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Abstract

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Evidence-based ADHD interventions such as self-monitoring are scarcely used by educators, especially those teaching in secondary schools (Sibley et al., 2016). Common barriers to intervention use include restricted time, poor knowledge of ADHD, and feelings of frustration and stress associated with teaching students with ADHD (Szép, 2021). Because barriers are often related to stimuli and events that result in increased mental effort, one theoretical lens through which such barriers can be understood is cognitive load. Therefore, in the present research, I used cognitive load theory as a framework to guide the design of a novel, computer-based, self-monitoring intervention intended to reduce barriers to teachers' intervention use. The purpose was (a) to evaluate the cognitive load experienced by teachers when implementing a self-monitoring intervention, and (b) to explore teachers' acceptability of the novel, computer-based self-monitoring intervention. To this end, secondary school teachers from the United States read a vignette description of an adolescent with ADHD and were subsequently randomly presented with one of two self-monitoring intervention modalities—computer-based or paper-and-pencil based—to support the student. Then, participants completed rating scales that assessed their likelihood of intervention use and perceived cognitive load associated with the intervention procedures. 336 participants met eligibility criteria to participate, but only 89 were included in the final analysis after listwise deletion of cases that failed to pass the validity check for adequate engagement with the intervention and vignette. Participants' acceptability ratings for both the computer-based intervention and analog intervention were favorable, and ratings for the computer-based intervention were somewhat higher than their ratings for the analog intervention. However, the difference was not practically significant. Limitations and future directions are discussed.

Intervention Acceptability of a Digitized Self-Monitoring Procedure for ADHD

Attention-Deficit/Hyperactivity Disorder (ADHD) is the most common neurodevelopmental disorder in school-aged populations worldwide, with an estimated 5% to 10% of children and adolescents meeting diagnostic criteria (Cortese & Coghill, 2018; Danielson et al., 2018; Diagnostic and Statistical Manual of Mental Disorders, 5th ed. [DSM-5]). The core symptoms of ADHD entail developmentally extreme behaviors marked by inattention, hyperactivity, and/or impulsivity. These behaviors often contribute to long-lasting skill deficits and functioning difficulties across multiple domains of daily living. In addition, researchers have established that ADHD is a complex disorder marked by interindividual heterogeneity in both etiology and symptom expression (Nigg et al., 2020; Steinberg & Drabick, 2015). However, there are also predictable changes in symptoms that unfold across development. Some of the most dramatic changes in symptoms, namely the normative reduction of symptoms related to hyperactivity, occur during the developmental period spanning childhood and adolescence (e.g., Langberg et al., 2008; Murray et al., 2018). Consequently, children and adolescents tend to exhibit qualitatively distinct symptom profiles and skill deficits (Langberg et al., 2008; Murray et al., 2018; Willoughby, 2003).

Adolescence, in particular, represents an insidiously challenging developmental period for individuals with ADHD. Unlike their preschool- or elementary-aged counterparts who exhibit a greater degree of readily-observable symptoms related to hyperactivity (Brock et al., 2009), adolescents tend to experience a greater degree of covert symptoms related to inattention (Langberg et al., 2008; Murray et al., 2018; Nahlik, 2004), disorganization, and executive dysfunction. Examples include difficulties with directing and sustaining attention, experiencing mental restlessness, and difficulties with motivation (Nahlik, 2004; Steinhoff, 2008). Because the inattentive symptoms that often characterize ADHD in adolescence involve subtle behaviors that are often not readily observable by others, and because deficits in social or academic functioning cannot be explained by a deficit in physical or intellectual functioning, researchers have described adolescent ADHD as an "invisible disability" (Murphy, 2005, p. 608).

Academic achievement is a core domain of dysfunction for adolescents with ADHD. Indeed, in the classroom setting, symptoms of inattention can manifest as engagement in off-task behaviors, difficulty with attending to and following instructions, difficulty with completing or submitting assignments, inefficient organization and planning, and difficulty with sustaining focus on assignments (DuPaul & Jimerson, 2014; Raggi & Chronis, 2006). For a sizable proportion of adolescents with ADHD, difficulties with foundational academic skills, especially in the absence of adequate intervention support, result in a litany of undesired short- and long-term consequences. Indeed, an estimated 80% of those with ADHD experience chronic underachievement and/or difficulties learning, 50% require additional tutoring, and 40–50% receive special education services. Even after statistically adjusting for cognitive abilities, socioeconomic status, and comorbid disorders that can affect learning, having an ADHD diagnosis is a substantial risk factor for grade retention and high school dropout (Fried et al., 2016). Furthermore, especially when left untreated, ADHD can contribute to cascading affects by adulthood. Examples of negative include reduced likelihood of graduating high school or receiving an advanced degree, and increased risk of unemployment, criminality, and illicit drug abuse (Arnold et al., 2015; Bernfort et al., 2008; Fletcher & Wolfe, 2009). Self-harm is another area of high risk (Hinshaw et al., 2022).

Despite the well-documented sequelae of ADHD, and despite the fact that school becomes increasingly demanding of foundational academic skills that are often poorly developed in students with ADHD (Litner, 2003), adolescents with ADHD largely remain overlooked and unsupported in secondary school settings. That adolescents with ADHD receive far fewer school-based supports than their elementary-aged counterparts (e.g., Gaastra et al., 2020) is especially surprising given that the more than two decades of research demonstrating that evidence-based, nonpharmacological interventions can improve foundational academic skills and, consequently, achievement outcomes (Gaastra et al., 2016). However, researchers have shown than a confluence of factors ranging from structural barriers (e.g., school funding; underfunded mandates like IDEA) to student-level barriers (e.g., resistance to intervention support) contribute to the lack of effective classroom support provided to adolescents with ADHD (Gaastra et al., 2020; Moore et al., 2019). Several barriers directly affect teachers' ability to select and implement evidence-based ADHD interventions with fidelity. Examples include limited classroom time for intervention delivery (Szép et al., 2021), large class size (Bussing et al., 2002), competing demands in the classroom (Lawson et al., 2022), misconceptions about and negative perceptions of ADHD (Elik et al., 2015), and stress associated with instructing students with ADHD (Schatz et al., 2021).

Although researchers acknowledge that secondary school teachers' scarce implementation of school-based, nonpharmacological interventions for ADHD is a pervasive problem (e.g., Sibley et al., 2016), solutions are thus far limited. One commonly proposed approach is in-service training. This training approach entails first providing teachers with professional development seminars to adequately build their background knowledge of ADHD neurobiology and symptoms, followed by ADHD intervention training and implementation support (Pfiffner et al., 2006). Yet a number of forces impede the delivery of effective training for teachers that are ubiquitous in U.S. schools. Examples include financial constraints; ineffective training design; the limited provision of time, resources, and ongoing support to facilitate teachers' implementation of new practices; and districts' tendencies to fall short when it comes to long-term data collection and outcome monitoring (Darling-Hammond et al., 2017).

Even in school settings where effective teacher training is implemented, barriers extraneous to teacher knowledge remain. Indeed, secondary school teachers have reported that some of the most impactful barriers to ADHD intervention implementation are those unrelated to their knowledge of ADHD and interventions, such as class size, lack of time, and feeling overwhelmed by the number of students who require individualized support (Szép et al., 2021). Therefore, augmenting teachers' knowledge through teacher training alone may not be sufficient to promote teachers' long-term adoption of effective interventions. Ultimately, researchers must conceive of alternative strategies to circumvent barriers related to both feasibility and long-term implementation.

Cognitive load theory is a theoretical framework that can guide the design of classroom-based interventions for adolescents with ADHD. Cognitive load is an index of mental effort derived from the number of non-automatic patterns of thought or behavior that one maintains in working memory while completing a task or solving a problem (Sweller, 2010). Because secondary school teachers, on average, possess insufficient or inaccurate background knowledge about ADHD and evidence-based ADHD interventions, learning about and implementing ADHD interventions in the classroom would constitute a non-automatic skill set. requiring additional mental effort to actualize in the classroom setting. In addition, common classroom stressors—such as large class sizes, the need to work with multiple students, and time constraints—would arguably exacerbate the cognitive load experienced by a given teacher trying to implement a new intervention strategy, thereby further decreasing the chances that the intervention will be implemented with fidelity . Therefore, developing strategies to decrease teachers' cognitive load during intervention delivery may meaningfully increase secondary school teachers' use of a newly-learned ADHD-related intervention.

One potentially effective, relevant strategy is to digitize evidence-based interventions that are typically delivered in an analog (i.e., paper-and-pencil based) format. In general, self-monitoring interventions require students to monitor and rate their engagement in a target behavior (e.g., on-task behavior) at timed intervals; concurrently, the teacher also monitors the student's target behavior during the same intervals in order to evaluate the accuracy of the student's self-monitoring ratings and track goal progress (Bruhn et al., 2022). Importantly, self-monitoring strategies can effectively ameliorate the core symptoms of ADHD and improve academic outcomes across age-groups (Bruhn et al., 2022), Importantly, they are amenable to digital presentation (e.g., Wills & Mason, 2014). Although some researchers warn against the overuse of digital technology in the classroom (Bergdahl et al., 2020; Cao et al., 2018; Sweller, 2010), a digital intervention that provides intervention directions, intervention delivery, data collection, and long-term data tracking would arguably reduce cognitive load and thereby increase the probability of teachers' use of a given intervention.

In sum, the purpose of the present dissertation research is to explore teachers' self-reported cognitive load and likelihood of intervention use when presented with a digital self-monitoring intervention in contrast to an analogous non-digital self-monitoring intervention. To this end, in my literature review, I present a detailed overview of ADHD symptomatology, etiology, and developmental trajectory through the lens of medical and psychological research. I then call upon what is currently known about the underlying components and complexities of ADHD in adolescent populations to present a review of the academic impairments that commonly arise for adolescents with ADHD. Next, I review nonpharmacological ADHD interventions and discuss barriers to secondary school teachers' implementation of evidence-based interventions. Although both student-originating and teacher-originating barriers are addressed, I place particular emphasis on teacher-originating barriers and discuss these barriers via a theoretical framework of cognitive load. I then propose that a digital (i.e., computer-delivered), self-monitoring intervention may effectively facilitate secondary school teachers' delivery of an evidence-based, ADHD intervention in the classroom. Subsequently, I present my research hypotheses, methodology, and data analyses. I conclude with a discussion of results. In doing so, I situate my findings in the context of related research, consider the limitations of the present dissertation research, and make recommendations for future research.

Overview of ADHD

It is widely acknowledged that ADHD is a complex disorder characterized by etiological and phenotypic heterogeneity (Nigg et al., 2020; Steinberg & Drabick, 2015). Furthermore, symptoms tend to change across development (Langberg et al., 2008; Murray et al., 2018; Willoughby, 2003). Indeed, contrary to historical beliefs about the persistence of ADHD, clinical symptoms (especially those related to inattention and poor self-regulation) often remain throughout adolescence and early adulthood (e.g., Agnew-Blais et al, 2016; Gordon & Hinshaw, 2019). Moreover, although researchers have shown that about 20% of those who had ADHD in childhood continue to meet clinical criteria in adulthood, it is also estimated that over 50% of adults who had a childhood diagnosis with ADHD continue to experience subclinical ADHD symptoms—such as forgetfulness and difficulties with planning and organization—that interfere with daily living (Sibley et al., 2019; Sibley, Swanson, et al., 2016; Sibley, Mitchell, et al., 2016). Overall, ADHD can have destabilizing and debilitating effects on multiple domains of daily living across the lifespan (Barkley, 2015).

Since the 1990s, researchers' and practitioners' understanding of ADHD symptoms, outcomes, etiology, and treatment has expanded substantially (Barkley, 2015). Currently, there are two complementary, conceptual frameworks through which ADHD can be understood. One framework encapsulates medical, neurobiological research on ADHD, and the other framework encapsulates neuropsychological research on the cognitive processes associated with ADHD. More specifically, the medical framework represents a traditional, psychiatric approach to understanding ADHD that concerns the diagnostic features, such as those outlined in the DSM-5, and the etiology of the disorder (Barkley, 2007). The cognitive framework expands upon the medical framework by using a neuropsychological approach to explore the cognitive processes that bridge neurobiological findings and observable ADHD symptomatology (Barkley, 2015). The two frameworks not only provide two different approaches to understanding what defines ADHD and what processes contribute to core symptomatology, but also contribute to two different approaches to ADHD treatment. Medical research contributes to the development of pharmacological treatments, such as psychostimulant treatments, and cognitive models of ADHD can richly inform researchers' and practitioners' development and use of nonpharmacological ADHD treatments and interventions.

Because ADHD treatments are heavily informed by how the symptoms, causal factors, and developmental progression of ADHD are framed, the following sections present an overview of ADHD through the lens of both medical and neuropsychological research. In the following sections, the medical framework is leveraged to summarize the clinical symptoms of ADHD, as defined by the DSM-5, and provide an overview of the etiological factors and developmental trajectories associated with ADHD. Subsequently, research from the cognitive, neuropsychological framework is reviewed to provide an overview of the specific cognitive processes that have been linked to ADHD's core symptomatology. Specifically, a well-established cognitive model of ADHD, proposed by Barkley (1997), is presented and is used as a guiding framework to describe the cognitive processes that underlie the core symptoms and sequelae of ADHD, specifically as experienced by adolescents in academic settings.

DSM-5 Diagnostic Criteria

Currently, ADHD is defined by two distinct dimensions: (a) inattentive-disorganized and (b) hyperactive-impulsive (Nigg, 2017). The most important diagnostic feature of ADHD is a "persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development" (DSM-5, p. 61). Broadly, inattention refers to difficulty with focusing and filtering information (DSM-5; Nigg, 2017). Examples of behaviors associated with inattention include making careless mistakes, difficulty sustaining attention, wandering off task, avoiding work that requires sustained mental effort, losing important objects or possessions, and being easily distracted by external stimuli or internal states. Hyperactivity refers to excessive motor activity (DSM-5; Nigg, 2017). Examples of hyperactive behaviors include excessive talking, fidgeting or squirming while seated, and experiencing internal feelings of restlessness. Finally, impulsivity refers to actions that are carried out without forethought and have potential to harm the individual (DSM-5; Nigg, 2017). Examples of behaviors associated with hyperactivity include interrupting others often, difficulty waiting for one's turn, frequently blurting out answers, and often leaving one's seat without permission (DSM-5; Nigg, 2017).

The core symptoms of inattention, hyperactivity, and impulsivity are each associated with distinct symptom presentations, which represent three separate diagnostic categories: combined presentation, predominantly inattentive presentation, and predominantly hyperactive/impulsive presentation (DSM-5). According to the DSM-5, in order for a school-aged individual (i.e., age 17 or under) to meet criteria for one of the diagnostic categories for ADHD, the individual must experience six or more symptoms consistent with an inattentive or hyperactive-impulsive presentation for at least the past six months. A combined presentation requires meeting symptom criteria for both inattentive and hyperactive/impulsive presentations. The symptoms must also interfere with social or academic functioning and must be present in at least two different settings (e.g., home and school). Finally, the individual's symptoms must have been present prior to age 12.

Selected Etiology

It is well-established in the empirical ADHD literature that ADHD is a highly heritable disorder. Using longitudinal data from many countries around the world, researchers have estimated that the heritability coefficient of ADHD is 0.76 (Doyle et al., 2004). Being a highly heritable disorder, it stands to reason that genetic factors contribute substantially to the development of ADHD—and that individual differences in symptom levels are primarily the result of genetic (rather than environmental) differences across individuals. However, researchers have also established that no single pathway leads to the development of ADHD (e.g., Thapar et al., 2013). Rather, ADHD symptomatology is the result of diverse, complexly interacting pathways that include both genetic and non-genetic factors. Additionally, there is no guarantee that a given pathway that results in ADHD in one individual will lead to the same result in another individual (Steinberg & Drabick, 2015). Thus, the etiology of ADHD is characterized by both equifinality and multifinality. The factors that can contribute to ADHD pathways are complex and range from the genetic to the environmental (Nigg, 2017). Although it is beyond the scope of the present paper to provide a comprehensive etiological account of ADHD, a brief summary of the neurobiological mechanisms implicated in the etiology of ADHD and, by extension, the cognitive and developmental characteristics of ADHD, is provided.

Neurobiological Mechanisms. In comparison to typically developing individuals, there are several features of ADHD, both neurobiological and neuropsychological, that remain relatively stable across development. Although it is beyond the scope of the present paper to provide a comprehensive review of the neurobiological features that are associated with ADHD, it is important to summarize some of the anatomical, neurophysiological, and neurochemical substrates that underlie the disorder and distinguish individuals with ADHD from their typically developing counterparts across development.

One of the most robust neuroanatomical features of ADHD is reduced brain volume (Castellanos & Swanson, 2002; Curatolo et al., 2010; Krain & Castellanos, 2006). Although there are some differences in the volume of structures that vary by biological sex, reduced volume in the prefrontal cortex, basal ganglia, and/or cerebellum are common features associated with ADHD (Castellanos & Swanson, 2002; Curatolo et al., 2010). Reduced brain volume in these structures results in their hypofunctioning, especially with respect to their synergistic role in executing and moderating complex motor and cognitive responses to stimuli (Castellanos & Swanson, 2002).

Functional brain imaging researchers have additionally revealed that a vast network of structures are implicated in ADHD symptomatology. Cognitive and behavioral deficits associated with ADHD stem from hypoactivation in some structures and networks and hyperactivation in others. Hypoactivation in specific prefrontal cortex regions likely contribute to individuals' persistent difficulties with executing higher order cognitive processes related to executive functions, such as working memory, emotional control, sustained attention, and motivation (Cheng et al., 2017; Fernández et al., 2009). Another common feature of ADHD is the presence of a hypoactive network of frontoparietal regions, including the lateral frontal pole, dorsal anterior cingulate, dorsolateral anterior prefrontal cortex, lateral cerebellum, anterior insula, and inferior parietal lobe (Cortese, 2012). This network of structures underlies behaviors and higher-order cognitive functioning deficits that are common to ADHD and implicated in executive functioning deficits (Cortese, 2012).

In addition to certain hypoactive neurological regions and substrates contributing to deficits in various higher-order cognitive processes, researchers have identified ADHD-related hyperactivation in select regions that are normally suppressed during tasks that demand sustained attention and goal-directed behavior. For example, suppression of the ventral attention network typically prevents attentional shifts to irrelevant stimuli while the individual is engaging in goal-directed behavior; however, for individuals with ADHD, the ventral attention network is hyperactive during goal-directed behavior (Cortese, 2012). Consequently, individuals with ADHD have difficulty ignoring task-irrelevant stimuli and are susceptible to frequent distraction. Additionally, the "default network" is another group of neurological structures that is prone to dysfunction for those with ADHD. The default network consists of a network of parietal, prefrontal, and temporal cortical structures that are typically suppressed during tasks demanding sustained attention and goal-directed behavior (Raichle, 2015; Sonuga-Barke & Castellanos, 2007). However, for those with ADHD, the default network is hyperactive during high-attention tasks (Cortese, 2012). Overactivity in this network during cognitively demanding tasks is associated with difficulty with focusing and the experience of mind-wandering, which can involve the spontaneous and distracting experience of images, thoughts, and feelings (Mason et al., 2007).

