

Smartphone Application to Supplement Treatment of  
Adult Attention-Deficit/Hyperactivity Disorder

by  
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### **Abstract**

ADHD is a neurocognitive disorder marked by inattention, hyperactivity, and impulsivity. Numerous treatments for this disorder exist, including medication, cognitive-behavioral therapy, and lifestyle changes. Cognitive-behavioral therapy for ADHD includes several components aimed to help clients strengthen their executive functioning, cope more effectively with distractions, and modify their maladaptive thoughts (Safren et al., 2017). However, these treatments rely on the patient's ability to sustain attention to the tasks necessary and engage in quotidian behaviors. Since doing these tasks is inherently difficult for those with ADHD, the primary goal of this study is to use evidence based cognitive-behavioral therapy as the foundation for developing a prototype of a phone application to supplement the treatment of adult ADHD. This phone application is intended to be an 'on the go' and easy to access resource that would augment CBT, medications or combined treatment. Thus, the creation of a smartphone app to supplement ADHD treatment may prove to be an asset to individuals with ADHD and to the medical professionals treating them.

### **Smartphone App to Supplement Treatment of Adult ADHD**

ADHD is a neurocognitive disorder marked by inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013). Numerous treatments for this disorder exist, including medication, cognitive-behavioral therapy, and lifestyle changes (Attention Deficit/Hyperactivity Disorder, n.d.). Cognitive-behavioral therapy for ADHD includes several components aimed to help clients strengthen their executive functioning, cope more effectively with distractions, and modify their maladaptive thoughts (Safren et al., 2017). Since doing these tasks is inherently difficult for those with ADHD, the primary goal of this study is to use evidence based cognitive-behavioral therapy as the foundation for developing a prototype of a phone application to supplement the treatment of adult ADHD. This phone application is intended to be an ‘on the go’ and easy to access resource that would augment CBT, medications or combined treatment. Thus, the creation of a smartphone app to supplement ADHD treatment may prove to be an asset to individuals with ADHD and to the medical professionals treating them.

As the goal of this study is to adapt evidence-based treatments to a phone application for supplemental use, it is important to understand what phone applications are already on the market. Upon scouring the Android and Apple app stores, one can see there is a definite lack of applications for the treatment and management of ADHD symptoms. Of the apps available, none address the core criteria of ADHD symptoms; available applications focus on the aforementioned lifestyle changes. These apps include periodic reminder apps that send a notification to the users phone every 10-15 minutes to remind them to complete a task, task list apps that are a digital replacement of a “to-do list”, apps that prompt users to log the amount of time they spend doing

certain activities, and applications that limit the amount of time the user is able to use certain other distracting applications on their phone.

### **Review of the Relevant Literature**

In creating a phone application to supplement treatment of adult ADHD, it is imperative to understand how ADHD is defined and classified, the epidemiology and etiology of ADHD, and the efficacy of available treatments. ADHD is a neurodevelopmental disorder categorized by a delay in brain maturation. This delay commonly effects the prefrontal cortex, the part of the brain dedicated to processing executive functions such as decision making, interference control, working memory, concept shifting, and verbal fluency (Vaidya, 2012). According to the DSM-V, a diagnosis of ADHD can only be given if the patient exhibits six or more of the symptoms present in either the inattentive category of symptoms and/or the hyperactive-impulsive category of symptoms. For the diagnosis of ADHD to be given, the symptoms must have persisted for at least six months to a degree that is inconsistent with the individual's age and developmental level. In addition, a diagnosis is only given if the symptoms interfere with functioning and negatively impacts social and academic/occupational activities. Inattentive symptoms include: careless mistakes/lack of attention to detail, difficulty sustaining attention, not seeming to listen when directly spoken to, failing to follow through on tasks and instructions, poor organization, avoiding/disliking tasks that require sustained mental effort, losing things, being easily distracted, and being forgetful in daily activities. Hyperactive-impulsive symptoms include: fidgeting/tapping/squirming, leaving a seat when expected to remain seated, feeling restless, difficulty engaging in quiet/leisurely activities, being "on the go" or as if "driven by a motor", talking excessively, blurting out answers, having difficulty waiting for one's turn, and

interrupting others (American Psychiatric Association, 2013). While an individual may be diagnosed with a predominantly inattentive, predominantly hyperactive/impulsive, or a combined presentation, the heterogeneous nature of the disorder means that no two individuals are alike. ADHD presents itself differently, even within the designated subtypes. ADHD current severity must be specified when a diagnosis is made. The symptoms may be mild (few, if any, in excess of those required to make the diagnosis, and minor impairment), moderate (symptoms and functional impairment between “mild” and “severe” may be present), or severe (symptoms are in excess of those required to make the diagnosis, or the symptoms result in marked impairment in social or occupational functioning).

