-down processes the brain can harness complex assemblies of different structures to complete the complex tasks required (Engel, Fries, and Singer, 2001).

**Childhood Development of Attentional Control**

Attentional control is often presented as a well-established executive function with three subcomponents: selective attention, sustained attention, and response inhibition. Evaluation using the Piagetian A-not-B task has indicated that the first signs of attentional control are at 12-months of age, peak growth occurs at 6-8 years old, and relative mastery is achieved around 12 years old. The frontal lobe circuits and other architecture in the frontal lobe and extending cortex appear to facilitate attentional control (Juaredo and Roselli, 2012).
Neurocognitive Affordances & Limitations

Affordances and limitations that exist for nervous system operations can be categorized in three main ways: structural, functional, and metabolic. Structural affordances/limitations are what happen because of the placement of operations in relations to each other and their material composition. If one could pay attention longer because the circuit ran through the amygdala as compared to if it did not, the increased affordance would be made possible by a structural reason.

If one could pay attention longer because they have trained attending to that stimulus, this would be a functional affordance. Functional affordances and limitations are defined by events and their order. Metabolic affordances and limitations would then describe what is possible for chemical and physical reasons. The availability of calcium ions necessarily limits attention span in the same way that it limits any nervous activity. The demarcation of these categories is entirely illusory, but it is useful particularly for highlighting alternative causes for the same limitation or affordance.

Sub-Components of Attentional Control

Component processing is a descriptive model of neuro-cognition that breaks any particular function down into task-units as compared to unified systems like a conceptual/perceptual system. Strategies for attentional control draw on a set of components, and the degree of reliance on one over the other may vary from individual to individual.

Four main components are fundamental and necessary for attentional control: selection/orientation, stimulus maintenance/inhibition, attention switching, and stimulus switching. None of these are particularly more important than the others, and all interact with each other during concentration and awareness. Different sub-components have different characteristics and indications of effective function.
Selection involves the discrimination of particular stimuli, either internal (like thoughts, feelings, emotions) or external (sounds, visions). The distinction between internal and external is not completely strict, for example pain is physical and external but also emotional, spoken words are both sounds and thoughts. During concentration, the task and task relevant stimuli would be considered selected and all other processing in working memory would be considered distractions.

Conflicting opinions exist regarding whether amplification of selected stimuli or distraction inhibition is more influential in attentional control. Both depend on effort and are limited by clarity in selection. Differential ability in regards to the ability to keep distractions at bay appears to be part of an individual’s temperament. Knowing where a distraction will be weakens the ability to inhibit it (Wyatt & Machado, 2012). Corticosteroids released during a distress response will create heightened sensitivity and therefore make inhibiting more difficult (Henckens, van Wingen, Joels, & Fernandez, 2012).

Attention monitoring is the metacognitive act of surveying the state of attention. This could be at a basic level (reviewing if distracted or focused) or more intricate (reviewing the saliency of multiple stimuli at once). Monitoring occupies a certain amount of working memory, so an individual may need to disengage from attending in order to monitor. In this way, excessive monitoring is also a form of distraction.

Last, switching is the complex process of moving from one stimulus to another. This may be disengaging from a distraction, moving to a new task-relevant stimulus, ending a task altogether, or others. There is a degree of lag for every person, and it is stronger in some patterns of switching than others. For example, switching targets in a card sort task without being transitioned will produce more errors than if an intermediate target exists as a transition step.
Research has provided evidence indicating that individuals diagnosed with major depressive disorder particularly struggle with switching from one thought to another (Whitmer & Gotlib, 2012).

**Evolution of Attentional Control**

Evolutionarily speaking, in order to determine if a trait emerged because of natural selection a trait must be heritable, must have specific functionality, have specific mechanisms that support that function, and it must increase an organism’s ability to reproduce (Wilson, et al, 2006). Evolved traits (i.e., adaptations) aggregate to define the function of an organism. An example is the adaptation of flight. Birds carry genes that they pass on to their offspring to shape wings for flying, and flying allows them to escape predators with a degree of ease.