Finally, biochemical abnormalities also persist across development for those with ADHD. One of the most widely researched biochemical abnormalities associated with ADHD is dysfunction pertaining to the neurological availability of catecholamine neurotransmitters. Initially proposed by Wender and colleagues (1971), the catecholamine hypothesis posits that abnormal availability and interactions among norepinephrine, epinephrine, and dopamine underlie core ADHD symptoms (Prince, 2008). The central role that these catecholamines have in contributing to ADHD core symptoms has been robustly supported in research (Prince, 2008). The overactivity of catecholamine neurotransmitters in neurological circuits that underlie motor activity and arousal is implicated in ADHD symptomatology related to hyperactivity and impulsivity, and the underactivity of catecholamines in neurological circuits that underlie higher-order cognitive processes and working memory is implicated in ADHD symptomatology related to inattention and difficulties with motivation (Castellanos & Swanson, 2002; Swanson et al., 2007). Consequently, the catecholamine hypothesis contributed to the development of stimulant medication ADHD treatments, which serve to counteract catecholamine dysfunction in specific neurological structures and networks implicated in ADHD (Castellanos & Swanson, 2002). Given that catecholamines serve a central contributing role to the core symptoms of ADHD, it is unsurprising that stimulant medications represent some of the most effective and robustly supported treatments of core ADHD symptoms (Caye et al., 2019).

Overall, ADHD is a chronic disorder driven by wide-ranging neurological dysfunction that contributes to the disorder's core symptomatology. However, researchers have also established that the neurological dysfunction common to ADHD changes across the course of development (e.g., Rubia, 2007), hence ADHD's classification as a neurodevelopmental disorder. Consequently, changes in ADHD symptomatology across development occur parallel to the underlying developmental changes in ADHD-related neurological structures and networks (Krain & Castellanos, 2006). That said, given that the present research involves the development of a specific nonpharmacological intervention approach to address ADHD-related impairments that contribute to academic difficulties in adolescence, it is clinically informative to identify what distinguishes the symptoms of ADHD in adolescent populations from the symptom profiles characteristic of other age groups.

ADHD Symptom Expression in Adolescence and Treatment Implications

From early childhood through young adulthood, ADHD is characterized by highly variable symptom trajectories (Franke et al., 2018; Martel et al., 2016; Murray et al., 2021). Variability in symptom expression across development is, in part, a product of normative, neurobiological change and exposure to a variety of risk and protective factors (Freitag et al., 2012). Despite the fact that ADHD is a heterogeneous disorder, some features of ADHD are characterized by a degree of predictable continuity and discontinuity across development (Sasser et al., 2016). Ultimately, identifying the continuities and discontinuities of ADHD features across development is clinically informative with respect to the development of ADHD treatments (Murray et al., 2021).

Features of ADHD that remain stable across development include lower average cognitive abilities, lower average psychosocial skills (e.g., propensity for accidents; daily living skills), and deficits in response inhibition (Agnew-Blais et al., 2020; Willoughby, 2003). With respect to cognitive abilities, deficits in executive functioning (EF) skills are particularly characteristic of ADHD and are thought to substantially contribute to core symptoms across development (see Barkley, 1997). EFs encompass a variety of internalized, self-directed, self-regulatory actions that occur during a delay in response to a given event or stimulus (Barkley, 1997). Consequently, EFs underlie skills such as self-regulation, planning and organization, and goal-directed behaviors (Barkley, 1997). Directly related to the fact that deficits in EFs constitute a defining feature of ADHD across development, researchers have found that the most commonly teacher-reported difficulties experienced by individuals aged 5 to 18 years are distractibility and difficulty sustaining attention (Agnew-Blais et al., 2020). Additional features that tend to remain stable across development include rates of comorbid psychiatric disorders (with the most common comorbidities including learning disorders, sleep disorders, oppositional defiant disorder, and anxiety disorder; Reale et al., 2017) and treatment response patterns (Langberg et al., 2008; Willoughby, 2003).

With respect to predictable changes in ADHD symptoms over time, the most salient, developmentally-related changes in symptom expression occur during the developmental transition from childhood to adolescence (Langberg et al., 2008; Levinson et al., 2016; Murray et al., 2021; Sasser et al., 2016; Willoughby, 2003). Generally, ADHD symptoms are more differentiated in adolescent cohorts than they are in preschool and elementary-aged cohorts (Martel et al., 2016). During childhood (i.e., ages 3 to 12) ADHD symptoms commonly involve hyperactivity and impulsivity, and the behaviors associated with these symptoms include classroom disruption (e.g., being loud or moving around when it is inappropriate to do so), seeming to be always on the go, and often interrupting others (Martel et al., 2016). During adolescence, ADHD symptoms differentiate into more nuanced clusters of behavior characterized by heterogeneous presentations of inattention, hyperactivity, and impulsivity (Martel et al., 2016). Although ADHD in adolescence is defined by symptom heterogeneity, adolescents' symptoms tend to be less severe and less noticeable than those experienced by preschool and elementary-aged cohorts, especially on measures of hyperactivity and impulsivity (Döpfner et al., 2015). Indeed, Willoughby (2003) observed that on average, easily observed hyperactive-impulsive symptoms substantially decline with increasing age and covert, inattentive symptoms remain stable.

One caveat to the finding that adolescents tend to experience less severe ADHD symptoms than children is that biological and environmental risk factors can drastically alter and exacerbate symptom trajectories across development. Exposure to risk factors contributes to the outcome that over 10% of individuals with ADHD experience persistent or worsening symptoms throughout adolescence (Murray et al., 2021). Examples of biological risk factors for increased symptom severity and persistence over time include premature birth, biological sex (whereby biological males are at higher risk for persistent or worsening symptoms of ADHD across development), and having one or more comorbid disorder (Hurtig et al., 2007; Murray et al., 2018; Newcorn et al., 2001; Scibberas et al., 2017). Environmental factors can also alter ADHD outcomes and are estimated to account for 10 to 40% of the variance in ADHD symptoms (Scibberas et al., 2017). Examples of environmental risk factors include prenatal exposure to environmental toxins, such as organophosphate pesticides, polychlorinated biphenyls (PCBs), and lead; maternal substance use during pregnancy, such as alcohol, tobacco, and antidepressant medication; and psychosocial adversity, such as family conflict and being raised in a low SES household (Banerjee et al., 2007; Freitag et al., 2012; Scibberas et al., 2017; Thapar et al., 2013). Although researchers have yet to determine causal relationships among risk factors and ADHD outcomes, researchers have identified associations between risk factor profiles and developmental trajectories of ADHD symptoms.

For example, Döpfner et al. (2015) found that symptom trajectories from childhood through adolescence are influenced by a number of risk and protective factors. Specifically, more severe ADHD symptoms were positively correlated with the presence of a comorbid disorder, low SES background, and lower quality of life ratings (as measured by physical well-being, emotional well-being, family and peer relationships, and school functioning) in comparison to other children. Moreover, the severity of ADHD symptoms was predictive of persistence across development, in that those with the most severe symptoms in childhood were most likely to continue to have severe symptoms in adolescence (Döpfner et al., 2015).

Similarly, in a longitudinal study of over 400 children at risk of clinically significant ADHD, Sasser et al. (2016) collected parent-reported ADHD symptom data in Grades 3, 6, 9, and 12. They found that over the course of the developmental period from childhood to late adolescence, three classes of developmental trajectory characterized participants' symptom expression, which they described as low, declining, and high. The low trajectory class represented the majority of participants (71%), who, despite being at-risk for developing clinically significant ADHD, never demonstrated clinically significant levels of inattention, hyperactivity, or impulsivity throughout the course of the study. The declining trajectory class represented 16% of the sample, and was characterized by clinically significant core ADHD symptoms in Grade 3 which gradually declined over time and reached sub-clinical symptoms in adolescence. The high trajectory class represented 13% of the sample, and was characterized by clinical levels of hyperactivity in grade 3, inattention and hyperactivity in grade 6, and inattention in grades 9 and 12. Importantly, several non-biological predictors were associated with each of the three trajectory classes. For example, high trajectory children were distinguished from declining and low trajectory children in that they were reported to have greater levels of aggression and hyperactivity at school, and greater emotional dysregulation at home. Additionally, both high and declining trajectory children were further distinguished from low trajectory children on multiple measures of difficulties at school and home. Specifically, unlike low trajectory children, high and declining trajectory children demonstrated more severe core ADHD symptoms at an early age, and were more likely to experience stressors that undermined familial support.

However, even for individuals who experience reduced symptom severity in adolescence, there are periods during adolescence that are associated with worsening symptoms. Indeed, the transition to middle school is characterized by a period of symptom regression and represents an inflection point in ADHD symptom trajectory (Langberg et al., 2008). In their longitudinal study of ADHD symptom change across development, Langberg et al. (2008) found that the transition to middle school is associated with an interruption in the decline in ADHD symptomatology across core symptom categories, even after accounting for concurrent use of medication. In their study, parents of children with ADHD reported that during the two years following the transition to middle school, their child engaged in more inattentive, hyperactive, and impulsive behaviors than they did in 5th grade. The researchers posited that temporarily worsening ADHD symptoms in middle school likely resulted, in part, from the sudden and drastic increase in EF demands experienced by students when they begin middle school (e.g., organizing notes, materials, and assignments for multiple classes; schoolwork requiring long-term goal setting and planning, such as tests, essays, and projects;

and inhibiting inappropriate or ineffective behaviors across multiple settings throughout the day).

In summary, ADHD is characterized by continuity and discontinuity in symptom expression across development. Researchers have demonstrated that developmentally-related changes in ADHD symptoms and impairments result from a confluence of both biological and environmental factors. Although the presentation of ADHD in adolescent age groups is far more heterogeneous than that observed in their elementary-aged counterparts, adolescents primarily experience core symptoms and difficulties related to inattentive symptoms and poor executive functions. Overall, the body of research on ADHD presentation and underpinnings within the medical framework has substantially contributed to researchers' increasingly sophisticated understanding of the symptoms that characterize ADHD across development and the development of effective medical treatments that address underlying neurobiological dysfunction associated with ADHD core symptoms. Indeed, the most well-researched, robustly supported, and common treatment for ADHD across age-groups is pharmacological treatment with stimulant or non-stimulant medication (Caye et al., 2019). However, there are several drawbacks associated with relying on pharmacological treatments alone, especially for adolescents.

One of the most notable drawbacks of medication use as the only treatment modality for ADHD is that 20 to 30% of those who receive pharmacological treatment are either non-responders or experience intolerable negative side effects and therefore cease pharmacological treatment (Brock et al., 2009). Furthermore, researchers have shown that medication adherence is a particular problem in adolescent cohorts in that many who begin treatment tend to stop and restart medication use or discontinue use altogether (Charach & Fernandez, 2013). Indeed, a recent study showed that in a sample of 1,200 adolescents (aged 12 to 18) with ADHD, 61% of participants disclosed nonadherence to medication (Kosse et al., 2017). Another problem associated with relying on medication management alone, even for those who do respond to pharmacological treatment, is the fact that medication without additional, skill-building interventions does not improve common academic deficits associated with ADHD (Caye et al., 2019; Trout et al., 2007).

Given the numerous drawbacks of relying on pharmacological interventions alone for ADHD, there is arguably a need for the use of non-pharmacological interventions. Even in cases where medication is effective, nonpharmacological ADHD interventions remain important given that combined treatments are consistently associated with the greatest degree of symptom reduction and improvements in multiple areas of impairment, including academic functioning in particular (e.g., Fabiano et al., 2007; Miranda et al., 2006; MTA Cooperative Group, 1999; Pelham et al., 2016). Although research on non-pharmacological interventions for ADHD is relatively nascent in comparison to research on pharmacological approaches (Caye et al., 2019), there are many nonpharmacological interventions that can effectively reduce both core symptoms and improve related functioning deficits for adolescents with ADHD, including academic functioning. As previously stated, the design of nonpharmacological interventions is informed by cognitive modeling research, which is informed by both medical research and neuropsychological research. Therefore, prior to delving into the effective nonpharmacological approaches that improve symptoms and outcomes for adolescents with ADHD, especially in the academic setting, it is important to first review the theoretical underpinnings of nonpharmacological interventions as articulated by researchers' cognitive models of ADHD.

Cognitive Models of ADHD

Unlike neurobiological ADHD research, which explores the underlying neurobiological mechanisms involved in the disorder, neuropsychological research involves theory-driven modeling of the cognitive processes involved in ADHD, which is subsequently empirically tested (Barkley, 1997; Sergeant et al., 2003). In line with the language used by some contemporary ADHD researchers (e.g., Castellanos et al., 2006), the term *cognitive model* will be used in the present paper to refer to any model that describes the neuropsychological processes underlying ADHD. Cognitive models of ADHD represent an important dimension of ADHD research because they allow researchers and practitioners to augment a purely descriptive conceptualization of the disorder with a theoretical basis for the underlying cognitive processes and mechanisms that drive ADHD symptomatology (Barkley, 1997). Thus, cognitive models of ADHD that explicitly propose underlying cognitive dysfunction are critical to the development of nonpharmacological interventions for the disorder, just as neurobiological research informs the development of pharmacological interventions that target the neurobiological processes involved in ADHD (Barkley, 1997).

Several cognitive models of ADHD have been proposed over the past 30 years (Barkley et al., 2006; see also Castellanos et al., 2006; Sergeant, 2000; Shanahan et al., 2006; Sonuga-Barke, 2002). Key cognitive processing deficits that researchers have outlined include deficits in motivational processes, deficits in voluntary attentional processes, and deficits in executive processes (Derryberry & Reed, 2008). Despite the fact that there are varying degrees of overlap in the neuropsychological deficits implicated in different cognitive models, researchers have yet to construct a unifying cognitive model that comprehensively accounts for the widely varying etiology, symptoms, and outcomes of ADHD (Nigg, 2017). Of the cognitive models proposed in contemporary ADHD literature, Barkley's (1997) EF model of ADHD gave rise to the now widely-accepted and research-supported assertion that deficits in behavioral inhibition and EF processes contribute substantially to the core symptom profiles across ADHD subtypes (Antshel et al., 2014; Derryberry & Reed, 2008). Additionally, although Barkley's cognitive model of ADHD does not account for the unique symptom profiles and deficits experienced by all individuals with ADHD (Nigg et al., 2005), it remains widely used as a framework for conceptualizing the neuropsychological processes that underlie ADHD. Therefore, in the present research, Barkley's model is leveraged as a primary theoretical framework for understanding the rationale behind the design of empirically-supported, nonpharmacological interventions. Furthermore, given that a sizable proportion of the nonpharmacological interventions in the literature are ineffective (e.g., Richardson et al., 2015), Barkley's model is also used as an explanatory framework to identify the features associated with the nonpharmacological interventions that tend to bring about desired behavioral change.

Barkley's Model of ADHD. In his seminal publication, Barkley (1997) delineated a cognitive model of ADHD linking the core ADHD symptoms of inattention, hyperactivity, and impulsivity to the dysfunction of three interrelated, hierarchically organized, neuropsychological processes: (a) behavioral inhibition, (b) executive functions, and (c) motor control. Although Barkley's model is not a developmental stage model, another important aspect of the model that has become more prominent as the research on the development of EFs has advanced (e.g., Best & Miller, 2010) is the notion that neuropsychological processes central to Barkley's model, particularly EFs, become increasingly sophisticated, albeit at different rates, from infancy to adulthood.

Relatedly, Barkley (1997) conceptualized that behavioral inhibition skills are foundational to the subsequent development of both EF and motor control. Following the same line of reasoning, Barkley held that EF skills are foundational to the development of motor control skills. The relative sequencing of the development of each neuropsychological process central to Barkley's cognitive model has since received empirical support (e.g., Klenberg et al., 2001). Because unique deficit profiles across the three components of Barkley's model are assumed to be directly related to ADHD symptom profiles and outcomes (Antshel et al., 2014), it is important to understand each component of Barkley's model in detail.

Behavioral Inhibition. Behavioral inhibition encompasses individuals' ability to delay or avoid engagement in a behavioral impulse to attain an outcome that is immediately rewarding or avoid an outcome that is immediately undesirable (Barkley, 1997). More specifically, behavioral inhibition is composed of three interrelated subprocesses that underlie individuals' ability to self regulate motor responses to stimuli: (a) prepotent response inhibition, (b) delay, and (c) interference control (Barkley, 1997). Prepotent response inhibition refers to the ability to delay acting out on an urge to respond immediately to a short-term contingency (i.e., a reinforcement or punishment that is enacted with no delay). Behavioral delay refers to the ability to interrupt an ongoing response to stimuli, which also requires ongoing self-monitoring and awareness of one's own behavior. Interference control refers to the ability to override urges to respond to competing events or stimuli during response inhibition or behavioral delay.

Barkley (1997) proposed that deficits in any of the three areas that compose behavioral inhibition result in observable patterns of behavior that are ultimately shaped by short-term contingencies. In other words, a behavioral inhibition deficit can result in behavior motivated by seeking in-the-moment rewards and avoiding in-the-moment punishments. Overall, the common denominator of behavioral inhibition deficits is poor self-control, which can manifest in both movement-related behaviors and internalized, cognitive behaviors (Barkley, 1997). At the root of behavioral inhibition deficits are structure and function abnormalities in prefrontal and frontal cortical structures (Crosbie et al., 2008).

Executive Functioning. EF skills represent a constellation of various self-regulatory, self-reflective, and self-directed actions and cognitive processes that occur during the delays between stimulus onset and response afforded by behavioral inhibition (Barkley, 1997). Overall, executive functions are best described as specialized, higher-order cognitive skills that allow individuals to constantly monitor and adjust their behavior (i.e., self-regulate), and engage in goal-directed behavior (Doyle, 2006). Researchers have identified a number of specific executive functions, which include working memory, response inhibition, set shifting, abstraction, planning, organization, and fluency (Doyle, 2006). Although EF is a relatively nebulous, multidimensional, neuropsychological construct that has thus far defied a consistent and agreed-upon definition in the ADHD literature, researchers have shown that there are specific EFs that appear to be central to the core symptoms of ADHD (Barkley, 2011; Friedman et al., 2007). In Barkley's (1997) model, Barkley proposed that four executive functions represent primary contributing factors to the core symptoms of ADHD. These executive functions were identified as (a) nonverbal working memory; (b) verbal working memory; (c) self-regulation of affect, motivation, and arousal; and (d) reconstitution.

Nonverbal working memory pertains to the privatization of sensory-motor activity and the memory of prior sensory events, and comprises two components: visual memory and auditory memory. Barkley (1997) theorized that both visual and auditory nonverbal working memory components play an important role in individuals' ability to develop hindsight (i.e., the temporal sequencing of past events), forethought (i.e., the process of referring to past sensory information to inform future behavioral sequences), and anticipatory set (i.e., the ability to anticipate future events and engage in a behavioral sequence that leads to a favorable outcome in response to an anticipated event). Barkley argued that these three components of nonverbal working memory create a sense of past, present and future, respectively, and are thus critical to an individual's ability to reflect upon past events and anticipate future events. Barkley also held that as nonverbal working memory skills become more sophisticated across development; consequently, individuals' ability to anticipate and plan for events that are increasingly temporally removed from the present improves over time. This developmental phenomenon related to sensing and anticipating the passage of time has since been robustly supported. For example, Steinberg et al. (2009) researched how participants aged 10–50 responded to immediate rewards in comparison to delayed rewards. They found that future-oriented reasoning is a function of age, in that younger participants demonstrated a strong preference for immediate rewards, even if those rewards were much smaller than another time-delayed reward, where delays ranged from one month to one year. Researchers have also found that time perception skills are developmentally delayed for those with ADHD and that working memory skills are strongly linked with time perception skills (Sonuga-Barke et al., 2010; Walg et al., 2017; Zheng et al., 2022). Importantly, as individuals' ability to accurately conceptualize increasingly large windows of time across development, so does individuals' ability to conceptualize and pursue increasingly long-term goals (e.g., Friedman, 2005).