ADHD is a neurodevelopmental disorder that typically develops around the age of seven. Symptoms of the disorder usually become noticeable in early childhood, with most diagnoses occurring between the ages of eight and ten. Around thirty to seventy percent of children with ADHD experience symptoms of the disorder through adulthood, though the severity of symptoms often decreases. Between five and ten percent of children in the United States have ADHD (Froehlich et al., 2011). ADHD is strongly influenced by genetics with an estimated heritability between 60%-80%. (Froehlich et al., 2011), but environmental and other modifiable risk factors have been identified. The modifiable risk factors include prenatal substance exposure (such as by smoking cigarettes or drinking alcohol or consuming drugs), heavy metal and chemical exposure (such as lead and pesticides), and poor nutrition (iron and copper deficiency, among others). Premature birth is also a risk factor for ADHD (Attention-deficit/hyperactivity disorder (ADHD) in children, 2019).

Treatments for ADHD include medications, and cognitive-behavioral therapy (CBT). Several specific lifestyle changes have proved helpful to many individuals with ADHD, such as establishing routines, managing distractions, limiting choices, engaging in exercise, having highly structured environments, specific and clear instructions, making plans, and establishing a system of goals and rewards. These lifestyle and organizational changes are integrated into CBT for ADHD, but CBT for ADHD includes other components as well. In addition to the base model for CBT, a modified form of CBT has been developed specifically for the treatment of adult ADHD (Safren et al., 2017).

In creating a phone application to supplement treatment of adult ADHD, it is imperative to understand the efficacy of available treatments. Of all the available treatments for ADHD, pharmaceutical intervention has been one of the most used and studied treatments for ADHD. There are three classes of drugs used to treat ADHD, with numerous variations in each class. These classes include short acting stimulants, long acting stimulants, and nonstimulants. The efficacy of these drugs was studied in a meta-analysis by Faraone and colleagues (2006). Their study aimed to examine the variability of effect sizes between ADHD medications. Twenty-nine studies which examined the effectiveness of fifteen drugs were included in the meta-analysis. The results of the meta-analysis suggest that while the drugs are effective in reducing the amount/severity of ADHD symptoms, there is a large variability in effect size between the drugs used and the ADHD subtype of the participants.

Medications for ADHD include central nervous system stimulants, atomoxetine, antidepressants, and antihypertensives (Attention Deficit/Hyperactivity Disorder, n.d.). In addition to the base model for CBT, a modified form of CBT has been developed specifically for

the treatment of adult ADHD (Safren et al., 2017). Central nervous system stimulants are the most commonly used, including drugs like methylphenidate and amphetamine, and can be either short lasting or long lasting. These medications can help mitigate certain symptoms of ADHD by helping clients to improve their attention, control their impulses, and following through with tasks, but they do little for forgetfulness, emotional problems, disorganization, and distractibility. common side effects for these drugs include restlessness, difficulty sleeping, loss of appetite, headaches, upset stomach, irritability, depression, dizziness, racing heartbeat, and tics (ADHD Medications, 2020). Stimulant medications are highly efficacious with an average response rate of 70%. These drugs also have one of the largest effect sizes of any treatment, averaging around 1.0. Long term exposure to this class of drugs has been shown to minorly stunt growth, and occasionally cause heart complications. While stimulants are a controlled substance, there is little risk of development of substance abuse disorders. These drugs are believed to stimulate dopamine activity in the prefrontal cortex, the area most responsible for executive functioning (Stevens et al., 2013).

Atomoxetine, a non-stimulant drug, affects the body's levels of norepinephrine. It is prescribed for patients with ADHD who have shown adverse side effects to stimulants, patients with substance use disorders, and patients with tic disorders. Side effects of this drug include nausea, decreased appetite, insomnia, increased blood pressure, decreased libido, and dysuria. In a double-blind trial to determine the efficacy of atomoxetine, results showed a significant improvement over placebo (Kolar et al., 2008).

Among all the antidepressant drugs, the most used in the treatment of ADHD are bupropion, and tricyclics. Bupropion is commonly used in patients with comorbid substance

abuse disorders, and bipolar disorder. Common side effects for this drug include headache, nausea, dry mouth, insomnia, sweating, and constipation. While research on this drug shows its effectiveness in treating ADHD as compared to placebo, it has yet to be approved for ADHD use by the FDA. Tricyclic antidepressants have been shown to decrease hyperactivity, but not improve concentration. While tricyclics have shown to be effective in treating ADHD, they are not nearly as effective as stimulants and are associated with more side effects. These side effects include dry mouth, sweating, constipation, blurred vision, insomnia, decreased appetite, tachycardia, increased blood pressure, EKG changes, hypotension, and drowsiness. (Kolar et al., 2008)

Among the antihypertensive drugs used to treat ADHD, the most commonly used are clonidine and guanfacine. Clonidine has been shown to be effective in reducing symptoms of hyperactivity and impulsivity, but not improving attention. Side effects of clonidine include dry mouth, sedation, drowsiness, dizziness, and constipation. Guanfacine is less sedating and longer lasting than clonidine and has the same side effects as clonidine. However, guanfacine has been shown to improve attentional abilities, as well as decrease hyperactive and impulsive behaviors (Kolar et al., 2008).