In the case of attentional control, the functionality is the technical manipulation of working memory, and the mechanisms are the involved brain structures starting with the frontal lobe. Inheritance first and foremost comes from the genetic basis of attentional control, but also from any cultural traditions, beliefs, and behaviors that support control. Based on the day-to-day usage, developmental factors, and cross-species comparisons there are multiple hypotheses on how attentional control benefits reproductive fitness.

**Development of Attention Mechanisms**

Brain cortices of the most ancient of animals were primarily sensory processing oriented for chemical olfaction, somatosensation, audition, and vision. As species have evolved over time the cortices and subcortical structures that facilitate the most vital behaviors become more complex and larger. Visual cortex in arboreal mammals has more contour-oriented subdivisions for depth perception, and species that cache food and must return to their hidden spots consistently have larger memory structures like the hippocampus (Farris, 2008).
To speculate an evolutionary development of attention provides the key situational context in which its modern function and the development over the lifetime are nested. Sensation is a foundation of all life forms, demonstrated by how prokaryotes react to their environment. Physiological organization, the use of tissues, emerges in multicellular organisms with cellular differentiation. Mechanisms for physiological control then emerge to coordinate tissue function.

An example of an organism like that is the sea sponge (phylum porifera). At least one species of sea sponge, *Geodia cydonium*, possesses a receptor gene for gamma-aminobutyric acid/glutamate (Farris, 2008). Other examples are the hormones of both plants and animals like progesterone.

Body plans are advanced by physiological control, and one can deduce that functionally differentiated structures and organs would soon evolve after to match the multiple struggles of organisms. Cnidarians (e.g., coral, jellyfish) are living fossils of this stage of development, and motor reflexes evolved in tandem. Venus flytraps (*Dionaea muscipula*) also have simple motor reflexes, as do *Codariocalyx motorius*, telegraph plants, which have constantly spinning leaflet-organs that provide information on light intensity (Roberts & Oosting, 1958).

The hypothetical urbilaterian, the common ancestor with coordinated locomotion, had a body plan that was oriented in two or three spatial dimensions and had eye spots. It likely must have had anterior, posterior, left right, dorsal, and lateral orientations based on the body structures of the closest living relatives like flatworms (Farris, 2008). Nematodes however only contract left and right, so the original bilaterian species may not have had all three planes of spatial orientation.

Encephalization marks the emergence of directed locomotion and necessarily elicited the emergence of spatial perception. This is necessary because spatial orientation is required for
successful movement. This is achieved through somatosensation and visual sensation. There are multiple original perceptual systems, such as those of octopi and those of cartilaginous fish.

An octopus’ proprioception represents a key steppingstone in the development of attention: the division between perceptual and conceptual components. When grasping with their tentacles, octopi cannot form a mental image of the object in their grasp, however they can perceptually register variation in texture (Hochner, Brown, Langella, Shomrate, and Fiorito, 2003).

**Hypothetical Psychological Adaptations**

Across research, three major functions of attentional control stand out. Learning, socializing, and goal achievement, though highly interrelated, independently stand out as adaptive functions benefitted by attentional control (Wilens, Martelon, Fried, Petty, Bateman, and Biederman, 2011). One can only speculate if one or two of these functions contributed more pressure to the evolutionary development of attentional control. Very likely a major shift in the lifestyles of ancestral humans, like the development of language and society, explain significant differences between us and our closes relatives, chimpanzees, or other animals (Whiten and Schaik, 2007).

Behavioral learning, the forming of associations with stimuli, is perceptual because it only requires the recognition of stimuli, as does working memory. Originally stimuli must have triggered automatic, reactive responses, like attacking prey or approaching potential mates (Zollo and Winter, 2002).

Beyond allowing for classical conditioning, attentional control also supports learning in terms of the construction of mental models. Attending to a stimulus fundamentally improves working memory processes (Gazzaley, 2011). Of course, this is what one would expect because
at its root attentional control is the centralized harnessing of cognitive processes on determined stimulus for the sake of improved function.

Top-down attentional control would have risen when situations with multiple conflicting stimuli were adaptively solved by decision-making (Shomstein, 2012). By directing focus towards one prey in a school of fish, predators can target their attacks effectively. Also, searching functions are benefitted by attentional control when the perceptual target is rare or concealed.