Verbal working memory pertains to the internalization of speech (Barkley, 1997). This EF skill is integral to self-reflective and self-referential processes that are verbally mediated. Examples of such processes include metacognitive thinking, problem solving, and the ability to infer and generalize unspoken rules across contexts (Barkley, 1997). Verbal working memory also plays an important role in language-based academic skills, such as reading comprehension. Researchers have found that verbal working memory dysfunction is common for those with ADHD. For example, Ramos et al. (2020) conducted the largest meta-analysis of studies of verbal working memory and ADHD to date. Using 49 studies that yielded verbal working memory data from nearly 5,000 participants with ADHD and over 3,000 non-clinical controls, Ramos et al. found that verbal working memory was a central deficit characterizing ADHD across age groups. They also found that the magnitude of verbal working memory deficits decreases as a function of age. Ultimately, both nonverbal and verbal working memory represent necessary, but not sufficient, cognitive processes that are foundational to the development of the other two EF skills in Barkley's (1997) model: self-regulation of affect, motivation, and arousal (i.e., self-regulation); and reconstitution.

Self-regulation skills pertain to the privatization, or internalization, of emotion and motivation (Barkley, 1997). According to Barkley (1997), both emotionally-salient imagery and self-speech that is held in nonverbal and verbal working memory allow for the internalization of emotions and motivation. Individuals' ability to exert executive control over their emotional responses to stimuli subsequently allows them to access additional higher-level cognitive processes that allow for greater objectivity in decision making, long-term goal setting, and engaging in goal-directed behaviors. Although there is scant research on Barkley's specific executive construct of self-regulation of affect, motivation, and arousal, those diagnosed with ADHD indeed have greater difficulties with emotional impulsivity and emotional self-regulation than non-clinical control groups (e.g., Sanabra et al., 2021). Furthermore, researchers who have investigated emotion dysregulation, behavioral outcomes, and ADHD support Barkley's assertion that executive control over emotions is an important scaffold for engagement in higher-level cognitive processes involved in decision making and goal-pursuit. Importantly, when emotional self-control is impaired, individuals tend to exhibit poor proactive responses and impulsively respond to stimuli (especially stimuli with a strong emotional valence; Bunford, 2019; Modecki et al., 2017). Consequences of this pattern of behavior can include engagement in risky behaviors (e.g., unsafe sex, drug use, reckless driving), emotional lability (i.e., excessive displays of and changes in positive and negative emotions), and difficulties developing positive social relationships (Bunford, 2019).

The final EF in Barkley's (1997) model that contributes to the core symptoms of ADHD is reconstitution. Reconstitution refers to the ability to generate diverse, yet situation-specific, novel behaviors that are intended to pursue a non-immediate goal. Similar to self-regulation of affect, motivation, and arousal, reconstitution skills are predicated upon verbal and nonverbal working memory skills. Specifically, Barkley held that reconstitution involves both verbal and nonverbal working memory to parse previous situation-specific behavioral sequences carried out by others or oneself in order to use that information to create new goal-directed behavioral sequences. According to Barkley, reconstitution comprises two subskills: analysis and synthesis. Analysis refers to the ability to parse one's own or others' actions into smaller, sequentially-organized units of behavior. Synthesis refers to the ability to reorder and recombine behavioral units into goal-directed behavioral sequences that are most likely to result in a favorable outcome given the situation and environmental context. Although reconstitution is also not a widely researched EF, researchers have found that difficulties with reconstitution, as defined by Barkley, are associated with symptoms associated with the inattentive subtype of ADHD, in particular (Harrier & DeOrnellas, 2005).

Motor Control, Fluency, and Syntax. The final component of Barkley's (1997) model of ADHD is motor control, fluency, and syntax. Barkley held that these skills represent the behavioral end product of a given individual's unique profile of behavioral inhibition and EF skills. In typically developing populations, motor control, fluency, and syntax skills manifest as complex forms of behavioral self-control. Examples of complex behavioral self-control include error sensitivity (i.e., the ability to hold in mind a previous response and use it to modify a future response in such a way that makes goal attainment more likely), long-term goal-pursuit in spite of interruptions (i.e., the ability to disengage in a behavior, respond to an interruption, and subsequently re-engage in the interrupted goal-directed sequence), and the cross-temporal organization of behavior (i.e., the ability to plan, organize, and modify goal-directed sequences of behavior over time). Complex forms of behavioral self-control are critical to individuals' ability to override impulses to respond to immediate contingencies and engage in meaningful long-term goal pursuit. For those with ADHD, Barkley argued that deficits in behavioral inhibition and/or one or more EF skill components—in combination with other environmental, social, and biological variables—result in difficulties with goal-directed persistence, which ultimately manifest as core symptoms of ADHD.

Expanding on this point, a central component of Barkley's (1997) model is that the core symptoms of ADHD are best understood as manifestations of developmental delays in accurately perceiving and conceptualizing the passage of time. Barkley argued that behavior dictated by actions and reactions to immediate stimuli precludes an individual's ability to accurately perceive the passage of time. In other words, if immediate stimuli in the present moment is the primary driver of behavior, as is often the case with ADHD, then it is exceedingly difficult for individuals with ADHD to accurately conceptualize long-term goals and behaviors in pursuit of those long-term goals (Barkley, 1997).

Researchers have since demonstrated that individuals with ADHD indeed have difficulties with conceptualizing the passage of time (Quartier et al., 2010). Their difficulties have been shown to reside specifically in accurate time reproduction. Time reproduction refers to an active estimation of the passage of a specified period time (as in by starting and stopping a stopwatch) as opposed to a retrospective estimation of the length of an already-elapsed period of time (Kerns et al., 2001; Laneri et al., 2001). Converging with Barkley's theory, researchers have shown that time reproduction deficits are related to difficulties with long-term goal setting and goal pursuit. For adolescents with ADHD, difficulties with the ability to accurately sense the passage of time in the present moment and consequent difficulties with goal setting and goal pursuit are particularly common and impairing for adolescents, especially in the academic setting (Johnson & Reid, 2011).

Summary and Implications. Overall, Barkley (1997) held that core symptoms of ADHD are driven by developmental delays in behavioral inhibition and EF skills. Although individuals with ADHD are likely to have idiosyncratic deficit profiles with respect to behavioral inhibition and EF skills, Barkley argued that a common outcome of these deficits is to engage in behaviors that are shaped by short-term contingencies. Ultimately, he argued that these behaviors manifest as inattention, hyperactivity, and/or impulsivity. Barkley's theory carries implications about the nature of the difficulties that those with ADHD are likely to experience, especially in the context of environments that place demands on attention, motivation, and long-term goal pursuit, such as the academic setting. His theory also is accompanied by several implications about how to best support these difficulties with nonpharmacological interventions. Therefore, Barkely's theory is employed as a framework through which academic difficulties and relevant nonpharmacological interventions are conceptualized in the present paper.

However, it is important to again emphasize that Barkley's (1997) theory of ADHD is not a comprehensive theory of ADHD, meaning that the executive functioning deficits implicated in Barkley's model are not the only neuropsychological deficits that account for ADHD symptomatology and outcomes. Relatedly, there are several other theories of ADHD that fill in the gaps in Barkley's model. For example, although EF deficits are a central component of Barkley's model, researchers have estimated that at least 20% of individuals who meet clinical diagnostic criteria for ADHD do not demonstrate EF impairments (e.g., Nigg et al., 2005). Other cognitive theories of ADHD that help account for ADHD symptoms include the dual-pathway model (Sonuga-Barke, 2002) and those that propose that processing speed deficits contribute to ADHD symptomatology (Shanahan et al., 2006).

Overall, researchers have demonstrated that no single cognitive theory of ADHD fully accounts for the symptoms associated with the disorder (e.g., Nigg, 2017). Nonetheless, consistent with Barkley's (1997) theory, EF deficits represent a common phenotypic trait that accompanies ADHD (see Kofler, Irwin, et al., 2019). Therefore, Barkley's model of ADHD remains a useful framework through which ADHD symptoms and nonpharmacological treatments can be conceptualized. In the forthcoming sections, I review academic impairments in adolescent populations with ADHD, followed by a review of evidence-based nonpharmacological ADHD interventions. In these reviews, Barkley's model of ADHD is employed as an overarching framework, in that emphasis is placed on how various EF deficits contribute to academic underachievement, and how EF deficits can be supported through nonpharmacological interventions.

Academic Impairment in Adolescent Populations with ADHD

Researchers have established that symptoms of ADHD contribute to impairments in multiple areas of functioning, including social interaction, emotional and behavioral control, and academics (e.g., Arnold et al., 2020; Sibley et al., 2014). In adolescent populations, one of the most adversely affected areas of functioning is academics (Barkley et al., 2006; Trout et al., 2007). Indeed, adolescents with ADHD remain at elevated risk of academic underachievement even after accounting for cognitive ability and common comorbidities that can adversely affect learning and performance in school, such as dyslexia and dyscalculia (Zentall, 2007).

There is a robust body of research in which ADHD is established as a meaningful risk factor for underachievement. For example, in Frazier et al.'s (2007) meta-analysis of nearly 20 years of research on ADHD and achievement outcomes, students of all ages with an ADHD diagnosis were found to perform below their peers on standardized tests of achievement. The researchers specifically found that relative to typically-developing participants, students with ADHD demonstrated achievement deficits of moderate to large effect sizes in foundational academic areas, including reading (d = 0.73), mathematics (d = 0.67), and spelling (d = 0.55). In addition, academic underachievement tends to be chronic throughout elementary and high school (DuPaul & Stoner, 2014). Relatedly, ADHD symptoms in childhood are strongly predictive of achievement problems in adolescence. Indeed, childhood ADHD is nearly as predictive as cognitive ability with respect to academic outcomes during adolescence, even when comorbidities and associated conditions are taken into consideration (Birchwood & Daley, 2012).

However, not all ADHD presentations predict academic difficulties. Indeed, the academic difficulties experienced by individuals with ADHD largely stem from core symptoms of inattention, as opposed to hyperactivity or impulsivity (DuPaul et al., 2009). This finding aligns with the fact that adolescents—a population that are more likely to have inattentive symptoms than their younger counterparts—are at particular risk for demonstrating difficulties in school (DuPaul & Stoner, 2014). Many researchers have sought to identify the underlying reasons that account for the strong relation between the inattentive presentation of ADHD and academic impairment. Although researchers have made clear the fact that achievement deficits cannot be accounted for with a single explanation (e.g., van Hulst et al., 2015), there are two key explanatory pathways that help identify the myriad reasons why academic impairments commonly accompany inattention. One pathway describes how the cognitive impairments commonly associated with ADHD can directly result in learning difficulties that directly contribute to underachievement. The other pathway describes how core symptoms of ADHD can indirectly contribute to underachievement by way of poor engagement in skills that support academic achievement.

Direct Effects of ADHD on Achievement

With respect to the ways in which EF deficits can directly affect achievement outcomes for individuals with ADHD, researchers have primarily found that working memory deficits, in particular, are associated with learning difficulties in core subject areas such as math and language abilities (e.g., Throell et al., 2013). Working memory deficits that characterize ADHD have been shown to result in slowed processing speed (i.e., delays between stimulus onset and response) which in turn can contribute to oral reading fluency deficits, even for those without a comorbid learning disability (Jacobson et al., 2011).

Researchers have also attempted to tease apart the unique affects that two specific working memory subtypes—phonological working memory and visuospatial working memory—have on learning in specific subject areas for those with ADHD. As previously summarized, phonological working memory involves private, internalized speech that plays a central role in digesting information and planning future action by way of reflection, description, and self-questioning (Barkley, 1997). Visuospatial working memory involves holding and manipulating nonverbal information in mind, which plays a central role in planning future behavior in response to sensory events (Barkley, 1997).

Of these two working memory subtypes, there appears to be stronger support for the direct, negative affects that phonological (i.e., auditory-verbal) working memory deficits have on achievement outcomes across areas of learning for adolescent populations with ADHD (Gut et al., 2012; Rogers et al., 2011). In general, phonological working memory deficits can hamper academic performance in foundational subject areas that require efficient phonological working memory skills, such as reading and math (Gut et al., 2012; Rogers et al., 2011). Although some discrepant findings exist (e.g., Kofler, Spiegel, et al., 2019), phonological working memory deficits have been implicated in the academic underachievement of adolescents with ADHD in foundational academic skill areas such as simple computation and number fact retrieval (Meyer et al., 2010), reading fluency (Jacobson et al., 2011), reading comprehension (Ramos et al., 2020), and written expression (Eckrich et al., 2018).

Visuospatial working memory deficits may also directly and negatively affect achievement outcomes. However, visuospatial working memory skill deficits are most commonly present in elementary aged populations with ADHD (van Ewijk et al., 2014), and the direct relation between visuospatial working memory deficits and achievement outcomes in adolescent populations with ADHD is mixed. Some research has supported visuospatial working memory deficits persisting into adolescence. For example, in Martinussen et al.'s (2005) meta-analysis of 26 empirical studies that explored working memory deficits in children and adolescents with ADHD, visuospatial working memory was consistently more impaired than phonological working memory across development. In addition, findings from a separate study suggested that visuospatial working memory deficits may be even more pronounced in adolescents with ADHD in comparison to children with ADHD (Westerberg et al., 2004).

However, other research indicates that visuospatial working memory deficits are less likely to be present in populations of adolescents with ADHD. In a tightly-controlled study in which researchers compared the working memory skills of individuals with and without an ADHD diagnosis, there were no differences in visuospatial working memory capacity in adolescent and young adult populations after matching participants by age and general intelligence (Spronk et al., 2013). Similarly, Gropper and Tannock (2009) found that in their sample of college-aged students with ADHD, auditory-verbal working memory deficits were positively correlated with self-reported GPA, whereas there was no significant relation between GPA and visual-spatial working memory. Given the conflicting findings on the presence and affect of visuospatial working memory deficits in adolescence, it is difficult to draw any definitive conclusions about whether visuospatial working memory deficits result in learning difficulties that meaningfully contribute to academic underachievement.

Overall, select EF deficits, particularly those related to working memory, can directly result in academic difficulties and underachievement for ADHD-diagnosed adolescents. However, the direct impacts that EF deficits can have on academic achievement do not fully account for the academic underachievement experienced by adolescents with ADHD. For example, even when the core inattentive symptoms that characterize adolescent ADHD are brought to subclinical levels through pharmacological treatment, academic underperformance across subject areas persists (Gaastra et al., 2016; Miller & Lee, 2013). In fact, studies have shown that academic behaviors mediated by executive functions (e.g., note-taking, planning, study skills) also affect academic outcomes, albeit indirectly. Moreover, for those with ADHD, core symptoms can negatively affect academic outcomes to an even greater degree than cognitive ability or academic skill (e.g., Arnold et al., 2020; Gut et al., 2012). Therefore, it is important to also review the ways in which ADHD symptoms can indirectly affect achievement outcomes as well.

Indirect Impacts of ADHD on Achievement

Similar to academic impairments that can arise as a result of various EF deficits for adolescents with ADHD, poor engagement in skills that support academic achievement can also arise from EF deficits. Researchers have shown that across home and school settings, adolescents with ADHD consistently fail to engage in a range of skills that typically underlie academic success in the secondary school setting. These include time management, organization, and planning skills (Langberg et al., 2013; Sibley et al., 2014). Furthermore, inaccurate self-awareness (Steward et al., 2017) and lower academic motivation (Smith et al.,

2020) are also commonly experienced by those with ADHD and can additionally contribute to academic underachievement in adolescent populations.

Among the most common academic skill deficits for those with ADHD are time management, organization, and planning. Sibley et al. (2014) demonstrated the ubiquity of these deficits among those with ADHD. Survey and rating scale data collected from parents and teachers of adolescents with ADHD illustrated that the students often missed class notes, haphazardly organized their classwork , carelessly completed assignments, forgot to keep track of assignments in an agenda or planner, and did not carefully follow assignment instructions. Survey data also showed that time management and planning represented the most pervasive difficulties for adolescents, especially with respect to getting started on assignments and completing long-term projects. Similarly, Langberg et al. (2008) demonstrated that poor time management, planning, and organization skills not only predicted lower school grades but were even more predictive of grades than other ADHD-impacted abilities, such as working memory and behavioral regulation.

Adolescents with ADHD also have been shown to possess an inaccurate self-perception of their own academic performance and skills. For example, one empirical study gathered EF data from participants aged 11 to 16, as well as data from participants' parents and teachers (Steward et al., 2017). Compared to their non-clinical counterparts, participants who had an ADHD diagnosis consistently rated themselves far more favorably than parent and teacher ratings with respect to academically-related EF impairments, including self-monitoring abilities, working memory skills, planning and organizational skills, and metacognitive skills. In keeping with Barkley's (1997) cognitive model of ADHD, it is plausible that poor self-reflective and metacognitive skills stem from deficits in verbal working memory, which has been established as a key domain of cognitive dysfunction in ADHD (Ramos et al., 2020). Ultimately, poor metacognitive skills as measured by the accuracy with which individuals evaluate their own performance can negatively influence academic outcomes, specifically predictive of lower overall course grades and lower GPA (Young & Fry, 2008). Even after adjusting for intelligence and parent education, metacognitive behaviors have been shown to account for up to 6% of the variance in academic performance as measured by GPA (Sibley et al., 2019).

Finally, with respect to academic motivation, Smith et al. (2020) found that adolescents with ADHD endorsed lower intrinsic and extrinsic academic motivation, as well as greater amotivation, in comparison to their typically-developing peers (Smith et al., 2020). Although measures of motivation were not strongly linked to overall GPA, motivation was predictive of general academic performance for adolescents with an ADHD diagnosis. Greater amotivation, in particular, was associated with poorer homework performance. However, not all motivational differences for those with ADHD were a hindrance to academic outcomes. For example, higher levels of extrinsic motivation were identified as something that can be framed as a potential asset for adolescents with ADHD, as it was associated with better homework performance and higher GPA.

Morsink et al. (2019) similarly explored motivation and academic outcomes in adolescents with ADHD and investigated whether specific types of academic tasks were associated with different degrees of motivation. They found that in a sample of participants ranging in age from 9 to 16, participants with ADHD consistently reported that cognitively challenging tasks are particularly unmotivating in comparison to ratings provided by their non-clinical counterparts. Furthermore,relatively low motivation to complete cognitively challenging tasks partially accounted for the association between ADHD symptom severity and GPA.