Unfortunately, medication response is not fully reliable, as 30% of individuals do not respond to stimulants. Furthermore, certain individuals report side effects that outweigh the benefits presented by medication. Further meta-analysis and research into drug efficacy should include data regarding individuals who ceased drug use, in order to understand the efficacy of drugs for ADHD, not just individuals who benefited from them. For the purposes of this project,



the only way to implement medication into the app would be to create a medication tracker and reminder system. This will be further discussed in later sections.

### **Review of Prior Research to Inform Development of a Phone App**

Of the available treatments for ADHD, CBT is the most effective and researched treatment next to pharmaceutical intervention. Knouse, Tedler, and Brooks' (2017) meta-analysis combined data from prior research to create a more accurate representation of the effectiveness of CBT in treating ADHD symptoms. Criteria for consideration were that studies only included participants aged 18 or older, participants who achieved diagnosis for ADHD according to the DSM-3/4/5, the studies tested cognitive or behavioral treatments for ADHD, the treatment goal was to reduce the amount of reported symptoms/symptom severity, and outcomes were measured before and after treatment. All data where participants had taken medication were excluded. Of the >10,000 articles reviewed, only 32 met inclusion criteria. Results of meta-analysis showed that for all trials CBT reduced the presence of inattentive symptoms significantly more than hyperactive-impulsive symptoms. This is possibly explained by the fact that CBT treatments for ADHD are specifically designed to address the inattentive symptoms rather than the hyperactive-impulsive symptoms. Knouse and colleagues' (2017) work is critical to the development of an ADHD treatment supplement as it highlights the shortcomings of currently available treatments. Additionally, even though medication is considered as the first line of treatment for ADHD, it is important to note that about 30% of those diagnosed do not take medication due to side effects and other medical conditions that prevent them from doing so. Furthermore, most of those who do use medication still report symptoms of ADHD.

Future meta-analyses should look at the effects of medication in managing ADHD symptoms. This meta-analysis looked solely at adults with ADHD who were treated with CBT and does not compare the results of CBT treatment to the results of medication treatment or combinatory medication and CBT treatment. It is impossible to achieve a clear outlook on symptom management without looking at how medication effects symptoms, and how medication and CBT combined, effect symptoms. Future meta-analyses should also look at the effects of CBT on children below age 18. By teaching children from a young age how to best manage their symptoms through therapy, and by making them more aware of said symptoms early on, one can hypothesize that the ability of people with ADHD to manage their symptoms could increase beyond that of adults who were recently exposed to CBT.

Multiple other studies explore the efficacy of CBT on ADHD and have found similar results as Knouse and colleagues. In a study by Dittner and colleagues (2018), sixty participants with adult ADHD were randomly selected to participate in a “treatment as usual” group, or a “treatment as usual” combined with CBT. Their scores on the Barkley Current Symptoms Scale and the Work and Social Adjustment Scale were taken. At the end of sixteen weeks, their scores were collected again. While the results showed a difference in effect size (0.52 – 1.01), the results were insignificant. This could be explained by the relatively small sample size, as mentioned in the stated article. However, the researchers failed to include information regarding prior treatment; it is possible the participants in this study had found treatments that were successful in reducing ADHD symptom presence prior to participating in the study.

Since CBT has proven to be effective in treating half of all the ADHD symptoms listed in the DSM-V, it is only logical to develop phone application features that would parallel and

support CBT for ADHD. It is necessary to develop the app with researched and tested techniques that have been proven to decrease the symptom severity of ADHD because an app that augments ADHD treatment needs to be built on a foundation of evidence-based research. Safren and colleagues (2017) wrote a therapist's guide to a cognitive behavioral treatment program for ADHD. This guide was chosen because the efficacy of this treatment has been thoroughly evaluated, and it has been found to be efficacious in diminishing the inattentive (but not the hyperactive) symptoms of ADHD. In a study, thirty-one adults with ADHD and stable medications were randomly sorted into two conditions; medication plus CBT, and medication alone. The severity of their ADHD symptoms was measured via self-report and independent evaluator pre and post treatment. Results indicated a significant reduction in symptom severity within the CBT and medication group as compared to the medication alone group. Analysis of participant data showed there were significantly more responders to the CBT and medication treatment (56%) than there were for the medication alone group (13%). The results of this study support the idea that Safren and colleagues guide to CBT for ADHD is an effective and reliable treatment (Safren et al., 2004).

Aside from the regular structure and steps in traditional CBT, Safren and colleagues' guide covers each step of the ADHD treatment in detail and breaks them down into three core stages. The first stage is about organization and planning skills. It includes teaching effective and consistent use of calendars and task lists, effective problem-solving skills (including breaking larger tasks into smaller/more manageable tasks and finding the most ideal solution in a situation) and developing a method of ranking and organizing papers/emails/mail. The second stage focuses on managing distractions. This includes gaining an understanding of optimal

lengths for sustained attention and learning how to use a timer and other technique to limit distractions. The third and final stage is about cognitive restructuring, or adaptive thinking. This stage covers how to view and think about problems/stressors more positively, dispute negative thoughts, and how to view situations rationally. “Mastering Your Adult ADHD” (Safren et al., 2017) outlines how each session will focus on establishing an agenda with the patient, to keep them on track with the treatment, monitor the patient’s progress, and review any and all homework assigned to the patient.