Evidence supporting attentional control influence on goal-directed behavior comes from the symptoms of Attention Deficit/Hyperactivity Disorder and other examples of variation. Weakened attentional control can be correlated with substance use disorders (Wilen, et al., 2011). Also, academic performance, which requires a great deal of mental flexibility, planning, and distraction inhibition, is correlated with attentional control skills (Preston, Heaton, McCann, Watson, and Selke, 2009).

The evolution of social intelligence is constrained most by the basic cognitive limitations that enable social strategies (e.g., memory, attending, and calculation) (Whiten and Schaik, 2007). The combined factors of goal-achievement and learning along with the introduction of more complex patterns of attentional control add precision, efficacy, and technique to social skills. The social complexities of family life, mate acquisition, alliances, and status hierarchy require deft maneuvering and stress appropriate behavior, which starts in appropriate attending (Western and Strum, 1983).

Morisaka (2007) reports strong evidence for joint attention (the usage of attention to draw a peer’s attention) in bottlenose dolphins and possibly other cetaceans. This finding supports the notion that refined attentional control is an adaptation for advanced sociality. Further evidence is
found in the social influences on brain plasticity, which are significant and can acutely enable or, more often, disable developing brains (Davidson and McEwen, 2012).

Attentional control is comprised by the basic mechanisms of isolating stimuli, sustaining stimuli, switching between stimuli, and inhibiting undesirable stimuli, poor attentional control leads to distractibility, lapsing, impulsivity, and low motivation (Sarter and Paolone, 2011). The development of these skills across the lifespan follows a trajectory that has a degree of developmental determination but is highly influenced by experience.

**General Review of Attention Deficit Hyperactivity Disorder**

Attention Deficit Hyperactivity Disorder (ADHD) is characterized by behavioral indications of high distractibility, restlessness, low task perseverance, low frustration tolerance, and difficulty in group situations (Preston, Heaton, McCann, & Watson, 2009). The two subtypes, ADHD and Attention Deficit Disorder (ADD) are differentiated by the presence of greater impulsivity and activity in the case of ADHD (Vance, Winther, & Rennie, 2012). However the same diagnosis has had many different names over the past 70 years, and the original terms all related to neurobiological dysfunction (e.g., “minimal cerebral insult”) (Seitler, 2006). About 5%-10% of the children worldwide appear to be affected with ADHD symptoms (Friedman-Hill, Wagman, Gex, Pine, Leibenfult, & Ungerleider, 2010).

The cause for ADHD is not fully understood. Some evidence exists for a lag in overall maturity, perhaps due to genetic dispositions (Steffensson, Larsson, Fried, El-Sayed, Rydelius, & Lichtenstein, 1999). Evidence for correlations with temperament measures of distractibility, activity, and intensity of reaction exist, also (Foley, McClowry, & Castellanos, 2008). Seitler (2006) discusses a largely unexplored hypothesis that deep emotionality and mood labiality in children with ADHD indicate that emotional instability from either traumatic experiences or
attachment insecurity may lead to obstacles in learning attentional control strategies. Panksepp (2007) also identifies a deficiency of pro-social play amongst ADHD-labeled youth.

Nearly all ADHD diagnoses stem originally from parent, teacher, or self report in academic settings (Preston, Heaton, McCann, & Watson, 2009). However, the validity of these reports is weak, if they are not completely inconsistent. Children labeled with ADHD usually exhibit poor or insufficient study strategies, and there is a tendency for above average delinquent behavior. Though boys are more often characterized as more impulsive than girls leading to more ADHD diagnoses (Chamorro, Bernardi, Potenza, Grant, Marsh, Wang & Blanco, 2012), this may be the ramification of more societal pressure on girls to socialize.

This brings the construct validity of ADHD as a disorder, comparable to common challenges against many Diagnostic and Statistical Manual (DSM) diagnoses. Based on the reporting system and the exclusively institutional context of ADHD, there is a good possibility that the stigmatizing effect of the label has a strong impact on the development of individuals, perhaps as strong as the original difference in distractibility (refer to Figure 1). Individual differences in attentional control skills are certainly evident, however.