Summary of Impacts of ADHD on Achievement

In line with Barkley's (1997) theory of ADHD, a common theme in explanatory frameworks for academic underachievement is that deficits in executive functions are widely considered to be primary drivers of academic underachievement. Across age groups, researchers have found that those with ADHD have substantially greater EF deficits in comparison to non-clinical control groups, and that EF difficulties predict poor academic outcomes, such as academic underachievement and grade retention (e.g., Biederman et al., 2004). In particular, deficits in working memory, attention shifting, and response inhibition have been implicated as contributing factors to underachievement in populations diagnosed with ADHD. Attention shifting is defined as the ability to efficiently switch from one situation, activity, or aspect of a problem to another, and is a skill deficit that persists into adolescence (Friedman et al., 2007; Qian et al., 2013). Using a sample of Chinese students aged 7 through 15, Qian et al. (2013) examined the relation between various EFs and ADHD across development. Their results indicated that of the various executive functions assessed, attention shifting deficits were the most persistent across development from childhood through adolescence for students with ADHD. More specifically, across age groups, those with ADHD performed similarly to typically-developing participants who were 2 years younger, thus implying that there is a developmental delay in attention shifting skills for those with an ADHD diagnosis. Although Qian et al. did not find evidence to support deficits that persist into adolescence, other researchers have demonstrated that adolescents with ADHD experience skill deficits in other forms of EF as well.

For example, one notable study conducted by Friedman and colleagues (2007) involved longitudinal data collected from the Colorado Longitudinal Twin Study, in which longitudinal data that pertained to child and adolescent behavioral development were collected annually. Over the course of the 8-year data collection period of the study, ratings of students' attention behaviors were collected from participants' teachers. EF data were collected directly from students, who completed a series of empirically validated EF tasks. Although teacher ratings of students' attention were used in lieu of a clinical diagnosis of ADHD, researchers found that from ages 7 to 14, attention problems consistently predicted individual differences in the EF skills related to response inhibition, updating working memory, and attention shifting. They specifically found that after covarying intelligence, teachers' attention ratings were most strongly predictive of students' later ability to inhibit automatic responses. Finally, longitudinal data analyses also suggested that the relations among attention problems and later EF abilities in adolescence remained stable over time, even though attention ratings were provided by a different teacher each year of the study.

Given that EF dysfunction appears to be a common factor that accounts for academic difficulties in adolescent populations, it stands to reason that nonpharmacological interventions that support specific EFs central to academic achievement in secondary schools should promote positive academic outcomes for adolescents with ADHD. Indeed, Barkley (1997) explicitly made recommendations about the specific ways in which interventions should be designed in order to effectively support EF deficits that are common for those with ADHD. In the next section, research on nonpharmacological ADHD interventions is reviewed and situated within Barkley's model. Barriers to nonpharmacological intervention implementation in the secondary school setting are also reviewed, with particular attention given to teacher-related and student-related barriers. Finally, a digital self-monitoring intervention is recommended as a viable intervention that can simultaneously provide evidence-based support for adolescents with ADHD and mitigate barriers to intervention use in secondary school classrooms.

Nonpharmacological ADHD Interventions: What Works, Barriers to Implementation in Secondary School Settings, and A Viable Solution

In line with Barkley's (1997) theory, effective nonpharmacological interventions for ADHD should target and support neuropsychological deficits that are associated with the disorder and that affect behavioral inhibition and executive functioning. Further, supports should be individualized to the greatest extent possible. Barkley provided several broad recommendations about how nonpharmacological interventions can be structured to best support the neuropsychological deficits related to ADHD and simultaneously address individual needs. Two recommendations appear to be particularly important fordelivering ADHD interventions in the classroom context.

First, treatments are more likely to be successful if they externalize information related to behavioral inhibition and executive functioning that is internally represented for typically-developing individuals. More specifically, nonpharmacological interventions are more likely to be effective if they externally represent information related to behavioral awareness, motivation, and the passage of time by providing visual or verbal cues that signal this information. Thus, making typically internalized processes—such as motivation and goal-directed behavior—represented externally is a key component of effective nonpharmacological ADHD interventions. According to Barkley's (1997) theory, such approaches are effective because they directly address core deficits in behavioral inhibition and executive functions that preclude normative internal representations of motivation and behavior. In short, it is crucial to create "prosthetic" (Barkley, 2011, p. 3) environments and behavioral representations for those with ADHD in order to support their engagement in executive processes that are typically mentally represented (i.e., internalized). A simple intervention is the use of visual cues in the classroom to signal typically internalized executive processes. A concrete example of this form of intervention is when a teacher displays a timer during assignments to help students better manage limited time.

Second, because ADHD is neurodevelopmental in nature and typically chronic, Barkley (1997) contended that treatments (pharmacological and nonpharmacological alike) cannot be expected to result in permanent changes in core symptoms for those with ADHD. In other words, ADHD treatments are acutely effective when administered, but do not tend to result in long-term, lasting behavioral change. In fact, researchers have confirmed that the core symptoms of ADHD primarily improve with neurological maturation over time (Langberg et al., 2008) and not as a result of pharmacological or nonpharmacological intervention. Indeed, it is well-established that ADHD medication produces short-term improvements in core symptoms when medication is regularly taken, which do not persist when medication is stopped (William et al., 2018). Similarly, evidence-based nonpharmacological interventions have been documented to produce short-term improvements in symptoms while the intervention is taking place, Yet when the intervention is removed, core symptom severity tends to rapidly return to baseline (e.g., Bruhn, Vogelgesang, et al., 2015). Still, ADHD treatments are most effective when delivered at the point of performance in the context that is relevant to the desired behavior (e.g., if the desired behavior is accurately following directions for in-class assignments, the intervention intended to promote this behavior should take place during assignment completion in the classroom setting).

Since Barkley's (1997) theory of ADHD was proposed, researchers have developed and investigated a vast range of nonpharmacological interventions that are intended to acutely reduce the core and secondary symptoms associated with ADHD (see DuPaul et al., 2011; Miranda et al., 2006; Pfiffner et al., 2006; Richardson et al., 2015). Examples of interventions that have been evaluated in the empirical literature include the following: contingency-management strategies, such as the use of consistent reward schedules, token economies, and response cost (e.g., Gomez, 2003; Miranda et al., 2006; Trout et al.); self-monitoring strategies (Alsalamah, 2017; Bruhn, McDaniel, et al., 2015; Harris et al., 2005; Moore et al., 2019; Scheithauer & Kelly, 2017); daily report cards (Pelham et al., 2016); skill-building treatments, such as the homework, organization, and planning skills (HOPS) curriculum and the Completing Homework by Improving Efficiency and Focus (CHIEF) curriculum (Breaux et al.; Evans et al.; Pfiffner et al.); peer tutoring (Plumer & Stoner, 2005); mindfulness training (Cairncross & Miller, 2020); motivational interviewing (Sibley et al., 2016); cognitive behavioral therapy (Antshel & Barkley, 2008; Sprich et al., 2015); universal design for learning (UDL) strategies (Zelenka, 2017); biofeedback and neurofeedback training (Steiner et al., 2014); and other unconventional interventions such as music therapy, dietary change, and massage (Richardson et al., 2015).

Given that this is a non-exhaustive list of nonpharmacological ADHD interventions, it is clear that the nonpharmacological ADHD intervention literature is sweeping in scope. Consequently, it can be difficult for educators and practitioners to independently engage in research given their limited time and limited access to evidence-based ADHD intervention resources (Elik et al., 2015). Moreover, researchers have yet to establish an agreed-upon, standardized tool that characterizes interventions and their specific designs (Richardson et al., 2015), which adds to both confusion around nonpharmacological ADHD interventions and systemic methodological inconsistencies in the research literature.

Several research teams have attempted to bring order to the nonpharmacological ADHD intervention literature by classifying interventions into broader intervention categories. For example, in Richardson et al.'s (2015) comprehensive, meta-analytical review of nonpharmacological treatments for ADHD, the researchers identified 26 unique nonpharmacological ADHD interventions that they grouped by four core intervention frameworks: (a) reward and punishment, (b) skills training and self-management, (c) creative therapies, and (d) physical treatment (i.e., exercise). Similarly, DuPaul et al. (2007) proposed three broad intervention categories consisting of contingency management interventions, cognitive-behavioral interventions, and academic interventions. Complementary to these classifications were those proposed by Trout et al. (2007) in their meta-analytic research. Using 41 empirical studies, these researchers primarily organized interventions by timing and delivery format, and found that interventions were best described as belonging to one of the five following categories: (a) antecedent-based interventions, (b) consequence-based interventions, (c) peer-mediated interventions, (d) adult-mediated interventions, and (e) self-regulation interventions.

Overall, there is at least some overlap among the intervention classifications proposed in the nonpharmacological ADHD literature. Generalizing across this body of work, ADHD interventions can be classified along the dimensions of intervention modality (e.g., behavior modification, counseling/therapy, and academic skills training), delivery location (e.g., classroom setting, home setting, one-on-one setting), and intervention delivery facilitator (e.g., parent, teacher, peer, or self). Additional authors have also highlighted the importance of conceptualizing an intervention's degree of complexity, defined as the number of distinct components that are present in a single intervention strategy (Miranda et al., 2006). In their review of empirical studies in which researchers examined ADHD interventions delivery in school settings, Miranda et al. (2006) argued that simple, single-component, nonpharmacological interventions are preferable, with the exception of medication use and/or parent and teacher psychoeducation in combination with a specific intervention strategy. Indeed, concurrent medication use and parent/teacher psychoeducation has consistently contributed to the most favorable behavioral and academic outcomes for students with ADHD (Caye et al., 2019; Fabiano et al., 2007), especially when a nonpharmacological intervention is introduced prior to medication use (Pelham et al., 2016).

Despite the diversity of nonpharmacological ADHD interventions, it is important to note that very few nonpharmacological ADHD interventions have garnered empirical support. The scarcity of empirically-supported nonpharmacological ADHD interventions is due in large part to methodological issues (e.g., single-subject designs, poor control of covariates, and poor intervention design) that pervade contemporary research on nonpharmacological ADHD interventions (Gaastra et al., 2016; Lambez et al., 2020; Richardson et al., 2015). However, there are a handful of promising nonpharmacological approaches that can effectively ameliorate core symptoms of ADHD and deficits in academic functioning. The intervention strategies that have garnered empirical support are as follows: behavioral interventions, self-monitoring interventions, and academic skill-building interventions.

Broadly speaking, behavioral interventions encompass any intervention that involves modifications made to the environment in order to promote desired behaviors and/or prevent undesired behaviors (DuPaul et al., 2011). These interventions also often employ contingencies (i.e., rewards and punishments) in order to alter the frequency of a target behavior (Gaastra et al., 2016). Results of meta-analytic research suggest that there is a range of effect sizes associated with behavioral interventions, ranging from small effects (e.g., d = .31) that have been associated with antecedent-based behavioral interventions, to large effects (e.g., d = 1.8) that have been associated with consequence-based interventions (Gaastra et al., 2016). Self-monitoring interventions represent a specific form of behavioral intervention that has also been associated with large effect sizes (e.g., d = 1.3; Gaastra et al., 2013). Unlike behavioral interventions that incentivize engagement in desired behaviors, self-monitoring interventions involve strategies intended to help individuals with ADHD build cognitive and/or behavioral awareness and self-control in order to elicit behavioral change (Gaastra et al., 2016).

Next, academic skill-building interventions are designed to help students build academic skills that are underdeveloped. Academic interventions may involve teacher- or counselor-mediated direct instruction in academic skill deficit areas (e.g., note-taking, planning, organizational skills), computer-assisted instruction, or classwide peer-tutoring approaches (DuPaul et al., 2011). Although academic skill-building interventions do not directly support core deficits associated with ADHD, such interventions have been associated with improved on-task behavior, increased engagement and performance outcomes on independent assignments, and improved social skills (Evans et al., 2014). However, effective academic skill-building is time-intensive and should entail one-on-one or small group skill building sessions that provide direct support with skills related to organization, note-taking, and study skills (e.g., Evans et al., 2014).

Of these interventions, both behavioral interventions and self-monitoring interventions have been associated with the largest effect sizes in the literature across age groups. These two classes of ADHD intervention are associated with other advantages as well. For example, behavioral and self-monitoring interventions are far more cost effective than more elaborate interventions, such as neurofeedback interventions (e.g., Richardson et al., 2015); can be embedded within a typical school day in the general education setting, unlike mindfulness interventions that require at least 20 minutes of dedicated guided practice (Cairncross & Miller, 2020); and can be implemented without the need for one-on-one or small group meetings (Bruhn, McDaniel, et al., 2015). Therefore, employing either behavioral interventions or self-monitoring interventions in the secondary school setting can effectively support the core symptom deficits and related academic difficulties of students with ADHD.

However, efficacy is not the only factor in choosing interventions best suited to support the specific needs of adolescents with ADHD in the school setting. Indeed, researchers have documented a hierarchy of unique contextual factors that represent barriers to the implementation and effectiveness of ADHD interventions in secondary schools. Barriers include certain features of normative adolescent development, family and teacher knowledge of and assumptions about ADHD, classroom characteristics, school characteristics, and even sociopolitical factors (Richardson et al., 2015). Of these, teacher-related factors represent a particularly salient bottleneck to the implementation of evidence-based interventions in secondary schools. Researchers have also demonstrated that providing teachers with supports, such as psychoeducation about ADHD, can dramatically improve their use of ADHD interventions (Montoya et al., 2010).

In the following section, I discuss how self-monitoring interventions, in particular, represent an example of an evidence-based intervention for ADHD that can simultaneously meet the needs of both adolescents and teachers in a sustainable manner. To understand how to best design and implement self-monitoring interventions for adolescents in the classroom setting, it is first necessary to understand the barriers that get in the way of implementation. Ultimately, the barriers directly related to teachers' capacity to implement interventions are emphasized and subsequently situated within a cognitive load framework. Then, the defining features of self-monitoring interventions are described in detail, followed by a review of the emerging literature on digitized self-monitoring interventions. Finally, I propose that providing teachers with a digital self-monitoring intervention represents one strategy that not only can support the unique needs of adolescents with ADHD, but can also facilitate teachers' implementation fidelity and long-term use of an evidence-based ADHD intervention.

Barriers to Nonpharmacological Interventions in the Classroom

Key barriers exist regarding the successful use of evidence-based practices to support students with ADHD and ADHD-consistent symptoms (e.g., Bussing et al., 2016; Collier-Meek et al., 2017; Elik et al., 2015; Lawson et al., 2022; Moore et al., 2017; Schatz et al., 2021; Strelow et al. 2020; Szep et al., 2021; Wright et al., 2015). Consistent with the definition used by Long et al. (2016), I define an intervention barrier as a factor that gets in the way of intervention implementation efforts or reduces the affect of an intervention. Drawing heavily on the intervention barrier models outlined by Wright et al. (2015) and Elik et al. (2015), four core sources are as follows: (a) intervention design factors (e.g., complexity, feasibility, user acceptability), (b) individual factors (i.e., originating from the parent, student, teacher), (c) organizational factors (e.g., school-level financial constraints, policy constraints, leadership support), and (d) societal factors (e.g., educational policy, cultural misconceptions). Of these barriers, I focus on those most proximal to intervention implementation: the intervention design itself. teacher factors (including knowledge of ADHD, attitudes toward ADHD), and classroom features; Szep et al., 2021).

Intervention Design Factors. Unsurprisingly, the design and requirements of a given intervention can get in the way of its implementation. In fact, Long (2016) found that nearly 60% of implementation barriers are related to the design of the intervention itself, and Collier-Meek et al. (2017) found that when teachers were asked to provide suggestions about how interventions might be more easily implemented, teachers primarily recommended simplifying intervention procedures (see Elik et al., 2015). In light of these findings, it is useful to examine how the core factors of complexity and feasibility, adaptability to individual contexts, user acceptability, and relevance can affect intervention implementation (Elik et al., 2015).

To begin, both simplicity and ease of implementation are among those most highly valued by teachers. As demonstrated by self-reported intervention preferences, teachers tend to prefer simple and straightforward interventions over those that are relatively more complex and time consuming (Elik et al., 2015; Gaastra et al., 2020). However, the strategies that teachers preferred in the Gaastra et al. study also tended to be those that are not strongly supported in the research literature (e.g., preferential seating, providing students with simple instructions). Specifically, Gaastra et al. found that the simple and straightforward ADHD interventions teachers gravitated toward were far less effective in supporting the needs of students with ADHD in comparison to the more complex and time-consuming interventions that have garnered strong support in the research literature, such as individualized behavior plans and self-monitoring strategies. Crucially, Gaastra et al. found that secondary school teachers reported using individualized and evidence-based strategies to a far lesser extent than their primary school teacher counterparts.

In fact, the vast majority of empirically supported intervention strategies for ADHD involve multiple time-consuming and individualized components. Take, for example, contingent positive reinforcement (DuPaul et al., 2011), which provides reinforcers to students when the student engages in a desired target behavior (e.g., staying on task for 5 consecutive minutes). When using contingent positive reinforcement strategies, teachers' responsibilities include individualizing reinforcers, frequently rotating reinforcers, actively tracking the target behavior throughout a class period, and administering the reinforcer as frequently and as temporally close to the occurrence of the target behavior as possible (DuPaul et al., 2011). However, employing this behavioral intervention approach would be demanding in terms of teachers' time and effort.

Self-monitoring represents another type of empirically-supported intervention that requires a nontrivial amount of time and effort for teachers to deliver. For example, Bruhn et al. (2022) explored the intervention components central to effective self-monitoring interventions. Finding that frequent monitoring intervals (i.e., 5-minutes or less), individualized goal setting and data tracking, explicit feedback from the teacher, and the use of reinforcements for engagement in desired target behaviors resulted in the most favorable behavioral and academic performance outcomes. Such an intervention would not only require a teacher to regularly monitor a given student's behavior over an extended period of time during class, but would also require a number of additional intervention maintenance efforts that go above and beyond their typical teaching duties: ensuring the student's accurate self-monitoring, tracking and compiling self-monitoring data, regularly training and updating goals, and providing behavioral reinforcements.

A number of other empirically-supported classroom ADHD interventions that have been described in the literature and recommended for the classroom also involve time-consuming and complex procedures. For example, Evans et al. (2014) reviewed a number of evidence-based interventions for ADHD. Finding that each involved multiple moving parts that would require substantial background knowledge for the individual delivering the intervention as well as coordination of school-based services. For example, Evans et al. described that effective self-monitoring interventions require systematically teaching students how to use a self-monitoring system, ensuring students keep track of their self-monitoring data and progress, and coordinating efforts with the school psychologist who conducted daily check-ins and goal setting meetings with students. Evans et al. also reviewed two comprehensive school-based ADHD treatments: the Challenging Horizons Program (CHP) and the Homework, Organization, and Planning Skills intervention (HOPS). Again, although CHP and HOPS were associated with meaningful gains in social, academic, and family functioning, both are characterized by a complex, multicomponent design that would be difficult to implement in a traditional public school setting.

In addition to time- and complexity-related barriers, demands that typically accompany effective psychoeducation and intervention implementation training can also get in the way of intervention delivery (Gaastra et al., 2020; Pfiffner et al., 2006). Although easily overlooked in practice, psychoeducation is a critical component of effective intervention implementation. When ADHD psychoeducation is effectively provided to teachers, teachers' use of empirically-supported interventions for ADHD increases (Gaastra et al., 2020). Similarly, psychoeducation has also been associated with an increased willingness to provide interventions and likelihood to seek out additional support for intervention implementation (Gaastra et al., 2020). Yet the single-day, in-service ADHD support training teachers commonly receive may not provide sufficient information about ADHD or evidence-based ADHD interventions (Dahl et al., 2019). In fact, effective psychoeducation should involve long-term, one-on-one meetings between a given teacher and behavioral consultant (Pfiffner et al., 2006). For a salient example, see Shapiro et al. (1996).