Those with ADHD are struggle with planning and prioritizing, task initiation, and organization. These are all executive function skills affected in ADHD. The organization and planning outlined in “Mastering your ADHD” (Safren et al., 2017) starts slowly by introducing the patient to a task list and calendar system. A heavy emphasis is placed on the development and application of said systems because of their importance in organizing thoughts and tasks. The calendar also serves to make sure all the necessary appointments and work are completed in a timely fashion. The book specifies that the system used is purely up to the patient to decide, whether it be a phone app or physical calendar/master task list, but there doesn’t appear to be a specific phone application designed for this structured therapy. After the patient becomes more comfortable with the calendar and task list, the therapist introduces the idea of prioritization of tasks, and subsequently developing a system to organize the task list to reflect priority levels from high priority to low priority; “A” level, “B” level, and “C” level. This is done to ensure the patient focuses on high priority tasks, like paying bills and doing necessary work, before completing lower priority tasks. Next, the patient is taught problem solving skills and breaking down tasks into smaller and more manageable chunks. The problem-solving system consists of

five steps; articulating the problem, listing all possible solutions, listing the pros and cons of each solution, rating each solution, and implementing the best option. To break down tasks, the patient is instructed to list each step involved in completing large or overwhelming tasks and add each step into their master task list. Finally, the patient is taught skills regarding the organization of digital and physical mail. This includes having select and specific locations for each type of important document (bills, tickets, bank notices, etc.), as well as discarding all unnecessary mail.

Distractibility is directly related to attention shifting, impulse control, and working memory. These are some of the executive function skills those with ADHD are deficient in. Distractibility reduction starts with understanding how much time the patient can reasonably sustain attention on one task and implement distractibility delay. Gauging attention span consists of the patient consciously thinking about their current state (understanding whether they are they hungry, fatigued, disinterested in the task, overwhelmed by the complexity, etc.). By understanding their limitations, they can judge more accurately which tasks to complete and what needs to be broken down or adjusted to fit their capabilities. The idea behind distractibility delay is to “park” unnecessary and disruptive thoughts and come back to them at a more appropriate time. A common concern of individuals with ADHD is that they often think of something while working on a task, and their anxiety about forgetting the thought causes them to shift their focus onto the new task and abandon the first. By writing down their distracting thoughts, they can focus their attention on the important task they were doing, and after completion decide whether the items on their list are worth doing, adding to their task list, or discarding. Next, the patient is taught to control their work environment, keep track of important items, set reminders, and use alarms. Strategies for maintaining a proper work environment

include putting your phone on “do not disturb”, closing web browsers/email, cleaning the workspace, turning off the radio or TV, and asking others to avoid distracting the patient.

Another technique is keeping track of important items includes designating specific locations for said items, for example placing glasses on top of the nightstand and a hanging rack next to the door for keys and coats. By using alarms or an electronic calendar, a patient could set reminders to go off at specific times to keep them on track with their task list and other necessary work.

Those with ADHD have difficulty with the executive function related to flexible thinking, emotional control, and self-monitoring. The final module of treatment outlined in “Mastering Your Adult ADHD” (Safren et al., 2017) is about adaptive thinking. This section of the book first covers the cognitive component of the cognitive-behavioral model of ADHD, automatic thinking, and the relationship of thoughts to behaviors and feelings. It starts by explaining the cognitive-behavioral model of ADHD and how by increasing awareness of the negative/unhelpful thoughts, the patient can reduce the degree to which these thoughts interfere with tasks and add to distress or distractibility. The first step is learning to identify the patient’s automatic thoughts when faced with an obstacle and labeling the thinking errors associated as; all-or-nothing thinking, overgeneralization, mental filtering, disqualifying the positive, jumping to conclusions, magnification/minimization, catastrophizing, emotional reasoning, “should” statements, labeling/mislabeling, personalization, maladaptive thinking, and overly optimistic thinking. After identifying the negative thought or thinking error, the patient is instructed to reframe the thought in a more productive manner. For example, thinking “I have to finish this today and it has to be perfect” is all or nothing thinking. A reframed response to these thoughts may be “It is due tomorrow, so I still have time to finish it” and “I can always ask my coworker

or boss for help if I need it". By reframing a maladaptive thought, the patient gains a new viewpoint on the situation that benefits them and reduces their stress/anxiety/depression.

### **Considerations for App Development**

A phone application that parallels and supports this treatment course would likely be highly beneficial to patients. Each aspect of treatment covered in this book can be translated into a mobile phone feature, thus making treatment more accessible. Not only would these application features be more accessible, they would make it easier for clients to track their progress, keep up to date with homework assigned by this program in the accompanying patient handbook, maintain and update task-lists and calendars, take notes for distractibility delay, and set alarms and reminders. In addition, these application features would provide immediate feedback on progress and work, and accessibility to both the patient and the medical professional treating them.