**Neural Descriptions of ADHD**

Many of the brain areas mentioned above in regards to attention control cognition were regions in which activation was highly correlated with ADHD. Networks involved in these areas connected both cortical and subcortical portions of the brain. Particular circuitry units involved were executive function (in the prefrontal cortex and dorsal striatum), motivational sources (ventral striatum), and stimulus expectancy (posterior cortex areas and cerebellum) (Depue, Burgess, Willcutt, Bidwell, Ruzic, & Banich, 2010).
These and other explorations of neuroscientific descriptions of ADHD conclude that interference in top-down processing is certainly involved with ADHD symptoms, and that patterns of distraction and struggles with inhibition have a shaping effect on other components of the central nervous system. Results do not indicate a anatomical difference in individuals in relation to the quality of nervous tissue, but instead a difference in activation levels and pathways (Banich, Burgess, Depue, Ruzic, Bidwell, Hitt-Lausten, Du, & Willcutt, 2009; Mazaheri, Coffey-Corina, Mangun, Bekker, Berry, & Corbett, 2010). None of the reviewed studies were conclusive to the point of saying that a clear cause of ADHD stemmed from a specific point in childhood development or what effect taking ADHD medications might have on observed differences.

**Ineffective Patterns of Attentional Behavior**

Patterns of attentional behavior that are ineffective relate back to the main subcomponents of attentional control. Impaired ability to selectively attend draws from a lack of information on what a task’s goal is or what information is required to achieve a goal. It also may draw from how convincing distracting stimuli are to the individual. Selective orientation is highly complex of the subcomponents due to the nature of the complexities of information in the environment (internal vs. external realms, non-physical patterns), and highly sensitive to socialization (Shomstein, 2012).

If an individual is struggling with particular ability to maintain selected focus or ignore unselected stimuli there is a good chance it is due to the degree of exhaustion they are facing or nutritional deficiencies. Mastery of effortful control skills is also vital to the ability to maintain and ignore (Panksepp, 2007). The more exertion an individual can summon the more effective they will be at keeping distractions at bay (Lutz, Slagter, Dunne, and Davidson, 2008).
Monitoring is a practiced skill and can only be acquired through natural reflection or education. In many ways, this is the keystone to effective concentration, and it is the central focus of mindfulness meditation (Preston, Heaton, McCann, & Watson, 2009). High affect states like panic, attraction, pain, and others heavily interfere with the ability to monitor (Engel, Fries, and Singer, 2001).

Finally, flexibility and attention switching can be ineffective in two different ways. In states of high distraction attention may be constantly switching and never rest on one place long. Alternatively, attention may get “sticky” on particular stimuli and take great exertion to navigate away from. Individual strategies for exploring which stimuli are available, disengaging from unselected stimuli, and returning to task-related stimuli vary greatly, and they can be both explicit and implicit (Wyatt & Machado, 2012).

**Comparison of Meditation & Medication**

**Neuroscience and Cognition in Meditation.**

Mindfulness meditation is the practice of using minimal effort to maintain orientation to a task. This may be for observing one’s awareness unrestrictedly, or sustaining concentration on a target. In doing mindfulness, an individual switches between monitoring and adjusting their degree of exertion, their stimulus orientation, and their efficiency to optimize focus (refer to Figure 2) (Chiesa & Malinowski, 2011). Solid evidence exists that mindfulness can improve ADHD symptoms. In addition, mindfulness can be effective in alleviating pain, anxiety, and depression (Zylowska, et al., 2007).

In a formal literature review, Lutz, Slagter, Dunne, And Davidson (2008) term the type of meditation that aims to sustain selective attention moment by moment on a chosen object Focused Attention (FA) meditation. Three main skills are lined out in this practice: monitoring
distraction, stably disengaging from distraction, and redirecting attention. The goal of their review was to produce a psychologically compatible definition of the practice based on the mental components and brain-based research in attention regulation and monitoring as they relate to meditation. Along with FA meditation, they discuss Open Monitoring (OM) meditation, defined as the un-reacting monitoring of experience. Specific pieces of evidence effectively ground the review. Two key differences between novice and expert meditation practitioners are the absence of amygdala activation in experts (improved ability to guide emotional reaction) and the amount of activity that is needed for the same amount of sustained attention.