Overall, the amount of time it takes to deliver a given ADHD intervention—which is mediated in part by the given intervention's design and implementation requirements—represents a core barrier to teachers' successful intervention use in the classroom setting. Relatedly, developing ways in which teachers can have access to effective yet feasible ADHD interventions is an increasingly important issue in contemporary education research. Longitudinal data collected between 1999 and 2019 suggest that over the course of the past decades, teachers have increasingly endorsed the sentiment that implementing ADHD interventions in the classroom is too time consuming (Schatz et al., 2021). Thus, it is important to understand the barriers, especially those at the level of the teacher, that contribute to teachers' preference for quick and easy-to-implement ADHD interventions.

Teacher Factors. Several researchers have explored the teacher-related factors that contribute to their limited use of evidence-based interventions for ADHD in the classroom (e.g., Bussing et al., 2012, 2016; Coles et al., 2015; Collier-Meek et al., 2017; Elik et al., 2015; Lawson et al., 2022; Moore et al., 2017; Schatz et al., 2021; Strelow et al., 2020; Szep et al., 2021; Wright et al., 2015). One research team found that a staggering 80% of the barriers to ADHD intervention implementation reported by teachers were associated with teachers' professional and psychological characteristics (Collier-Meek et al., 2017). Among the individual-level barriers most frequently endorsed by teachers include those related to negative affect, limited knowledge and beliefs about ADHD, and having limited cognitive resources available to implement a given intervention.

As for negative affect, teachers across grade levels commonly report experiencing stress and frustration while supporting students with ADHD; consequently, teachers' experience of stress and frustration can get in the way of their use of evidence-based interventions (Greene et al., 2002; Greenway & Edwards, 2020; Lawson et al., 2022; Mulholland et al., 2015). Dort et al. (2020) conducted an illustrative study, sampling over 1,000 teacher participants across primary and secondary grade levels. Participants also had varied roles and credentials, and included both general and special education teachers, as well as pre-service and in-service teachers. During the survey-based study, each participant was asked to share information about their attitudes toward ADHD among other control measures such as stress reactivity, personality traits, and perceived behavioral control. Using a latent profile analysis approach, researchers found that about one-third of the in-service teachers held negative attitudes about students with ADHD (e.g., more likely to endorse that, compared to typically developing children, those with ADHD engage in more disruptive behaviors, are poorer listeners, and more frequently experience negative emotions). Furthermore, teachers who demonstrated a negative attitude profile reported that their perceived stress is heightened when supporting students with ADHD. It is noteworthy and unsurprising that all participants reported experiencing a moderate degree of stress when working with students who have ADHD (i.e., scoring an average of 3 to 3.5 on a perceived stress Likert scale ranging from 0 [*not severe*] to 6 [*very severe*]).

Researchers have demonstrated that teachers' feelings of stress associated with working with students who have ADHD can even be elicited by hypothetical classroom scenarios. In a study conducted by Ohan et al. (2011), teacher participants were provided with vignettes that described children who engaged in behavior consistent with ADHD symptoms; half of the vignettes included the label “ADHD” and half did not. In comparison to teachers who read the vignettes that did not use the label “ADHD” to describe the hypothetical student, the teachers who read labeled vignettes reported feeling more stress. Finally, teachers are not the only school personnel who report stress when working with students who have ADHD. Domsch et al. (2022) investigated the subjective level of stress reported by school support staff involved in delivering ADHD interventions (e.g., after-school student supervisors, caregivers, social workers). On average, support staff perceived children with ADHD to be more stressful to work with than their typically-developing peers. Moreover, greater levels of stress predicted staff members’ perceptions of ADHD intervention feasibility, with greater degrees of stress predicting perceptions of ADHD interventions as less feasible (Domsch et al., 2022).

In addition to stress, teachers’ knowledge related to ADHD and evidence-based ADHD interventions predicts teachers’ perceptions of intervention acceptability and self-reported intervention use. Although researchers have long known that teachers’ knowledge of ADHD predicts their treatment acceptability ratings of students’ use of medication to treat ADHD (e.g., Vereb & DiPerna, 2004), more recent findings reveal that knowledge of ADHD is also associated with the degree to which teachers report using classroom-based ADHD interventions (Anderson et al., 2012; Bussing et al., 2012; Coles et al., 2015; Dort et al., 2020; Schatz et al., 2021; Szep et al., 2021). Strelow et al. (2020) recently conducted a study on how teachers’ attitudes and knowledge about ADHD relate to their use of effective classroom management strategies to support students with ADHD. Not only did the researchers identify a knowledge gap about ADHD in the teacher participants, but ADHD knowledge indirectly predicted teachers’ intentions to use effective classroom interventions. This relation was mediated by an inverse association between teachers’ ADHD knowledge and their expectations about the efficacy of ADHD interventions. Simply put, the less ADHD-specific knowledge teachers had, the more likely they were to evaluate a given ADHD intervention as ineffective, which consequently resulted in teachers being less likely to plan on using the given ADHD intervention in the future.

Unfortunately, researchers have documented that across grade levels, teachers tend to possess relatively limited knowledge about the characteristics, treatments, and outcomes of ADHD (Guerra & Brown, 2012; Sciutto et al., 2016; Szep et al., 2021; White et al., 2011). Furthermore, this phenomenon is not unique to the United States. In their study that compared teachers’ knowledge and misconceptions about ADHD across nine countries (i.e., Czech Republic, Germany, Greece, Iraq, North Korea, Saudi Arabia, South Africa, the United States, and Vietnam), Sciutto et al. (201) showed that, cross-nationally, teachers consistently lack knowledge about ADHD and relevant evidence-based classroom interventions. Unsurprisingly, knowledge gaps about ADHD not only pervade the teaching profession but are pervasive at the pre-service level of teaching as well (Poznanski et al., 2018). Factors that contribute to teachers’ generally limited knowledge about ADHD include the following: a systemic lack of communication between the fields of psychological research and educational research pertaining to supporting ADHD in schools (Dort et al., 2020); a lack of explicit pre-service teacher training on how to support specific, high-incidence disorders like ADHD (Flower et al., 2017; Lawson et al., 2022); and a lack of effective and evidence-based professional development and training provided to in-service teachers (Schatz et al., 2021).

Furthermore, teachers have commonly indicated that, oftentimes, they simply do not have the cognitive bandwidth to implement interventions on top of their usual teaching duties. Factors that can decrease teachers' cognitive capacity for implementing interventions during class time include having limited time and managing competing demands while teaching. Drawing on data from over 1,200 preschool through 12th grade teachers, Long et al. (2016) carried out a survey-based study that explored factors that facilitated and inhibited teachers' intervention use. Long et al. found that 21% of teacher respondents reported that the greatest barrier to their use of interventions was the time requirements associated with the intervention. Moreover, Lawson et al. (2022) conducted a similar study with the aim of identifying barriers associated with teachers' implementation of classroom interventions for ADHD, using a mixed-methods approach by collecting data from teacher participants through both surveys and semi-structured interviews. A key finding was that one of the most frequently endorsed barriers to intervention use was being distracted or being forgetful as a result of competing demands: limited class time; typical classroom teaching activities such as direct instruction; managing student work time; and class-wide behavior management. Experiencing stress and frustration, lacking key knowledge about ADHD, and having limited cognitive resources are all arguably interrelated, individual-level barriers that all serve to increase the barrier of entry when it comes to learning about and implementing classroom-based ADHD interventions.

Overall, a theme that arguably unites each of the aforementioned individual-level barriers is cognitive effort. When teachers lack important background knowledge that would otherwise help teachers make sense of ADHD interventions and best practices, the cognitive burden of selecting and implementing interventions is heightened. Likewise, when teachers experience stress and frustration while instructing students with ADHD, they have fewer cognitive resources to allocate toward engaging in additional activities, especially those that are unpracticed and extraneous to typical teaching responsibilities. Finally, when teachers have limited time and are already attending to multiple sources of information (e.g., students' engagement, direct instruction, staying on schedule), it may be difficult to allocate additional cognitive resources to managing new sources of information, such as ensuring that individualized interventions are implemented with fidelity. One theoretical framework that captures the excess mental effort that is associated with ADHD intervention delivery is cognitive load theory (CLT).

Cognitive Load. Originally conceived as a means of conceptualizing how irrelevant classroom activities can impede students' learning and problem solving performance (Chandler & Sweller, 1991), CLT is now used to better understand how accurate problem solving or task execution in a variety of contexts can be hampered by heightened information processing. Relatedly, CLT is now used as a framework for conceptualizing how to improve learning and performance outcomes not only for students, but for professionals as well. Cognitive load especially applies to professionals when their work is completed in demanding environments that can negatively affect working memory, such as environments that may elicit heightened negative emotionality and/or require professionals to process multiple sources of information (Leppink et al., 2015).

Broadly speaking, cognitive load is an index of mental effort defined by the number of elements being processed in working memory while carrying out an activity (Sweller, 2010). Therefore, a central premise of CLT is that any conscious mental operation occupies space in limited working memory and consequently limits attention available for other cognitive activities (Feldon, 2007). According to CLT, cognitive load is heightened while executing a task or skill in which one has not yet gained automaticity (Feldon, 2007). Conversely, cognitive load is reduced as one develops more elaborate and automated schemas related to successfully carrying out the given skill or task (Feldon, 2007). It is also important to note that the degree of cognitive load that is experienced is mediated by both working memory capacity and long-term memory retrieval (Schoor et al., 2012). Therefore, reducing cognitive load represents one strategy to facilitate individuals' accuracy when engaging in more complex forms of problem solving and efficiency with decision making (Sweller, 2010). However, researchers have proposed that in order to meaningfully reduce cognitive load, it is necessary to identify the sources that contribute to heightened cognitive load states.

There are three primary sources of cognitive load outlined in the research literature: intrinsic load, extrinsic load, and germane load. Young et al. (2015) provided a succinct summary of each of these cognitive load elements. *Intrinsic cognitive load* pertains to the complexity of the information relevant to the task at hand. Therefore, intrinsic load is inversely related to the individual's task-relevant background knowledge, meaning that the more relevant background knowledge the individual has to draw on, the less intrinsic load will be experienced. *Extraneous cognitive load* pertains to the processing of information unrelated to the task at hand, such as internal distractions (e.g., anxiety) or external distractions (e.g., visual stimuli, auditory stimuli). Thus, extraneous load can be reduced by minimizing external distractions and interruptions. Finally, *germane cognitive load* pertains to how learning or problem solving takes place while processing one or more elements of information in working memory. Relatedly, the intentional and effortful use of cognitive strategies (e.g., mental imagery, chunking information) to facilitate learning can serve to reduce germane load; conversely, not engaging the use of such strategies can increase germane load.

Regarding teachers, Feldon (2007) identified several sources of intrinsic, extraneous, and germane load experienced in the classroom. Sources of intrinsic load include content knowledge and pedagogical techniques. Sources of extraneous load include attention allocated to events or stimuli irrelevant to the lesson or activity, such as a distracting noise or interruption. Finally, sources of germane load include cognitive resources used to modify a given pedagogical approach based on active evaluation of students' degree of comprehension and attention to the lesson.

For teachers who need to provide additional classroom-based supports for students with ADHD or ADHD-consistent symptoms, it is likely that evidence-based ADHD interventions introduce both intrinsic and germane load. As previously summarized, evidence-based ADHD interventions require a degree of learning new information and applying that information to the execution of an intervention while simultaneously engaging in typical teaching responsibilities. As such, there is arguably a degree of intrinsic load introduced by ADHD interventions themselves, which are often multicomponent and/or multistep. Germane load is also likely introduced by multiple avenues. First, the difficulty associated with learning and applying a given intervention can escalate when a teacher does not have sufficient background knowledge about ADHD on which to draw. Germane load is also introduced by the need to maintain new information about an ADHD intervention and manipulate this information in working memory during real-time implementation. Finally, teachers must also contend with unique sources of extrinsic load that arise from the students who are receiving supports. Namely, behaviors associated with ADHD core symptoms are associated with teachers' reports of heightened stress (Bussing et al., 2002; Monteiro et al., 2022; Strelow et al., 2020).

Yet few empirical studies have been conducted to explore how cognitive load affects teachers' performance in the classroom. In one study researchers investigated how pre-service teachers' degree of mental effort related to various teaching activities, such as monitoring students' attention, meeting needs of diverse learners, and managing internal and external distractions (Moos & Pitton, 2015). Increased mental effort was primarily associated with managing external distractions, such as dealing with student behavior (Moos & Pitton, 2015). The association between mental effort and external cognitive load was mediated by teacher familiarity, or automaticity, with the lesson plan. Yet those with more than a year of experience teaching the lesson plan used in the study did not experience heightened cognitive load when faced with external distractions to the same degree as did participants for whom the lesson plan was new. The researchers concluded that automaticity is a key component of keeping heightened cognitive load at bay.

Broyles et al. (2011) similarly examined pre-service teachers' experience of cognitive load. Specifically, they explored how states of heightened cognitive load corresponded with teachers' instructional skills and ability to synthesize information. Pre-service teacher participants were asked to reflect aloud upon their teaching while watching a videotaped lesson they recently taught. The high cognitive load group was asked to reflect upon several aspects of their teaching, and the low load group was asked to reflect upon just one aspect of their teaching. The high cognitive load group demonstrated more difficulties with information synthesis as evidenced by their shallower depth of reflection and use of fewer critical thinking skills when reflecting upon their teaching skills in the videotaped lesson. Moreover, the high load group demonstrated more difficulty coming up with relevant teaching skills that could be used to improve their performance. An implication of this result is that when teachers add new practices to their routine classroom duties, such as implementing a new classroom intervention, teachers may have more difficulty with finding ways to improve the quality and implementation fidelity of the new practice without additional, external guided support.

Overall, the work of Moos and Pitton (2015) and Broyles et al. (2011) suggests that in order to help teachers implement a new classroom practice with fidelity, it is important to facilitate teachers' development of automaticity and provide opportunities for meaningful, focused reflection in the interest of improving future performance. Additionally, findings from cognitive load research in other contexts can provide insights about how teachers might experience heightened load when attempting to incorporate a new practice, especially because researchers have shown that high cognitive load hinders task performance regardless of performance domain or cognitive load source (Samson & Kostyszyn, 2015). More specifically, CLT research in the medical field might offer additional insights about how cognitive load can affect teachers' performance outcomes in the classroom. Indeed, Sewell et al. (2019) contended that despite apparent marked differences between educational professions and healthcare professions, the associations between cognitive load and a variety of performance outcomes are well-aligned. CLT functions well as an explanatory framework for individuals' performance in contexts characterized by complexity, stress, and uncertainty (Feldon, 2007), each of which represent constants in both the medical field and the educational field.

A key finding is that reducing cognitive load is associated with better learning and performance outcomes in high-stress contexts (e.g., Fraser et al., 2015; Sarkar et al., 2019; Sewell et al., 2019; Szulewski et al., 2021). For example, one team of researchers (Fraser et al., 2012) investigated whether the experience of negatively valenced emotions (e.g., feeling nervous, stressed, upset, sad, etc.) increases intrinsic cognitive load. Subsequently, they investigated whether the experience of negative emotions is associated with medical students' reduced accuracy when identifying a medical condition. They found that negative emotionality was indeed associated with increased cognitive load. Furthermore, they found that those who experienced heightened negative emotions demonstrated substantially less accuracy when identifying a given medical condition. A relevant conclusion negative emotionality experienced by teachers may increase cognitive load and consequently negatively affect aspects of their teaching practice. Therefore, because teachers have an increased likelihood of experiencing negative emotionality, such as stress, while working with students who have ADHD (e.g., Domsch et al., 2022; Ohan et al., 2011), attempting to use a new ADHD intervention may result in poor implementation accuracy.

Other researchers in the medical field have demonstrated that degree of expertise in a given domain of knowledge matters a great deal, Specifically, Szulewski et al. (2017) found that in a sample composed of novice physicians (1st and 2nd year medical school students), intermediate physicians (4th and 5th year residents), and expert physicians (attending physicians in their first years of practice), novices experienced substantially more cognitive load and less accuracy than the intermediate and expert students when answering questions that assessed medical knowledge. However, when engaged in solving arithmetic problems—a skill in which all participants had already gained expertise—there were no longer between-group differences in cognitive load or problem solving accuracy. This result suggests that for teachers, both limited background knowledge about ADHD in combination with attempting to implement a new and unfamiliar intervention may contribute to increased intervention implementation errors.

In summary, CLT research findings from both educational and medical contexts suggest the following: (a) heightened cognitive load is most likely to hamper performance outcomes if expertise or automaticity have not yet been attained, (b) cognitive load increases as the amount of information one must keep track of in working memory increases, and (c) the experience of negatively valanced emotions can increase the likelihood of experiencing heightened cognitive load. For teachers who are implementing a new intervention with one or more students with ADHD, a lack of automaticity combined with feelings of frustration may contribute to a heightened cognitive load state. As a consequence, teachers may inadvertently make mistakes while implementing a given ADHD intervention or experience difficulties with long-term implementation fidelity.

CLT research findings from both educational and medical contexts also suggest that the more complex and multi-step the intervention is, the more cognitive load will be experienced. The positive association between cognitive load and intervention complexity is concerning in the context of implementing ADHD interventions in the classroom given that many evidence-based ADHD interventions involve multiple steps and require teachers to keep track of several sources of information. Finally, findings suggest that merely working with students who have ADHD can increase cognitive load, especially since teachers have reported that students with ADHD represent a particularly stressful subset of students to work with (Bussing et al., 2002; Monteiro et al., 2022; Strelow et al., 2020). Overall, it is clear that teachers run the risk of experiencing heightened cognitive load in the process of providing additional supports and interventions to students with ADHD. This is a problem not only because heightened cognitive load can result in increased errors and poorer accuracy when carrying out a new practice, but also because heightened cognitive load is also associated with a number of negative, unintended consequences that can negatively affect student-teacher relationships and student experiences in school.

One such consequence is *cognitive defaulting*. Cognitive defaulting refers to when a high degree of cognitive load is experienced, previously learned/automatic processes take over (Feldon, 2007). Feldon (2007) illustrated that in the context of teaching, teachers' experience of heightened cognitive load could result in an increase in the frequency of potentially harmful biased thinking by way of a couple key cognitive processes. For example, high cognitive load can make it more likely for individuals to fail to consider information that does not align with stereotypic preconceptions about group memberships (e.g., van Knippenberg et al., 1999); high cognitive load can also increase the likelihood that individuals have greater difficulty suppressing deeply-ingrained, biased notions, which can increase the presence of biased perceptions (e.g., Wang et al., 2020).

Another unintended consequence of high cognitive load is an increased likelihood to be less trusting of others and engage in more impulsive decision making. Samson and Kostyszyn (2015) demonstrated this phenomenon in their study that involved participants who were paired up to play a game during which players attempted to maximize their score by reciprocally demonstrating trust under conditions of uncertainty. During the game, the researchers also subjected participants to one of three cognitive load conditions: no load, extraneous load (an unexpected noise), or intrinsic load (maintaining a string of numbers in working memory). Participants in both cognitive load scenarios not only demonstrated far more distrust of their partner, but also demonstrated a greater propensity toward impulsive and reactive decision making. Other negative, unintended consequences associated with heightened cognitive load include an increased reliance on bias in decision-making (Feldon, 2007); experiencing a reduced degree of self-efficacy (Feldon et al., 2019); and difficulty encoding information into long-term memory (Sweller, 2022).