Finally, an application designed to supplement the treatment of ADHD would have to appeal to as many users as possible in order to be considered an effective tool for the treatment/management of ADHD. It is known that ADHD affects executive function, however it is not the only disorder known to do so. Marchetta and colleagues (2008) examined the disorders commonly associated with ADHD in their study "Interference Control, Working Memory, Concept Shifting, and Verbal Fluency in Adults with ADHD". Their study analyzed the executive function ability of individuals with just ADHD (ADHD-), individuals with ADHD and one or more comorbid disorders (ADHD+), individuals who exhibited some of the symptoms of ADHD but failed to meet the requirements for diagnosis (non-ADHD), and a control group of individuals without ADHD. Their study found that the ADHD-, ADHD+, and non-ADHD

groups performed at a lower level than the control group in verbal working memory and concept shifting, supporting the results of prior research in this field. Marchetta and colleagues (2008) also found that the ADHD+ group did significantly worse than the ADHD- group, supporting the conclusion that the comorbid disorders associated with ADHD add significantly to impairment in executive functioning experienced by people with ADHD. In designing a supplementary application for the treatment of ADHD, this is important information to consider and account for; ADHD has a comorbidity rate of thirty to sixty percent. These comorbid disorders include antisocial-personality disorder, substance abuse disorder, anxiety disorders, mood disorders, and learning disabilities. Since ADHD is often comorbid with other psychological disorders, an application designed to help augment the treatment/management of ADHD must account for the large population of individuals who fall into this category.

Unfortunately, Marchetta and colleagues (2008) failed to differentiate between the types of comorbid disorders as well as the severity and amounts used in the ADHD+ group. Thus, there is a possibility that different comorbid disorders affect executive function differently. Future studies should analyze the differences between the ADHD+ subgroups to determine whether those with ADHD and comorbid disorders differ from each other and the comorbid disorder by itself.

ADHD is a neurodevelopmental disorder categorized by a variety of inattentive and hyperactive-impulsive symptoms, as well as deficits in executive function and working memory. While treatments for ADHD exist, they require the individual to perform tasks that they would normally have difficulty performing. However, not only do the treatments for ADHD not address all the symptoms of ADHD but improving inattention and hyperactivity-impulsivity requires



sustained attention and self-control; this presents a “catch-22”. To reduce the difficulties associated with the treatment of ADHD, a smartphone-based supplement to aid said treatments would provide an on the go and easily available method for monitoring and maintaining progress for both the patient and professional treating them. It would provide external cues and reminders to keep them focused on their tasks, as well as provide easy access to materials used in treatment. This app, in conjunction with regular visits to mental health professionals, would theoretically improve the effectiveness of treatment and prove to be an asset in the treatment of ADHD. In addition, by providing exercises that focus on improvement of executive function, symptom severity in patients with ADHD could be diminished.

### **Prototype App Design**

To illustrate how a phone app to augment ADHD treatment would work, the researchers of the current study have designed a prototype. This prototype is based off the guide by Safren and colleagues. The phone application will adapt the necessary functions and tools described in the three stages of treatment. Stage one relies on the usage of a calendar and task list sorted by priority. Stage two involves the usage of a timer, alarms, and a notepad for distractibility delay. Stage two also mentions reduction of distractors, which will be implemented in the form of a “work mode” feature. This feature will not allow the user to access any other apps on their phone until turned off. Stage three involves cognitive restructuring of automatic thoughts. A worksheet for cognitive restructuring will be added to the app as well. Among the listed items, a system of goals and rewards will be implemented as a form of positive reinforcement for using the app. The app will also be directly connected to an administrator account operated by the therapist performing the treatment. The administrative account will be used to assign homework, reveal

sections of the app as treatment progresses, and monitor the patients use of the app. This is to ensure that the patient is consistent with the treatment and for the therapist to track the patients progress more accurately.

The prototype app will contain all the features mentioned in Safren and colleagues' guide. The app will start with a calendar as a home page, where each date on the calendar opens to reveal the day's events, task list icon, timer icon, and notes icon (Appendix A). The task list icon will open to reveal an itemized task list where entries can be added, removed, crossed off, and sorted by level of priority as discussed in the treatment guide (Appendix B). The timer icon will open to reveal a list of programmable timers and alarms (Appendix C). The notepad icon will open to reveal an itemized notepad where the user can create written notes, take photographs, record audio, and record video (Appendix D). On the home page there will be buttons for a list of the homework the patient will have needed to complete as assigned by their provider, and a list of worksheets to be used as necessary. An example of a worksheet has been provided (Appendix E). The home screen will also include a toggle for activating "work mode", in which only chosen phone apps and functions are accessible. The prototype was designed as a localized app for all the tools necessary for the treatment. It was designed as an accompaniment to regular visits to a therapist, not as a replacement for treatment.