For FA meditation specifically, the authors predict that the dorsal anterior cingulated cortex and the dorsolateral prefrontal cortex would be used for distraction monitoring components. The temporoparietal junction, ventrolateral prefrontal cortex, frontal eye fields, and intraparietal sulcus would be used for selective attention, and the right frontal and parietal areas and the thalamus would activate for sustaining attention. This is not exhaustive because activation will also include areas where the associations for the objects focused on reside (Lutz, et al., 2008).

The amount of effortful activity present during a single focusing task follows an inverted U-shape function throughout the course of mindfulness training. With more practice a person can effectively maintain, inhibit, and direct with greater effort, but with even more training the amount of activation necessary to achieve the same level of focus goes down. Well-trained experts can sustain attention with little to no effort. In this way, the benefits of transient mindfulness practice become stable attributes of an individual (Lutz, Slagter, Dunne, and Davidson, 2008).
As a neuro-dynamical process, meditation is the intentional activation of global scale neural assemblies that harness the necessary brain areas to achieve a task, then evaluate success, activate new areas, evaluate, and repeat. Over time these assemblies establish greater complexity and automaticity. Meditation can be made easier and relatable between individuals by isolating and verbally labeling steps in the cycle (Lutz, et al., 2008).

Two key observations in their conceptualization of meditation explain how meditation works. They demonstrate that meditation practice involves a schedule of state changes that lead to trait changes producing a difference in the neural activation patterns that show up in brains of novices and trained experts. Also, meditation uses and acts on the skills and neural architecture that already exist inherently in people and that are also trainable (Lutz, et al., 2008).

Neuroscience and Cognition in Amphetamines

It is difficult if impossible to separate the study of psychostimulants like amphetamines from clinical trials for ADHD specifically, and the more descriptive studies usually use animal models. Hodgkins, Shaw, McCarthy, and Sallee (2012) present a metanalysis of 330 studies on pharmacological ADHD treatment. The three main root chemicals compared were amphetamine, methylphenidate, and atomoxetine, along with respective varieties.

Amphetamines and psychostimulants appear to use noradrenaline released in the prefrontal cortex to calm and focus children who have been treated with them. Effect size and duration vary among the different drugs, and side effects also vary (presence or absence of dopamine and serotonin released in the striatum, for example). The effects usually show up between 1-2 hours after administration and last anywhere between six to 12 hours depending. Amphetamines are the preferred drugs based on their ability to meet qualities desirable in a one-per-day pill with the least side effects (Hodgkins, et al., 2012). Ignoring insurance coverage, the
average medical costs, including prescriptions, across six months was about $2,200 with atomoxetine ranking as the most expensive pharmaceutical alternative, perhaps due to its less addictive character (Wu, Birnbaum, Zhang, Ivanova, Yang, & Mallet, 2007).

Psychostimulants do cause sensitization, meaning that an individual’s responsiveness to their action becomes more acute depending on how much is taken and for how long. Kalvias, Sorg, and Hooks (1993) review this for behavioral sensitization exclusively, but it is not inappropriate to assume that if behavior is sensitized attentional control is, also. This is associated with the increase in extracellular dopamine, so prescriptions that do not release dopamine (like atomoxetine) are less likely to sensitize individuals and subsequently less likely to create addiction and withdrawal symptoms.

The success of psychostimulants in moderating the symptoms of ADHD without immediate side effects is evident. Amongst the drug test trials reviewed, several were able to provide outstanding evidence for their success and reported little to no adverse effects. However, only one study of four that looked at the life quality increase of participants had a statistically significant finding; two did not report p-values, and the other was non-significant (Hodgkins, et al., 2012).