Overall, the cognitive load literature paints a clear picture with respect to ADHD intervention design: there is a pressing need to provide teachers with intervention strategies that are not only evidence-based, but are also designed such that teachers' experience of cognitive load is minimized. Researchers have shown that one strategy to reduce cognitive load is to reduce the complexity of the task that is introducing the load (Feldon, 2007; Sweller, 2010). Another strategy is to increase individuals' task-relevant background knowledge (Moos & Pitton, 2015; Szulewski et al., 2017). It follows that reducing the complexity associated with evidence-based interventions for ADHD—by creating an intervention that simultaneously provides a simplified intervention implementation process and psychoeducation about ADHD—may improve teachers' intervention implementation by way of several mechanisms. An intervention that is easily implemented may promote longer-term use and greater implementation fidelity, which may in turn afford teachers an opportunity to perceive the efficacy of the intervention. At the same time, implementation of a more efficacious intervention may reduce the stress that teachers typically associate with working with students who have ADHD or ADHD-consistent symptoms. More positive teacher-student relationships can then serve as a catalyst for sustained intervention use, effectively creating a positive feedback loop for long-term intervention implementation.

One concrete approach to help teachers deliver evidence-based interventions for ADHD while reducing the cognitive load is to leverage computer delivery systems (e.g., mobile applications, web applications) for intervention implementation. A digital intervention could conceivably automate many cognitively taxing aspects that tend to characterize evidence-based ADHD interventions. Aspects of interventions that could be easily automated include the intervention implementation steps, data collection, and longitudinal data tracking. Automating typically time-consuming intervention components that teachers must otherwise complete and keep track of on their own could reduce a great deal of teachers' time and reduce cognitive effort typically dedicated to ADHD intervention implementation. A digital intervention approach could provide teachers with much-needed ADHD psychoeducation as well, further reducing cognitive load. In the forthcoming section, I outline how self-monitoring is one evidence-based ADHD intervention that is particularly amenable to a digital format. To this end, I first provide an in-depth literature review of self-monitoring as an ADHD intervention, followed by a description of how self-monitoring accompanied by psychoeducation can be re-envisioned as a digital intervention for ADHD that meets the needs of both students and teachers alike.

Overcoming Intervention Barriers with A Digital Self-Monitoring Intervention

In general, self-monitoring interventions encompass intervention strategies that help individuals consciously detect and evaluate their degree of engagement in one or more target behaviors (DuPaul et al., 2011). To achieve conscious detection and evaluation of one's own behaviors, self-monitoring interventions involve a multistage process of cueing self-assessment and of a target behavior and subsequent behavior recording (Reid et al., 2005). Regardless of approach, the intended outcome of self-monitoring interventions is behavioral change (Bruhn, McDaniel, et al., 2015). Self-monitoring interventions can be used to address neurodivergent behaviors across a range of disabilities (e.g., autism spectrum disorder, emotional and behavioral disorders, speech and language impairments, specific learning disability, etc.). When used in the context of ADHD, behaviors related to core symptoms are often what students are prompted to self-monitor (Alsalamah, 2017; Reid et al., 2005). Academic performance measures are common proxies for behavioral change. Typical examples of such measures include completed classwork, following directions accurately, on-task behavior, and note-taking behavior (Briere & Simonsen, 2011; Bruhn, Vogelgesang, et al., 2015; Daley & Birchwood, 2009).

Typically, self-monitoring strategies follow a specific, predictable framework (Haraway, 2012; Scheithauer & Kelley, 2017). First, a specific target behavior (or set of behaviors) is identified. For those with ADHD, the target behavior should be related to the individual's core symptoms that contribute to undesired academic or behavioral outcomes. Ideally, target behavior identification (along with other intervention-relevant decision-making) should collaboratively involve the student who will be receiving the intervention. Involving adolescent students in a collaborative capacity is important because it can increase students' perceptions of intervention acceptability and willingness to participate in the intervention (Golson et al., 2021). Next, a goal behavior or outcome that is functionally relevant to the target behavior is defined, and a means of tracking the student's degree of engagement in the replacement behavior must be determined (Bruhn et al., 2022). Typically, tracking is completed with a checklist delivered in analog (i.e., paper and pencil) format (e.g., Scheithauer & Kelley, 2017). With respect to interval timing, the interval may be as infrequent as monitoring engagement in a target behavior every 30 minutes (e.g., Barry & Messer, 2003) or may be as frequent as once every 45 seconds (Mathes & Bender, 1997); however, researchers have shown that ideal interval timing should occur every 5 minutes (Bruhn et al., 2022). During each self-monitoring session, both the student and teacher should independently track the student's engagement in the agreed-upon replacement behavior(s) at the conclusion of each timed interval. These ratings are later compared to determine the accuracy of students' self-ratings. Finally, emphasis on students' self-monitoring accuracy is preferable to solely assessing goal progress because emphasis on accuracy ratings can more effectively contribute to desired behavioral change (Bruhn, McDaniel, et al., 2015; Graham-Day et al., 2010).

In the school setting, the specified period of time during which a self-monitoring intervention takes place should be consistently implemented during a specified activity (e.g., independent work, note taking, etc.) or during a specified class period (Bruhn et al., 2022). Self-monitoring interventions that use relatively infrequent intervals usually entail monitoring of specific academic behaviors that take relatively long time to complete, such as completing homework or studying for a test (e.g., Scheithauer & Kelley, 2017). Conversely, higher frequency monitoring is typically associated with monitoring attention-related behaviors that are liable to quickly change over short periods of time.

Researchers have consistently demonstrated that self-monitoring is associated with desired behavioral change in both academic engagement and disruptive behavior (Bruhn, McDaniel, et al., 2015; Bruhn et al., 2022; Reid et al., 2005). For example, Bruhn et al. (2022) conducted meta-analytical research on how self-monitoring interventions influence academic and behavioral outcomes for students with executive functioning and behavioral difficulties. However, most of the students represented in the study's dataset had an ADHD diagnosis. Using a dataset composed of 87 single-case studies in which participants ranged in age from 6 to 17 years, Bruhn et al. found that on average, every 10 minutes of class time was associated with the equivalent of 3.4 more minutes of engagement and 3 fewer minutes of disruptive behavior for students who were trained to use a self-monitoring intervention. The researchers also identified several factors that moderated the efficacy of self-monitoring interventions. Key moderators that improved outcomes associated with academic engagement included the following: shorter monitoring intervals, whereby intervals of 5 minutes or less are associated with higher rates of desired behavioral engagement; the presence of a concrete goal, especially those that are made in collaboration with the student; and the use of feedback or reinforcements for performance.

Although self-monitoring interventions are a promising strategy to support academic outcomes and reduce disruptive behaviors, one limitation of Bruhn et al.'s (2022) research is that a range of disabilities and disability statuses were represented in the different participant pools included in the meta-analysis. Another limitation is that although participants included both children and adolescents, the average age of participants was about 10 years old, which limits the generalizability of Bruhn et al.'s findings to different age groups. However, it is worth noting that regardless of disability type, disability status, and participant age, self-monitoring interventions were associated with desired behavioral change.

Several other studies have similarly demonstrated that self-monitoring interventions are particularly effective at reducing core symptoms of ADHD (e.g., Alsalamah, 2017; Gaastra et al., 2016; Harris et al., 2005; Hinshaw & Melnick, 1992; Mathes & Bender, 1997; Scheithauer & Kelley, 2017; Sluiter et al., 2020). For example, both Gaastra et al. (2016) and Alsalamah (2017) conducted meta-analytic research involving how students with ADHD respond to self-monitoring interventions. Gaastra et al. found that self-monitoring interventions were among the most effective classroom-based interventions with respect to reducing the core symptoms and promoting the positive academic and behavioral outcomes of students with ADHD.

In a similar vein, Alsalamah (2017) conducted meta-analytical research using studies published between 2000 and 2016. The primary distinguishing factor between Alsalamah's research and Gaastra et al.'s (2016) research was that Alsalamah's meta-analysis required that studies meet rigorous methodological guidelines outlined by the What Works Clearinghouse (2010). Therefore, each of the studies used in Alsalamah's meta-analysis employed evidence-based practices. Overall, although most participants represented in Alsalamah's meta-analytical research were elementary-aged, self-monitoring interventions were associated with improvements in academic performance and on-task behavior, and reductions in disruptive behavior.

In addition to the two aforementioned meta-analytical studies, Sluiter et al. (2020) also found that self-monitoring interventions are associated with improvements in core symptoms, academic difficulties, and disruptive behaviors. In their research, elementary-aged students with ADHD received one week of self-monitoring intervention training and three weeks of intervention use during independent seatwork. Across third-party observations, teacher ratings, and standardized cognitive testing results, improvements in on-task behavior and reductions in off-task behavior were indicated were reported.

Notwithstanding the efficacy of self-monitoring interventions, it is important to emphasize that researchers primarily gather data from elementary-aged participants, and findings derived from elementary-aged populations cannot necessarily be generalized to adolescent populations. However, results from the few small-scale self-monitoring studies that have involved adolescent participants with ADHD (e.g., Briere & Simonsen, 2011; Graham-Day et al., 2010; Gureasko-Moore et al., 2007) suggest that self-monitoring interventions are both effective and well-suited to meet the unique needs of adolescents with ADHD. For example, results from a small-scale study conducted by Gureasko-Moore et al. (2007) indicated that a classroom-based self-monitoring intervention resulted in improvements in the organizational skills and homework completion of six male middle-school students with ADHD.

Similarly, Briere and Simonsen (2011) demonstrated that a self-monitoring intervention used with two middle school students led to desirable changes in behavior. Although the students did not have an ADHD diagnosis, they consistently demonstrated high levels of off-task behavior prior to intervention implementation. Additionally, their off-task behavior was not improved by previously used interventions, such as school-wide positive behavioral interventions and supports (SWPBS). During the self-monitoring intervention, the students' on-task behavior measurably improved; notably, the largest improvements were associated with self-monitoring prompts that involved functionally-relevant replacements for off-task behaviors (e.g., working quietly, appropriate peer or teacher interactions) as opposed to self-monitoring prompts that were not functionally related to the off-task behaviors targeted by the intervention (e.g., asking for a break).

Finally, Scheithauer and Kelley (2017) conducted a larger-scale study in which they investigated how a self-monitoring intervention affects core symptoms and common academic difficulties (e.g., organization, test taking, note taking, reading comprehension) experienced by college students with ADHD. Overall, participants in the self-monitoring treatment group demonstrated meaningful reductions in symptoms as measured by ADHD rating scales as well as meaningful improvements in GPA and academic behaviors. Additionally, the specific self-monitoring procedure that Scheithauer and Kelley used required all participants set two to three academic goals that they worked toward throughout the course of the study. Those who received the self-monitoring treatment reported a greater degree of goal attainment in comparison to those who did not receive self-monitoring treatment. Although participants in this study had an average age of 20.28 years, the results are arguably applicable to adolescent populations given that the most commonly-reported core symptoms across both age groups are related to inattention (Murray et al., 2018; Shaw & Sudre, 2021).

Overall, the efficacy of self-monitoring as an ADHD intervention is strongly supported in the literature. Despite the limitation that most of the self-monitoring intervention research has involved elementary-aged participants, findings from the few studies that have involved adolescent and young adult participants indicate that self-monitoring can be just as effective at reducing core ADHD symptoms in older populations. Moreover, self-monitoring interventions are easy to implement, inexpensive, and have a relatively high degree of social validity in comparison to other evidence-based intervention strategies (Alsalamah, 2017; Sluiter et al., 2020). Finally, relative to other ADHD interventions, self-monitoring interventions are unique in that they are particularly amenable to delivery via digital format, which is important because digital self-monitoring interventions can arguably enhance intervention implementation feasibility while maintaining efficacy.

Namely, several components of digital self-monitoring interventions automated (e.g., intervention prompting, data collection, data tracking), which can reduce the time and cognitive resources teachers might otherwise exert while carrying out analog ADHD interventions. In recent years, a few ADHD intervention researchers have acknowledged the benefits of digitizing ADHD interventions such as self-monitoring. For example, Bruhn, Vogelgesang, et al. (2015) and Bruhn et al. (2022) called for a shift toward digital self-monitoring interventions in the classroom to avoid the pitfalls associated with the time, resources, and planning required by traditional analog self-monitoring approaches. Therefore, if digital self-monitoring is to be presented as a viable alternative to analog self-monitoring, it is necessary to explore the features that distinguish extant digital self-monitoring approaches from traditional analog approaches. It is also necessary to explore the effectiveness of digital self-monitoring approaches.

Digital Self-Monitoring.

The presence of digital technologies in the classroom is nothing new. Over the past 20 years, teachers' and students' use of digital technologies has rapidly increased. The shift toward digital technology was initially facilitated, in part, by the U.S. Department of Education's National Education Technology Plan (NETP; U.S. Department of Education, 2010, 2017), which pushed for schools to incorporate digital technology (i.e., computers) in the classroom to maximize student learning and achievement. In fact, the presence of computers in contemporary schooling has become so widespread that research on technology in the classroom has quickly evolved from investigating how teachers can incorporate computer technologies into their curriculum (e.g., Goddard, 2002) to investigating the ways in which omnipresent digitization in the classroom can be detrimental to educational, social, and mental health outcomes, to name a few (e.g., Selwyn et al., 2023). Such concerns became even more heightened in the wake of the digital wave of remote learning that resulted from the SARS Covid-19 pandemic, during which millions of students experienced an average of 4 to 9 weeks of remote learning over digital video conferencing platforms, such as Zoom (Reimers, 2022; Serhan, 2020). Despite concerns about the prevalence and use of highly automated, digital technologies in the classroom—especially when the use of such technologies go uninterrogated or replace effective educational experiences instead of complementing them—technology-based tools in education also have many merits and represent one way to quickly and effectively provide learning and behavioral supports to students, especially those with disabilities.

Broadly, digital interventions encompass intervention approaches that use computer technology or devices to support student learning and behavioral outcomes. Oftentimes, such technologies also allow for collaboration and data sharing among teachers and students (Cambridge Assessment, 2017; Higgins et al., 2012). For students with ADHD or ADHD-consistent symptoms, researchers have determined that self-monitoring interventions are amenable to technology- and digital intervention formats. One of the earliest iterations of technology-based self-monitoring was developed in the early 1980s, where pre-recorded audio cues and digital timers were used to aid in prompting students to self-monitor (e.g., Hallahan et al., 1981). Over the past two decades, researchers have elaborated upon simple timer-based procedures and have developed a wide variety of digital self-monitoring strategies. In fact, in their review of self-monitoring interventions for students with behavior difficulties, Bruhn, McDaniel, et al. (2015) found that about 50% of the studies they reviewed used some form of technology to either cue or record self-monitoring. Arguably, the most prominent technology-based self-monitoring interventions in the research literature include the MotivAider (Amato-Zech et al., 2006), CellF-monitoring (Schardt et al., 2019), ScoreIt (Vogelgesang et al., 2016), and I-Connect (Wills & Mason, 2014).

The MotivAider represents a hybrid self-monitoring technology. Developed by Amato-Zech et al. (2006), the MotivAider was designed to deliver haptic vibrations at regular intervals to cue students' self-monitoring. Although the MotivAider procedure still entailed behavior monitoring with paper and pencil on a self-monitoring form, the researchers found that the intervention was effective. Specifically, students' average on-task behavior increased from 55% to greater than 90% across the observed intervals.

In the years after the MotivAider was developed, researchers began to delve into more fully computerized self-monitoring intervention approaches. CellF-monitoring represents an early iteration of a fully digital self-monitoring approach (Schardt et al., 2019). The approach leverages an existing digital platform, Twitter, as a means for students to engage in self-monitoring. Specifically, students receive four cell phone messages from Twitter (each sent after a 7-minute interval) over the course of a 20-minute instructional period. Each message prompts the student to respond to the question, "Are you on task?" by replying to the message with either "Yes" or "No". The researchers who developed CellF-monitoring conducted two case studies with middle school students in a naturalistic classroom setting to investigate the efficacy of the approach. Overall, they found that over the course of 12 observation sessions, both participants' on-task behavior increased from less than 50% to about 70%.

As for, fully digital self-monitoring approaches, empirically-based technologies are few and far between. Two prominent technologies are I-Connect (Wills & Mason, 2014) and ScoreIt (Bruhn, Vogelgesang, et al., 2016). Both are computer application-based technologies classroom use, and are intended to be delivered by a classroom teacher. I-Connect was developed by a research team at the University of Kansas and is currently available for commercial use. The app allows users to create an account and set personalized self-monitoring goals. While in use, the application alerts the student user to self-monitor at regular intervals by displaying the text, "Are you on task?" Each alert is preceded by either a flashing screen, a chime tone, or haptic vibration according to the user's preferences. The alert disappears after 6 seconds and begins the next timed interval. I-Connect also tracks and visualizes user data over time.

ScoreIt has several commonalities with I-Connect, although it is not currently available for commercial use. Similarly to I-Connect, ScoreIt allows users to create an account, prompts users to assess their engagement in a goal behavior, and delivers prompts at fixed intervals. Furthermore, in both studies that were used to examine the efficacy of these app-based approaches to self-monitoring, researchers helped the teachers who administered the intervention to provide in-person directions, performance feedback, and positively reinforcing comments (contingent on engagement in goal behaviors) to student users. There are also key differences between the apps. Unlike I-Connect, SCORE IT prompts teachers to also rate students' behavior after students provide their self-rating. When students and teachers are prompted to monitor the specified goal behavior, SCORE IT prompts users to respond according to a Likert-type scale (ranging from *Never* [0] to *Always* [4]) as opposed to a binary scale, which allows for a "Yes" or "No" response.

Ultimately, researchers have found that both I-Connect and SCORE IT can effectively reduce undesired behaviors and increase desired behaviors. Moreover, both digital interventions have resulted in desirable behavior and academic outcomes when used with adolescents. In the I-Connect research conducted by Wills and Mason (2014), an ABAB withdrawal design was used to investigate the efficacy and acceptability of the app over the course of 22, 15-minute self-monitoring sessions. Both participants were high school students aged 14 and 15 years old. Students' race/ethnicity information was also reported; one student was White and one student was Native American. The researchers found that during the app-based intervention use, both students demonstrated substantially greater time on-task and fewer in-class disruptions. Likewise, in the SCORE IT research conducted by Bruhn, Vogelgesang, et al. (2016), an ABAB design was used to investigate the efficacy and acceptability of the app over the course of 24, 20-minute self-monitoring sessions. Both participants were middle school students, aged 12 and 13 years old; other demographic information about the students was not reported. It should also be noted one student engaged in the intervention in a small, 5-student group setting. Regardless, both demonstrated meaningful behavioral change while using the app. In general, both students demonstrated increased academic engagement and decreased disruptive behavior (e.g., talk outs, leaving seat).