In summary, the app will be the first phone application to adapt evidence-based therapy techniques to augment the treatment of ADHD. This app improves upon evidence-based CBT by providing an on the go, compact, and simple to use program that contains the necessary tools described in the treatment of ADHD with CBT. In addition to hosting features described in the treatment plan for ADHD, users can limit their distractions and organize certain systems more

efficiently as they are all located in one virtual space. There are, unfortunately, several limitations with this technology. Mail sent by postal service and objects in the physical world will still need to be accounted for, only individuals with smartphones will be able to use this app, certain individuals prefer not to rely on technology or become more distracted by it, and there is the possibility of the app being used as a crutch for a patient's ADHD instead of a tool.

Future research and development on the app should integrate other types of therapy for ADHD, including dialectical behavioral therapy. Future research should also be conducted to investigate available and proven treatments for the hyperactive and impulsive symptoms of ADHD, as CBT is ineffective in treating these symptoms. Further development of the app should include a system for managing medications; whether the patient has taken them as needed, what effects they have noticed, what side effects they've noticed, etc. Future development of the app should also include an option to connect therapist and patient accounts to track their progress in real time, assign necessary homework, and make sure the patient is using the app features as recommended. Should the app design be completed, a functioning prototype app should be developed and tested, and eventually implemented as an augment to treatment.

### **Executive Functioning and ADHD**

The key symptoms of ADHD that patients often find especially difficult to cope with concern about executive functioning and working memory. An ideal phone app would include features that address these concerns. For these reasons, it is important to review the literature that might inform the development of these features. Previous research into the working memory and central executive functions of those with ADHD showed marked deficits in ability as compared to the neurotypical population. Alderson and colleagues (2013) used this information and

previous studies to perform a meta-analysis of executive function ability in adults with ADHD. Alderson and colleagues (2013) examined previous studies that compared adults over the age of eighteen with ADHD to adults over the age of eighteen without ADHD. Inclusion criteria for the meta-analysis were: the studies were published articles written in English, included between-subjects comparisons, phonological or visuospatial working memory tasks, and sufficient data to calculate an effect size. Thirty-eight studies that met the requirements were selected. The moderating variables used in the meta-analysis include the process of obtaining information, gender, age, trials per set size, response modality, performance metric, central executive demand, and effect size estimation.

The findings of said meta-analysis show a significant effect size of 0.55 and 0.49 for phonological and visuo-spatial working memory, respectively. This indicates that adults with ADHD have worse working memory abilities than neurotypical individuals. However, the findings of the current study do not support the findings of previous studies, as their effect sizes were smaller. This suggests that a difference in methodology affects results on working memory tasks. Several variables were found to affect reported effect sizes and can account for the significant difference in effect size between studies. Specifically, it was found that phonological working-memory studies used recall tasks were associated with a larger effect sizes than phonological studies that used recognition tasks. Phonological studies that had a greater number of trials had larger in group differences in results than studies with less trials. Visuospatial studies that looked at number of correct trials had smaller effect sizes than studies that analyzed the number of correct responses. Nevertheless, the results of this study clearly indicate that there

is reduced performance regarding executive functioning in adults with ADHD, regardless of the variations in methodology.

Alderson and colleagues' (2017) meta-analysis is crucial to understanding the differences in executive function between ADHD and non-ADHD individuals, as well as the limitations and errors produced by various methodologies. Their research, while important to understanding the effect of methodological variables, fails to account for a very important aspect of ADHD; there are three subtypes of ADHD, all of which present different symptoms and can all be determined to be affected by different areas of executive function and working memory. An individual with predominantly hyperactive-impulsive type ADHD could theoretically perform differently than an individual diagnosed with predominantly inattentive ADHD; one has difficulty staying still and being patient while the other has difficulty maintaining focus on the task at hand, respectively. The ability to focus and maintain attention is critical to any kind of working memory task. As such, an experiment that focuses on working memory in individuals with ADHD, whether phonological or visuospatial, should account for the variance in subtypes. Future meta-analyses and studies should separate participants based on ADHD subtype to ascertain the executive function differences between subtypes. Likewise, future research on preparing the phone application to augment CBT should consider how people with different subtypes might have different needs from the phone app. Since the development of the ADHD phone application parallels CBT, the hyperactive-impulsive symptoms are not well addressed by CBT so future work on the phone application should address this deficit.

A smartphone-based supplement to ADHD treatment should account for and mitigate executive function deficits. In a study by Dosis and colleagues (2015), children with ADHD

played computer games that trained their executive functions skills. After three months, the researchers found that visuospatial short-term memory, working memory, and response inhibition skills had significantly improved. By implementing the same executive function training games into a phone application, one could theoretically further improve patients' executive functioning skills (Dovis et al., 2015).