The moderating effect of psychostimulants is the result of increased noradrenaline and sometimes dopamine in the synaptic clefts between nerve cells, according to the current understanding. The precise mechanism is unknown. Psychostimulants decrease acidity and are attracted to the lipids that cellular membranes are made of. Sulzer and Rayport (1990) discuss the possibility that their nature as bases may cause dispersal of monoamines, specifically dopamine, which would dampen the rate of neurotransmitter reuptake. Gainetdinov, Wetsel, Jones, Levin, Jaber, and Caron (1999) also explored the role of transmitter proteins in the vesicles that release
dopamine, and hypothesize that the release of serotonin, either directly or subsequently from psychostimulant’s mechanism of action, helps to explain the paradoxical calming effect psychostimulants have.

Methylphenidate (MPH) has been shown to selectively increase attentional control skills independently of working memory improvements in animal testing. In addition, the increase of attentional control follows an inverted U-shape; at significantly higher doses MPH notably interferes with attentional control (Berridge, et al., 2012). Since appropriate dosage is highly dependent on individual sensitivity, it is possible that a dosage that is ideal for one person may be too much for another.

Methamphetamine, a similar chemical composite as current ADHD prescription drugs, is no longer used for treatment due to the prevalence of addiction amongst patients, neurodegenerative side effects over time, permanent damage to dopaminergic and serotonergic axons, the reduction of grey brain matter, and overproduction of white brain matter (Hodgkins, et al., 2012).

**Comparison & Outcomes**

It is clear that both methods of improving attentional control have substantial effects. Some is understood of their underlying mechanisms and characteristics, but more exploration is required for both. Specifically, the nervous system pathways of meditation can be further explored in depth. Also, the effects of amphetamines at the cellular level can be explored in expansively more detail.

Amphetamines and psychostimulants appear to impact maintenance and distraction inhibition the most. This perhaps leads to improved switching, as well, but has little impact on monitoring and effective selection of task related stimuli. Whether stimulants improve attentional
control strategies therefore would appear highly dependent on the individual. It appears that amphetamines improve levels of activation in the appropriate brain areas the most.

Meditation is the specific practice of monitoring and Focused Attention is meditation that specifically practices effective selection and task orientation. There seems to be long-term improvement of ability to maintain focus and inhibit distraction, though not nearly as imminent as pharmaceutical options. Hypothetically, meditation has much greater impact on the development of effective pathways.

The long term effects of both, rates of change for both, and financial demands of either are needed to compare them. It would be beneficial to determine how using amphetamines while performing focused attention meditation would affect attentional control, though this research has not been performed yet.

**Ideal Attentional Control Improvement Method**

For severe cases of distraction and hyperactivity, pharmaceutical options far outweigh meditative components. However, because they offer no permanent solution, they are unviable as a treatment. Their financial cost is also a major drawback compared to meditation, for which the only cost is time. Meditation has been used by cultures for centuries; we know that it is clearly safe and effective. On the other hand many risks, both known and unknown come with the administration of psychostimulants.

The ideal method would be a hybrid treatment of mindfulness, psychostimulants, and lifestyle choices that also improve skills like effortful control and self-care. By giving individuals the tools to master their attention, they are not only given the ability to wield their pharmaceutical options better, but they may actually overcome the need for them. From a very global perspective, the desire to improve our attentional control skills represents a very
fascinating attribute for humans. If done properly, the nurturing of advanced mental techniques could radically alter society and people. It is perhaps ironic that the current drive to use pharmaceuticals is stemming from the institutions designed to achieve exactly what the pharmaceuticals do in the first place. In many ways, the discussion about ADHD is the discussion about what needs to change about contemporary education.


Figure 1. The interaction between academic evaluations for youth and subsequent Attention Deficit Hyperactivity Disorder (ADHD) diagnoses has not been given much attention. A student’s inability to maintain the institutional environment of schools may trigger a report of ADHD. This in turn may lead to greater disengagement from the academic environment, due to felt stigmatization. It also may lead to allotment of extra resources for the student in order to academically succeed. At least in part, ADHD is certainly a diagnosis of fitness in the institutional environment.
Figure 2. Mindfulness involves two main acts, evaluating and adjusting. In Focused Attention Meditation the goal is the most relaxed and on target focus that the individual can achieve, sustained for longer and longer periods.