In spite of the efficacy of digital self-monitoring approaches suggested by researchers, there remain several drawbacks associated with existing digital self-monitoring technologies. First, both I-Connect and SCORE IT were examined within the parameters of a single-subject research design. Such studies are common in research on educational interventions (e.g., Alnahdi, 2015; Richardson et al., 2015). Although there are merits to single-subject designs—in that they allow for researchers to have greater experimental control, have greater capacity to investigate relatively complex intervention procedures, and engage in rich data collection—there are many limitations associated with single-subject research. One major limitation is that single-subject research does not lend toward strong external validity (i.e., generalizability of results; Alnahdi, 2015). Internal validity is also problematic in single-subject design research, especially when researchers do not pursue replication studies (Alnahdi, 2015), as is the case with the empirical investigations of the I-Connect and SCORE IT applications. As a consequence, there is a need for further research on the efficacy and intervention acceptability of such approaches, especially in the secondary school setting where teachers' use of evidence-based interventions to support ADHD is scarce (e.g., Sibley et al., 2016).

Next, there are several design limitations present in extant digital self-monitoring technologies. Such limitations may result in poor efficacy outcomes when used without the additional supports that are typically provided in the context of research (i.e., interventions are administered under close observation). For example, neither I-Connect nor SCORE IT comprehensively address several of the factors that can greatly affect teachers' long-term use or compliance with best-practices associated with desired outcomes related to behavioral change. Examples of best practices that are not integrated in the I-Connect and SCORE IT technologies are psychoeducation for teacher users, instruction that emphasizes the importance of providing students with a form of reinforcement (e.g., verbal reinforcement, tangible reinforcement) for providing accurate ratings, guidance on the need to set the self-monitoring interval length to 5 minutes or less, and instruction that provides teachers with information about the importance of helping students engage in long-term goal setting and goal modification associated with self-monitoring (Bruhn, Vogelgesang, et al., 2015, 2022). Relatedly, based on their review of the technology-based self-monitoring literature, Bruhn & Wills (2018) recommended that technology-based self-monitoring strategies provide effective support for treatment integrity, involve data collection and visualization, and facilitate communication and feedback between teachers and students.

Despite the shortcomings of extant digital self-monitoring tools currently available, researchers have called for the development and refinement of technology-based self-monitoring tools to promote students' academic and behavioral outcomes. Bruhn, Vogelgesang, et al. (2015) acknowledged that technology-based self-monitoring is "an effective and socially valid method for improving behavior" (p. 142). An easy-to-implement, technology-based self-monitoring intervention may also help address an enduring problem raised by Amato-Zech et al. (2006), which is that traditional self-monitoring procedures have high potential to be impractical, infeasible, or disruptive in the classroom. However, even if technology-based self-monitoring approaches are effective, it is necessary to determine the extent to which teachers—especially those at the secondary school level—find the intervention acceptable for classroom use. Although extant research that has explored the efficacy of self-monitoring technologies indicate that teachers have provided primarily positive feedback about these interventions and, similarly, have reported that technology-based self-monitoring approaches are socially valid in the classroom setting, researchers have yet to conduct a larger scale investigation of the intervention acceptability of a technology-based self-monitoring intervention.

The Present Study

For the proposed quantitative, survey-based study, I gathered data from secondary-school teachers to assess their acceptability of a digital self-monitoring intervention designed for classroom use with students with ADHD, in comparison to the acceptability ratings of an analogous self-monitoring intervention that is delivered in analog format. Data were used to pursue the following research aims: (a) whether having prior knowledge about ADHD is related to teachers' receptivity toward an empirically-supported, self-monitoring intervention for ADHD, (b) whether teachers evaluate a digital self-monitoring intervention as more acceptable than an analogous intervention delivered in analog format, (c) whether there is an interaction effect between prior knowledge and intervention modality, such that the effect of prior knowledge on intervention acceptability differs depending on intervention modality, and (d) whether teachers' intervention acceptability ratings may be additionally accounted for by relevant key variables (e.g., cognitive load, teaching self-efficacy, teaching experience, technological competency).

Ultimately, I anticipate that participants who learn about the etiology and symptoms of ADHD prior to exposure to a self-monitoring intervention in a vignette scenario will report greater receptivity to intervention implementation (digital or non-digital) compared to teachers who do not receive prior learning about ADHD. An interaction effect between the prior learning condition and intervention modality is also expected. Specifically, participants who receive prior learning about ADHD and are exposed to a digital self-monitoring intervention will report the lowest cognitive load and the highest intervention acceptability ratings. Conversely, participants who receive no prior learning about ADHD and are exposed to a non-digital self-monitoring intervention are expected to report the highest cognitive load and the lowest intervention acceptability ratings. Even without prior learning about ADHD, participants exposed to a digital self-monitoring intervention will report lower cognitive load ratings and higher intervention acceptability ratings than participants exposed to a non-digital self-monitoring intervention after receiving prior learning about ADHD. Finally, key variables will account for some variance in outcomes. Specifically, greater teaching self-efficacy and more teaching experience is anticipated to be associated with an overall greater degree of openness to intervention use, regardless of intervention modality. Additionally, preferences for the digital intervention format are expected to be associated with reduced cognitive load and greater self-reported facility with digital technology.

Method

Overview of Procedures

All participants read an informed consent form prior to beginning the survey. To participate, each participant needed to indicate their consent to participate by signing the informed consent form. Upon consenting to participate, participants were asked to first complete a demographic questionnaire. Subsequently, participants completed a series of questionnaires. First, participants completed the Computer Anxiety Rating Scale (CARS) and the Ohio State Teacher Efficacy Scale (OSTES). The purpose of the CARS was to ascertain participants' level of comfort with and openness to using digital technology. The purpose of the OSTES was to determine participants' beliefs about their own ability to meaningfully produce intended results or changes through their work with students in the classroom setting.

Participants were then randomly assigned to an ADHD psychoeducation condition, wherein participants received ADHD psychoeducation either before (i.e., pre-learning) or after (i.e., post-learning) learning about an ADHD self-monitoring intervention. If the participant was assigned to a pre-learning condition, they were prompted to read about background information regarding ADHD symptoms, causes, and best-practices for interventions. Those in the pre-learning group were then presented with a questionnaire that assessed their knowledge of ADHD (i.e., the Test of ADHD Knowledge [TOAK]). Alternatively, if the participant was assigned to the post-learning condition, they were presented with the TOAK immediately after the CARS and OSTES, and accessed the ADHD learning module at the end of the survey.

All participants then read a vignette description of a fictitious student with ADHD-consistent symptoms, followed by a randomly assigned description of either a digital or non-digital self-monitoring intervention to support the fictitious student. Both intervention descriptions were presented in text format with accompanying images that depicted the given intervention. After reading through the intervention and referencing sample images of the intervention materials, participants next completed a cognitive load measure regarding the mental effort they anticipated investing in executing the intervention. Subsequently, participants filled out an intervention acceptability questionnaire, which was a measure of how participants appraised the self-monitoring intervention they just read about. For those in the pre-learning condition, the intervention acceptability questionnaire was the final step. For those in the post-learning condition, the final step was to read through the same learning module used in the pre-learning condition.

Upon completing the final step in the study, participants were thanked for participation and were compensated for their time and effort by having the opportunity to enter into a raffle to receive one of four $50 Amazon gift cards. After data collection was completed, four participants were randomly selected to receive a gift card and the gift cards were distributed either via email. Entry to the raffle was completed through a link to a separate survey that prevented identifying information (name and email address) from being associated with a given individual's survey responses. It was not anticipated that the proposed incentive for participation would place any undue inducement on participants since the incentive structure was a reasonably valued, raffle-based, monetary award.

Participants

Participants were restricted to secondary school teachers who instructed Grades 6 through 12. Additional eligibility requirements included current employment in a secondary school setting or current enrollment in a teacher credentialing program. Convenience sampling was used to select participants. Participants were primarily recruited by way of electronic communication, including invitation via email, newsletter, and social media (e.g., Facebook, Instagram, Reddit). Invitations to participate posted on social media were made only on forums directed at teacher users (e.g., r/education on Reddit). Of the participants who met eligibility criteria, a validity check for adequate engagement with the intervention and vignette was used to obtain a final participant sample. Adequate engagement with the intervention was defined as spending at least 30 seconds reading about the procedures. Adequate engagement with the vignette was defined as spending at least 20 seconds reading about the hypothetical student. Participants' time spent reading was measured by an embedded timer that captured the length of time participants spent on both the survey page that presented the intervention and the page that presented the vignette. An Additional inclusion requirement was that participants must have completed the entire survey and attested to reading the psychoeducation slides.

Measures and Materials

Participants' intervention acceptability ratings were used as the criterion (dependent) variable. The predictor (independent) variables included modality of self-monitoring intervention and timing of participants' exposure to an ADHD psychoeducation module. Regarding the latter, there were two conditions associated with the timing of ADHD psychoeducation: (a) exposure to the psychoeducation module prior to reading the student vignette and self-monitoring intervention vs. (b) exposure to the psychoeducation module after reading the student vignette and self-monitoring intervention. Assignment to these conditions was performed via random assignment. Similarly, there were two conditions associated with the self-monitoring intervention modality: (a) a digital self-monitoring intervention vs. (b) a self-monitoring intervention delivered in analog format; participants' assignment to the intervention modality was also random.

Several covariates were used: demographic variables (e.g., age, race/ethnicity, grade level taught, teaching status, and years of teaching experience), a measure of level of comfort with the use of digital technology, a measure of teacher self-efficacy, accuracy of background knowledge about ADHD, and a measure of cognitive load experienced while envisioning implementing the self-monitoring intervention.

Data Collection Questionnaires and Measures

Demographic Variables. Demographic variables comprised both traditional demographic data and teaching experience data. See Appendix A for detailed item response options associated with each demographic item. The teaching experience data included grade level assignment, years of teaching experience, and previous experience teaching a student with ADHD. The grade level assignment item presented seven, ordinal response options, ranging from 6th grade through 12th grade. The years of teaching experience item allowed participants to enter their years of teaching experience, rounded to the nearest integer. The item pertaining to previous experience with students who have ADHD or ADHD-consistent symptoms was measured with a categorical item with three response options: “yes,” “no,” and “other.”

Next, the demographic data included age, gender, race/ethnicity, and educational background. Participants were asked to report their age in years, rounded to the nearest integer. Gender was ascertained by an item that provides five response options: “Female,” “Male,” “Non-binary,” “Prefer to self-describe” (accompanied by a write-in space where participants can self-describe their gender), and “Prefer not to answer.” Race and ethnicity were ascertained with a scale that provided both broad categories of racial/ethnic groups accompanied by a list of more specific racial/ethnic subgroups that were encompassed by the given broad, descriptive category. Finally, education was evaluated according to a categorical item consisting of four response options: “Bachelor’s,” “Master’s,” “Doctoral degree,” and “Other”. The “Other” option allowed participants to specify their educational background if it was not best described by the available options.

Behavior Intervention Rating Scale (BIRS). The Behavior Intervention Rating Scale (BIRS) is a 24-item measure of teachers’ perceptions of treatment acceptability and efficacy (Elliott & Treuting, 1991; see Appendix B). Each item is evaluated on a 6-point Likert scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). Elliott and Treuting (1991) reported that, in their study, scores on the BIRS had high internal consistency, α = .97. Scores on the two factors of the BIRS—acceptability (α = .97) and effectiveness (α = .92)—also had high internal consistency. Finally, BIRS scores were reported to have both content and construct validity (Elliot & Treuting, 1991).

Computer Anxiety Rating Scale (CARS). The Computer Anxiety Scale (CARS) is a 20-item measure of the construct of anxiety associated with the use of, or prospect of using, computer technology (Heinsen et al., 1987; see Appendix C). Each item of the CARS is evaluated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). In the original CARS validation study, Heinsen et al. (1987) reported that the scale’s overall scores had acceptable internal consistency, α = .87. Heinsen et al. also reported that the CARS scores in their study demonstrated both construct validity and convergent validity with other rating scales that measure computer use anxiety or technology-related anxiety. Further research on the factor structure of the CARS suggests that the scale has a 4-factor structure, which includes general anxiety toward computer usage, confidence in learning ability, motivation to learn, and power or control over usage (Havelka & Beasley, 2004). However, Havelka & Beasley (2004) did not report the internal consistency of each of the four subscales. Thus, the overall scale was used in the present study.

The Ohio State Teacher Efficacy Scale (OSTES). The Ohio State Teacher Efficacy Scale (OSTES; see Appendix D) is a 12-item short form designed to measure a given teacher's beliefs about their capability to bring about desired changes and outcomes in student engagement and learning (Tschannen-Moran & Woolfolk Hoy, 2001). Each item is evaluated on a 9-point Likert scale ranging from 1 (*nothing*) to 9 (*a great deal*). The scale was validated by Tschannen-Moran and Woolfolk Hoy (2001). They reported that the scores from the OSTES demonstrated acceptable internal consistency, α = .90. The researchers also assessed the OSTES is strongly correlated with other measures of personal teaching efficacy. Thus, Tschannen-Moran and Woolfolk Hoy concluded that the scores from the OSTES have acceptable construct validity, especially with respect to measuring teaching-related efficacy beliefs.

Test of ADHD Knowledge (TOAK). The Test of ADHD Knowledge (TOAK) is a 40-item scale developed by Anastopoulos et al. (2021), designed to measure general knowledge of ADHD, including knowledge of information, knowledge of symptoms and diagnosis, and knowledge of evidence-based treatment. Each item is evaluated according to three response options: "Agree," "Disagree," and "Not Sure" (see Appendix E). According to Anastopoulos et al., items that are correctly endorsed with "Agree" and "Disagree" are summed to yield a total score. Higher scores indicate greater knowledge of ADHD. Anastopoulos et al. reported that the scores from the TOAK had acceptable overall internal consistency, α = 0.86. The researchers concluded that the TOAK scores were reliable and demonstrated evidence of convergent validity.

For the purposes of the present study, the TOAK was minorly adapted for secondary school teachers. First, since the TOAK originally used language referencing adults and college students, these descriptive labels were changed to "children" and "students", respectively. Next, one item from the TOAK was omitted for reasons related to overly technical language that may not be well-understood by teachers. The omitted item read as follows: "Some college students "fake bad" during evaluations in order to receive an ADHD diagnosis." Using the final dataset of the present study, the adapted version of the TOAD still demonstrated acceptable overall internal consistency, α = 0.88.

Cognitive Load. Cognitive load is defined as an index of mental effort derived from non-automatic patterns of thought or behavior one maintains in working memory while completing a task or solving a problem (Sweller, 2010; see Appendix F). In the present study, Paas' (1992) single-item measure was used to assess participants' subjective sense of cognitive load associated with imagining implementing a self-monitoring intervention. The item used to estimate cognitive load was evaluated on a 9-point Likert scale ranging from 1 (*very, very low mental effort*) to 9 (*very, very high mental effort*). Paas et al. (1994) compared Paas' single item measure to three additional measures of cognitive load. They found that Paas' measure appears to have acceptable convergent validity with other measures of cognitive load, especially when used to measure complex (i.e., multistep) cognitive tasks.

Materials

ADHD Psychoeducation Module. Information about ADHD was presented to participants in a self-guided slide show presentation (see Appendix G for a summary of the content of the module). The information presented provided a summary of ADHD prevalence, symptoms, and developmental features. The ADHD psychoeducation module also provided a summary of when and where symptoms arise, as well as how both medication management and behavioral interventions represent two empirically-supported methods of ADHD treatment.

Vignette Description. A vignette was used to describe a fictitious student with ADHD-consistent symptoms (see Appendix H). The participant reading the description was asked to imagine that the student described in the vignette is currently a student in their class. The vignette described a student whose age and gender are not disclosed. The fictitious student's ADHD-consistent symptoms included difficulties with sustained engagement in classroom activities and engagement in off-task behaviors. The vignette concluded by asking the participant to imagine that they have also recently spoken to the student's parents, who have confirmed that the student has a long history of experiencing similar problems with sustained attention and distractibility at home.

Intervention Description. Two different self-monitoring intervention vignettes were used to present a description of a digital self-monitoring intervention and an analog self-monitoring intervention (see Appendix I). The intervention procedures were analogous in both conditions, meaning that they described the same self-monitoring interventions with the primary difference being intervention modality. In both vignettes, the intervention procedure was outlined in detail. The intervention implementation procedure for each intervention modality was accompanied by a detailed outline of how a student might use the intervention and what the teacher's role would be during intervention implementation.

Data Analytic Plan and Power Analysis

Descriptive statistics and a multiple regression model were used to analyze the data collected and address the research questions of the present study. The multiple regression model was run to determine the following: (a) if prior ADHD knowledge predicts intervention acceptability ratings of an empirically-supported, self-monitoring intervention for ADHD, (b) if self-monitoring intervention modality predicts acceptability ratings of the intervention, (c) if an interaction between prior knowledge about ADHD and self-monitoring intervention modality predicts acceptability ratings of the intervention, and (d) if teachers' intervention acceptability ratings are additionally predicted by relevant covariates. It is important to note, however, that due to an error in the data collection software, the pre- and post-intervention psychoeducation conditions were not tracked accurately; consequently, data related to the timing of psychoeducation could not be used in statistical analyses. Therefore, the final multiple regression model included self-monitoring intervention modality as the primary predictor variable with two levels: digital self-monitoring and traditional analog self-monitoring. The dependent variable of interest was intervention acceptability and was operationalized by participants' mean BIRS scores. Model covariates (i.e., additional predictor variables) included demographic data, cognitive load, knowledge of ADHD (i.e., total TOAK score), computer anxiety (i.e., total CARS score), and teaching self-efficacy (i.e., mean OSTES score).

A power analysis was used to estimate the minimum sample size required for the proposed research. The calculated target total sample size was 158 participants, which is large enough to yield a small effect size (f = 0.25), given a minimum Type I error probability value of 0.05 and a minimum Type II error probability value of 0.20. However, a minimum sample size of

73 participants could have been used to achieve a medium effect size (*f* = 0.40) given the same aforementioned Type I and Type II error parameters.

Results

Descriptive Statistics

Participant Demographic Data

Of the 336 participants who met eligibility criteria, 89 participants were included in the final analysis after listwise deletion of cases that (a) failed to pass the validity check for adequate engagement with the intervention and vignette (*n* = 232), and (b) failed to meet additional inclusion criteria regarding the need to have completed the entire survey and to have attested to reading the psychoeducation slides (*n* = 15). Participants primarily included those who self-identified as White (74.16%), followed by those who identified as American Indian or Alaska Native (8.99 %), Hispanic/Latino (5.62%), Black/African American (4.49%), multiple races (4.49%), and Asian (2.25%). With respect to age, over half of the participants were 20–40 years old, with an average age of 39.52 years and a standard deviation of 12.57 years. The majority of participants (88.76%) reported earning either a bachelor's or master's degree, with the remaining participants reporting either a higher degree or multiple degrees earned. See Table 1 for additional detailed information about participant demographic data.

With respect to participants' teaching experience, 68.54% of participants self-identified as current teachers; the remaining participants self-identified as former teachers. On average, participants reported having 10.5 years of teaching experience, with a standard deviation of about 9 years. The majority of participants (94.38%) stated that they had previously taught at least one student with ADHD or ADHD-consistent symptoms; the remaining participants were either unsure of whether they had taught a student with ADHD before (4.49%) or had never taught a student with ADHD (1.12%). Finally, with respect to the grade levels taught by participants, 39.33% were high school teachers, 40.45% were middle school teachers, and the remaining 20.22% had experience teaching at both the middle and high school levels.