There are numerous programs with games created specifically for improving executive function skills of people with ADHD. In a study by Wexler et al (2020), 73 children used the cognitive training program ACTIVATE™ by C8Sciences. In this program, children with ADHD were brought into the testing lab after school 3-4 times a week where they would play cognitive training games for 45 minutes. The participants' executive functioning skills were measured prior to, and post treatment. Results of the experiment showed that after a fifteen-week period, there was a significant improvement in response inhibition, sustained attention, cognitive flexibility, and working memory (Wexler et al., 2020). Future development of the app to supplement treatment of ADHD should include adaptations of the games and exercises used in this program, as well as an analysis and adaptation of other programs. The specific exercises used to enhance executive functioning will not be included in the app at this time because the information is patented.

There are several programs that examine the user's executive function capabilities. One of these programs, the Conners' Continuous Performance Test II (CPT II) is frequently used as a tool to assess attention problems and treatment usefulness in ADHD. It is a computerized test in which the participant presses the spacebar when a letter other than X appears on the screen. Letters appear on the screen at different time intervals, and the entire test takes place over 14

minutes. This directly tests impulse control (not hitting the X) and working memory (staying focused on hitting X); two important executive functions (Conners, n.d.). The test itself measures the omissions, commissions, hit reaction time, standard error, and more. Scores of those with ADHD are compared to those without ADHD and used in diagnosis (CPT II V.5 Profile Report for Jane Sample, 2004). This test could be recreated with more visually entertaining stimuli and easily identifiable scores as a training tool/game for executive function skills. The more a person plays the game, the more they use their executive function skills. A score report would help them visualize their progress and motivate them to achieve higher scores.

Treating ADHD through CBT is a difficult task. To improve the symptoms of ADHD requires sustained focus, attention, and impulse inhibition; things that those with ADHD typically find difficult to do. By using CBT as a foundation for developing a prototype application of a phone application to supplement the treatment of adult ADHD, patients would have an “on the go” and easily accessible resource to aid their treatment. The app could also include a medication tracker for those taking medication, and a series of executive function training games to improve working memory and short-term memory.

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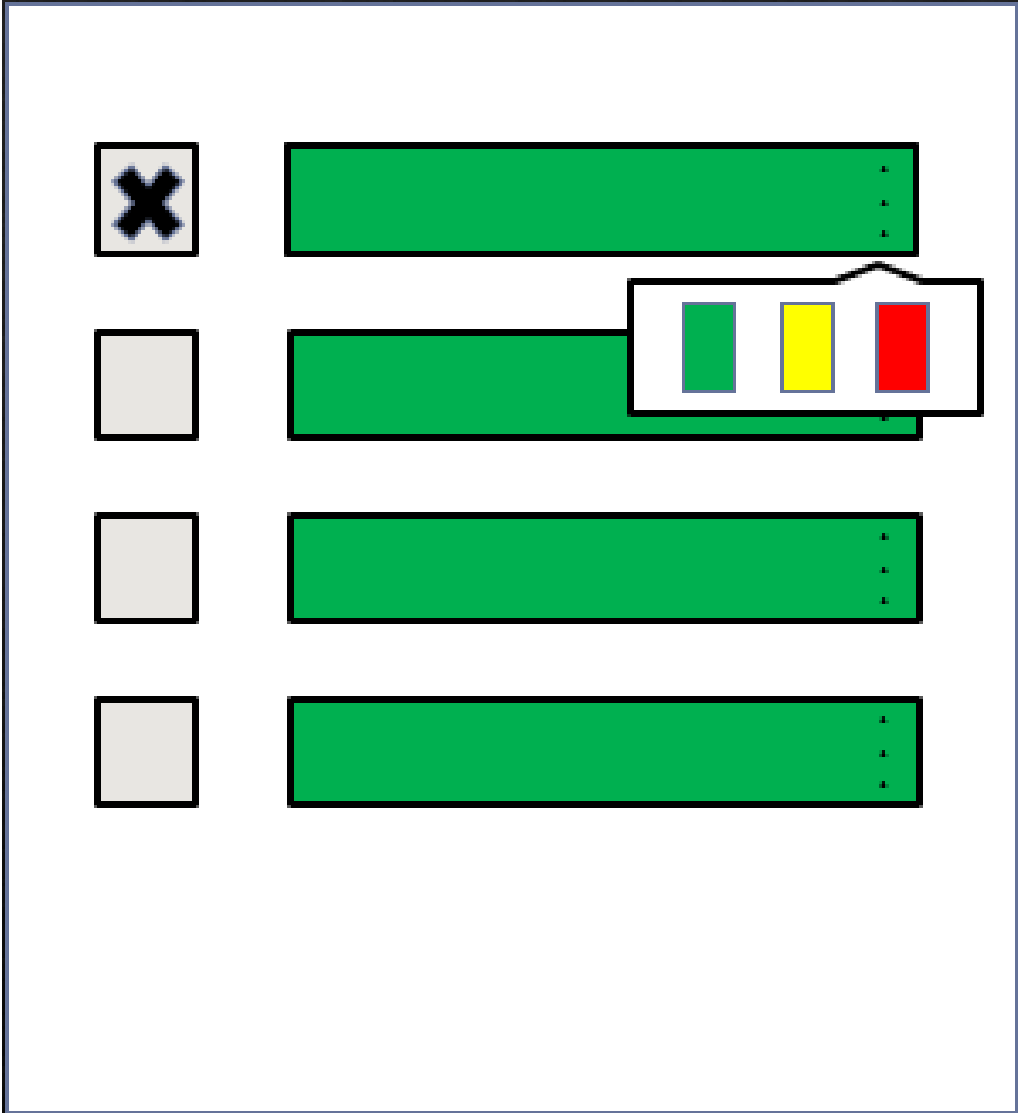
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Appendix A

Sun									
<p>1</p>   	<table border="1"> <tr> <td>9:00 - 11:00</td> <td>Do This</td> </tr> <tr> <td>12:30 - 1:30</td> <td>Do That</td> </tr> <tr> <td>3:00 - 5:00</td> <td>Do This Again</td> </tr> <tr> <td>6:00 - 9:00</td> <td>Do Something Else</td> </tr> </table>	9:00 - 11:00	Do This	12:30 - 1:30	Do That	3:00 - 5:00	Do This Again	6:00 - 9:00	Do Something Else
	9:00 - 11:00	Do This							
	12:30 - 1:30	Do That							
	3:00 - 5:00	Do This Again							
6:00 - 9:00	Do Something Else								

Appendix B



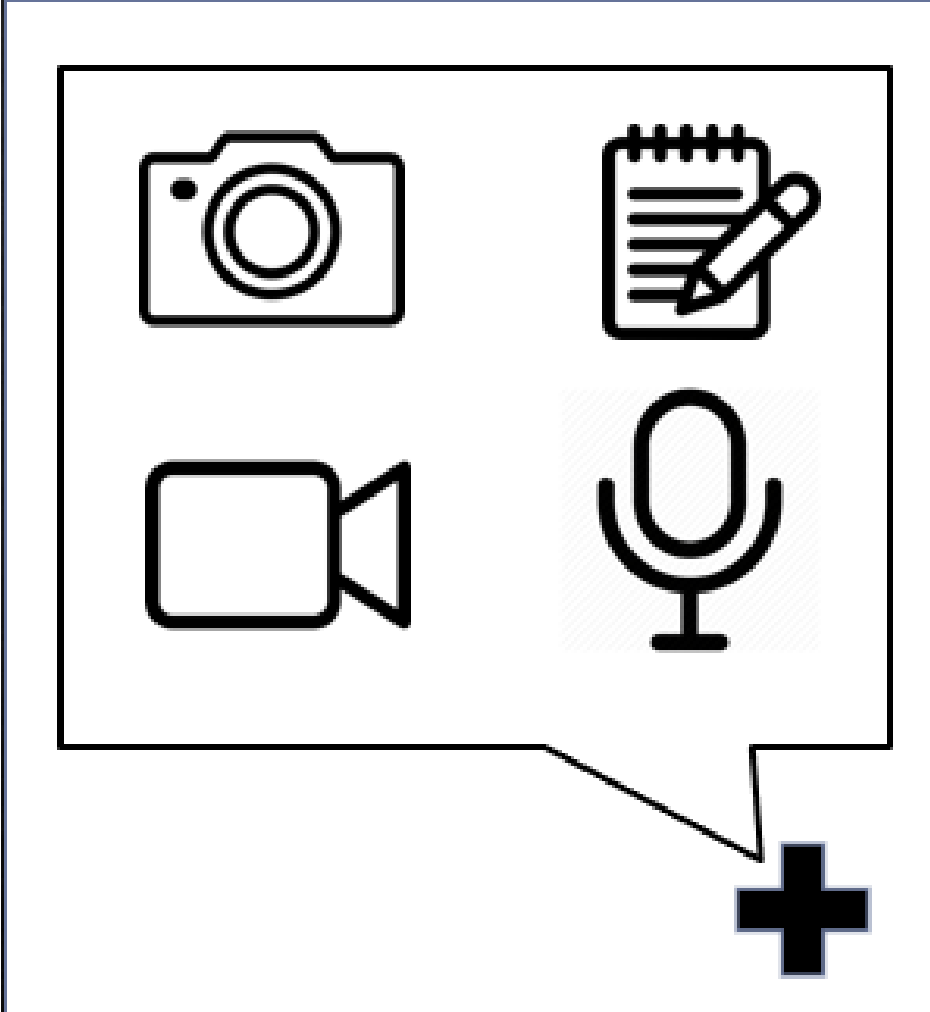
Appendix C



9 AM
2 PM
5 PM

5 Min
10 Min
15 Min

Appendix D



Appendix E

Automatic Thought	Error	Reframed Thought
I must finish my entire senior project TODAY	All-or-Nothing Thinking	I can start today, finish tomorrow, and still have time
<ul style="list-style-type: none"><li>• All-or-Nothing Thinking</li><li>• Overgeneralization</li><li>• Mental Filter</li><li>• Disqualifying the Positive</li><li>• Jumping to Conclusions</li></ul>		