Experimental Conditions, Dependent Variable, and Additional Covariates

With respect to participant assignment to intervention modality condition, 43.82% (*n* = 39) of participants were assigned to the digital self-monitoring intervention condition, and 56.18% (*n* = 50) of participants were assigned to the analog self-monitoring intervention condition. Table 2 shows the means and standard deviations of participants' intervention acceptability ratings associated with the self-monitoring intervention modality to which participants were exposed. These descriptive data suggested that participants evaluated both intervention modalities as acceptable. In addition, Table 3 shows the correlations among all variables that were treated as continuous variables in the present study. Although most continuous variables were uncorrelated, knowledge of ADHD had a medium negative correlation with computer anxiety (*r* = -0.33) and a medium negative correlation with teacher self-efficacy (*r* = -0.43).

A *t*-test was also conducted to determine whether the mean intervention acceptability scores of the analog intervention group were lower than the mean intervention acceptability scores of the digital intervention group. The mean difference between intervention modality groups was statistically significant at the $p < 0.05$ level ($t(87) = -1.80$, *p*, = 0.037) with a Cohen's d effect size of -0.37 (95% CI[-0.80, 0.049]). This result indicates that without adjusting for additional variables, the mean intervention acceptability scores of the analog intervention group (*M* = 3.34) were significantly lower than the mean intervention acceptability scores of the digital intervention group (*M* = 3.50). The effect size indicates a medium difference between the mean acceptability scores of the two groups (Ferguson, 2009). In addition, the difference in acceptability ratings on the basis of intervention modality nearly meets the recommended minimum effect size that represents a practically significant effect (i.e., 0.41) for social science data (Ferguson, 2009). That said, without adjusting for the influence of the covariates, participants rated the digital self-monitoring intervention as somewhat more acceptable than the analog self-monitoring intervention, and this difference in intervention acceptability scores, albeit small, may be meaningfully noticeable in real world settings, especially given the Ferguson (2009) that cut off scores for minimum practical significance need not be applied rigidly.

Multiple Regression Model

Model Assumptions

Tests of normality and homoskedasticity were conducted to determine whether the intervention acceptability scores met regression model assumptions. The normality of the distribution of residuals of the dependent variable of interest, intervention acceptability scores, was plotted on a Q–Q plot and appeared to be normally distributed. Figure 1 shows histograms depicting the dependent variable of interest, intervention acceptability, plotted against the two self-monitoring intervention conditions. These data were also visualized with boxplots (Figure 2). Both the histograms and boxplots show that the distribution of intervention acceptability scores are somewhat negatively skewed. Follow-up analyses indicated that the skewness (0.09) and kurtosis (0.55) probabilities of the intervention acceptability scores in both experimental conditions were within normal ranges. Next, to check for multicollinearity (i.e., whether any linear relationships existed among the predictors used in the multiple regression model), variance inflation factors (VIFs) were calculated for each predictor variable. VIF values ranged from 1.07 to 3.85, with a mean VIF of 1.70. These results indicated that multicollinearity was not a major concern in the present regression analysis.

Beyond the fact that typical model assumptions were met, is important to note that the model does not meet the recommended minimum predictor to participant ratio. VanVoorhis & Morgan (2007) described that when regression models involve six or more predictors, it is recommended to have at least ten participants per predictor variable. In the present study, given the high rate of attrition due to incomplete participation in the present study, the final sample size (*N* = 89) did not technically accommodate the 11 predictor variables used in the present study. Although it is technically permissible to have fewer than ten participants per predictor variable (Jenkins & Quintana-Ascencio, 2020), consequences that can arise from exceeding the recommended minimum predictor to participant ratio include decreased probability of detecting statistical differences and reduced power to detect small effect sizes.

Regression Analyses

Given that regression model assumptions were met, a multiple regression model was used to examine the relations among intervention modality, demographic variables, relevant covariates (i.e., demographic variables, ADHD knowledge, teaching self-efficacy, computer anxiety, and cognitive load), and intervention acceptability scores. Regarding intervention modality, a dummy variable was created to indicate assignment to intervention modality condition and was used in the regression model. Specifically, the analog intervention condition was coded as 0 and the digital intervention condition was coded as 1. The results of the multiple regression model are provided in Table 4. Results revealed that the overall model was non-significant, $F(11, 77) = 0.87$, $p = 0.87$, $R^2 = 0.071$. According to these results, only 7.10% of the variability in the dependent variable was accounted for by the variables included in the regression model. When all covariates were removed from the model, even less variance in intervention acceptability (3.40%) was accounted for by intervention modality, $F(1, 87) = 3.08$, $p = 0.083$, $R^2 = 0.034$. Given that the overall regression model did not achieve significance at the $p < .05$ level, none of the research hypotheses was supported.

Because the error in data collection did not allow for investigation of whether prior ADHD knowledge predicted intervention acceptability ratings, the first research aim could not be adequately investigated. Therefore, I instead examined whether participants' ADHD knowledge was related to intervention acceptability ratings, collapsing across the experimental conditions of pre-psychoeducation and post-psychoeducation. Overall, after adjusting for covariates, participants' ADHD knowledge was not significantly associated with intervention acceptability ratings of an empirically-supported, self-monitoring intervention for ADHD ($\beta = 0.0044$, $t = 0.60$, $p = 0.55$). Indeed, upon visually inspecting the relation between these variables on a scatter plot, the relationship between ADHD knowledge and intervention acceptability ratings appeared random.

Regarding the second research aim, the dummy variable representing the digital intervention was not significantly associated with participants' intervention acceptability ratings after controlling for covariates ($\beta = 0.18$, $t = 1.82$, $p = 0.073$). Next, the third research aim, which concerned whether there was an interaction between prior knowledge about ADHD and self-monitoring intervention modality predicts acceptability ratings of the intervention, could not be investigated due to the data collection error that rendered pre- and post-psychoeducation grouping data indistinguishable. Finally, regarding the fourth research aim, teachers' intervention acceptability ratings were not meaningfully predicted by any additional relevant covariates. However, the model did account for an additional 3.70% of variance in intervention acceptability scores when all covariates were included in the overall regression model in comparison to when they were not included in the overall regression model.

Discussion

In the present dissertation research, four research questions guided the investigation of teachers' acceptability of a digital self-monitoring intervention designed for classroom use with students who have ADHD. The first research question explored whether having prior knowledge about ADHD is related to teachers' receptivity of an empirically-supported, self-monitoring intervention for ADHD. The second explored whether teachers evaluate a digital self-monitoring intervention as more acceptable than an analogous intervention delivered in analog format. Third, I investigated whether there is an interaction effect between prior knowledge about ADHD and intervention acceptability across intervention modalities (i.e., analog, and digital). The fourth question was related to whether teachers' intervention acceptability ratings may be additionally accounted for by other potentially confounding variables (i.e., demographic variables, ADHD knowledge, teaching self-efficacy, computer anxiety, and cognitive load). A multiple regression analysis was used to address the research questions. Results from the overall regression model suggested that intervention modality was not found to be significantly related to intervention acceptability, and none of the covariates used in the present study significantly accounted for participants' intervention acceptability ratings. However, as noted below in terms of limitations, the projected sample size was seriously truncated by the failure of many participants to have shown adequate engagement with the research design and materials, and one of the experimental manipulations was not effected because of a data collection error.

Is Knowledge of ADHD Symptoms and Treatment Related to Intervention Acceptability Scores?

The key measures that were used to explore whether teachers' knowledge of symptoms and treatment related to ADHD was related to intervention acceptability scores were as follows: ADHD knowledge scores and intervention acceptability scores. For the purposes of statistical analysis, the original intention was to group participants by whether they received ADHD psychoeducation before or after reading about a self-monitoring intervention. Then, a multiple regression model that statistically adjusted for a variety of potentially confounding variables (i.e., demographic variables, ADHD knowledge, teaching self-efficacy, computer anxiety, and cognitive load) was planned to determine whether there was a significant main effect that psychoeducation condition had on intervention acceptability scores. Unfortunately, a data collection error resulted in the incorrect coding of pre- and post-psychoeducation conditions. Therefore, the first research question could not be addressed as originally intended and, ultimately, results were inconclusive. Nonetheless, participants' ADHD knowledge scores were still used in the multiple regression model as a predictor of intervention acceptability scores.

Overall, results did not support the hypothesis that greater knowledge of ADHD symptoms and treatment predicts more favorable treatment acceptability scores regardless of the self-monitoring intervention modality participants evaluated. More specifically, adjusting for relevant potentially confounding variables, there was no meaningful difference in the intervention acceptability scores predicted on the basis of ADHD knowledge. In fact, in the present study, there was no detectable pattern with respect to how intervention acceptability scores were associated with ADHD knowledge scores.

Because it was not possible to distinguish the timing at which participants received psychoeducation about ADHD, each participants' ADHD knowledge score used in data analyses was no longer meaningful in the context of the present study, in that it was not possible to accurately ascertain participants' ADHD knowledge prior to evaluating the self-monitoring intervention with which they were presented. Consequently, the non-significant result regarding whether greater knowledge of ADHD predicting greater acceptability scores was expected. However, had the timing of the psychoeducation condition presentation been tracked relative to when participants provided intervention acceptability ratings, the literature on intervention acceptability suggests that teachers' knowledge of ADHD may have meaningfully predicted their willingness to use and acceptability of a given evidence-based intervention (e.g., Bussing et al., 2012; Coles et al., 2015; Dort et al., 2020; Elik et al., 2015).

Do Teachers Evaluate A Digital Self-Monitoring Intervention As More Acceptable Than An Analogous Intervention Delivered In Analog Format?

The key variables that were used to explore whether there was a relation between intervention modality and acceptability ratings were intervention treatment group and intervention acceptability scores. Intervention treatment group was determined by randomly assigning participants to read about and evaluate either a computer-based (i.e., digital) self-monitoring intervention delivered via iPad or a traditional (i.e., analog) self-monitoring procedure that involved manual use of a timer and recording self-monitoring evaluations on paper. Based on the data collected for the present study, it remains unclear whether a digital self-monitoring intervention is evaluated by teachers as more acceptable than an analogous analog self-monitoring intervention. Participants evaluated both the digital and analog self-monitoring interventions as acceptable, and acceptability ratings were somewhat higher for the digital intervention compared to those associated with the analog intervention. This result was unexpected, given that previous researchers have found that secondary school teachers are generally prefer easily-implemented interventions (e.g., Elik et al., 2015; Gaastra et al., 2020). Without considering the influence of relevant covariates, acceptability ratings across conditions were found to be meaningfully different. In other words, although numerical differences in average acceptability scores across intervention modality groups appeared to be small, the effect size approached the minimum threshold for practical significance in the social sciences, as defined by Ferguson (2009).

That teachers evaluated both self-monitoring interventions as acceptable for classroom use was not consistent with previous research findings given that research has shown that teachers—especially those who teach adolescents—prefer simple and easy-to-implement interventions (e.g., Elik et al., 2015; Gaastra et al., 2020). Relatedly, the analog self-monitoring intervention was not anticipated to be perceived as simple or easy to implement as it involved a multi-step process that would be more demanding of teachers' time and attention in comparison to an app-based intervention modality. Nonetheless, there are a few explanations that may account for this result.

First, it is possible that participants perceived that both interventions could be easily implemented. If this were the case, participants may have been more inclined to evaluate both self-monitoring interventions as acceptable. Although this assumption cannot be directly substantiated in the present study because none of the questionnaires were used to explicitly assess participants' perceptions of ease of intervention implementation, two items from the intervention acceptability rating scale approximated participants' perceptions of ease of implementation. One item required participants to indicate their agreement with the statement, "I like the procedures used in the intervention," and another item read, "I would be willing to use this [intervention] in the classroom setting." Upon evaluating participants' responses to these items across experimental groupings by intervention modality, average ratings suggested that participants did indeed perceive both interventions to be easily implemented.

Regardless of intervention modality to which participants were exposed, over half (about 65%) of all participants either agreed or strongly agreed to be willing to implement a self-monitoring intervention in the classroom setting, and only 12% expressed that they would be unwilling to implement a self-monitoring intervention in the classroom. Similarly, over half (57%) of all participants either agreed or strongly agreed to liking the self-monitoring procedures they read about, and 21% reported that they did not like the self-monitoring procedures. However, it is worth noting that there were some major differences in perceptions about ease of implementation across experimental groups according to the item that assessed willingness to use the given intervention in the classroom setting. Of those who were in the digital intervention group, about 21% (or eight participants out of 39 total) strongly agreed that they would be willing to use the self-monitoring procedure; in the same experimental group, only 5% of participants expressed they would not be willing to use the self-monitoring procedure. On the other hand, of those who were in the analog intervention group, only 2% (or one participant out of 50 total) strongly agreed that they would be willing to use the self-monitoring procedure, and about 18% expressed that they would not be willing to use the self-monitoring procedure.

It is also possible that teachers' perceptions of interventions differ on the basis of whether they are actually implementing an intervention or are only imagining implementing an intervention. Along these lines, Power et al. (1995) asserted that perceptions of intervention acceptability can be different on the basis of whether acceptability data are collected prior to treatment, during treatment, or after treatment. Convergent with this assertion, the results of other intervention acceptability research suggest that acceptability ratings are influenced by whether teachers actually implement an intervention or just imagine its implementation.

For example, Briesch et al. (2015) conducted a study on K-12th grade teachers' perceptions and acceptability ratings related to five evidence-based classroom management strategies. The researchers found that on average, participants evaluated four out of the five interventions as similarly acceptable and feasible for classroom use even though each of the positively regarded strategies varied greatly in terms of complexity and time requirements. Illustrating this point, one intervention in Briesch et al.'s study involved a simple classroom management intervention, positive verbal praise. This intervention is simple for teachers to execute and requires very little time to implement. Other interventions in the study, however, required multiple steps, data tracking, and a nontrivial amount of time to implement (e.g., response cost strategies with home-school communication). Despite the range of intervention complexity in the study, the majority of interventions were well-received by teacher participants and were evaluated to be acceptable for classroom use. In line with the results of the present dissertation research, the results from the Briesch et al. study are at odds with the research suggesting that intervention complexity and acceptability are inversely related (e.g., Collier-Meek et al., 2017; Elik et al., 2015).

Similarly, researchers have found that when digital self-monitoring interventions are used in real-time (i.e., when an intervention is actually used as opposed to just thinking about using an intervention), teachers evaluate digital self-monitoring interventions to be more effective and easier to use than comparable analog interventions (e.g., Bruhn, Waller, et al., 2016). Similar findings have been reported in other digital intervention research, in that when teachers actually try to use an intervention in their classroom they consistently report finding digital interventions desirable, easier to implement than paper-based interventions, socially valid, and helpful (e.g., Amato-Zech et al., 2006; Corkum et al., 2019; Flower, 2014; Amato-Zech et al, 2006; Schuck et al., 2016; Wills & Mason, 2014).

Expanding upon the previous point, the hypothetical nature of the interventions presented to participants may have also reduced the ecological validity of participants' intervention acceptability ratings, especially because there exist several other factors in real-world classrooms that can substantially influence intervention acceptability, which were not experienced by participants in the present study. Such factors include the added stress and complexity of managing behaviors in real time (Collier-Meek et al., 2017), juggling competing demands in the classroom (Lawson et al., 2022), students' receptivity to interventions (Bussing et al., 2016), and quality of student-teacher relationships (Lawson et al., 2022). If participants had the opportunity to engage in the self-monitoring interventions in-person, it is possible that common classroom demands, such as those listed previously, may have elicited more ecologically valid ratings of intervention acceptability consistent with research results that indicate teachers prefer interventions that are easier to implement over more complex interventions (e.g., Elik et al., 2015).

Is There An Interaction Effect Between Prior Knowledge of ADHD and Intervention Modality?

Although data on participants' knowledge of ADHD were collected in the present study, it was not possible to explore whether interaction effect between intervention modality and timing of ADHD psychoeducation was present. Again, the reason is that a data collection error that occurred with respect to the timing of participants' psychoeducation, making it impossible to distinguish whether participants' ADHD knowledge scores represented their knowledge before or after receiving psychoeducation. Consequently, I could not determine whether participants' ADHD knowledge scores reflected knowledge before or after participants' evaluation of the ADHD intervention modality to which they were exposed. Considering the psychoeducation timing data collection error, an interaction effect could not be explored in the present study; thus, it remains unknown whether prior knowledge of ADHD is related to differing acceptability perceptions based on intervention modality.

However, it is important to explore in future research whether there is an interaction effect between prior knowledge of ADHD and intervention modality. Previous research findings show that when teachers have more knowledge about ADHD, they are more likely to try evidence-based ADHD interventions and use such interventions with greater frequency than those with less ADHD-related knowledge (e.g., Anderson et al., 2012; Bussing et al., 2012; Coles et al., 2015; Dort et al., 2020; Schatz et al., 2021; Szep et al., 2021). Keeping in mind the pressing need to increase secondary school teachers' use of ADHD interventions, it would be extremely useful to know whether providing teachers with prior psychoeducation could be used as a strategy to increase their acceptability perceptions of specific ADHD intervention modalities. If it were the case that prior ADHD psychoeducation is not only associated higher intervention acceptability scores, but also is associated with preference for digital interventions, in particular, prior ADHD psychoeducation could be used strategically to facilitate teachers' transition to using digitally-based intervention tools in the classroom.

Are Teachers' Intervention Acceptability Ratings Additionally Accounted For By Relevant Key Variables?

The covariates that were included in the multiple regression model were as follows: demographic variables (including age, race, ethnicity, years of teaching experience, grade level taught, and experience teaching students with ADHD), computer anxiety, teaching self-efficacy, knowledge of ADHD, and cognitive load. Ultimately, none of the covariates included in the model significantly accounted for any of the variance in predicted intervention acceptability ratings. However, this result can still provide some useful insights about the utility of certain covariates in future research conducted to explore the relationship between intervention modality and intervention acceptability.

Among the most unexpected results was that computer anxiety, teaching self-efficacy, and cognitive load had no meaningful bearing on the extent to which teachers rated a self-monitoring intervention as acceptable for classroom use. With respect to computer anxiety, it was anticipated that a greater degree of computer anxiety would be associated with lower intervention acceptability ratings for the digital self-monitoring intervention, especially since researchers have shown that greater computer anxiety is associated with perceived ease of use of computer-based applications (e.g., Saadé et al., 2009). Given that self-reported computer anxiety did not account for any of the variance in intervention acceptability scores, it is possible that computer anxiety is not meaningfully related to individuals' willingness to use app-based technology. Considering that computer technology, and app-based technology in particular, has become all but ubiquitous at the time of writing this study, it is possible that people's willingness to use technology has no relation to their self-assessed degree of comfort with digital technology. Moreover, considering that teachers' use of digital technology increased immensely as a result of the rapid switch to remote schooling during the COVID-19 pandemic (Singh et al., 2022; Vargo et al., 2020), it is possible that teachers have become accepting of digital technologies like web and mobile applications regardless of their degree of comfort or expertise with the technology.

Similar to computer anxiety, teaching self-efficacy was also not found to have a meaningful association with teachers' intervention acceptability ratings. This finding was also unexpected given that researchers have demonstrated that self-efficacy does play a role in teachers' evaluation of classroom interventions. For example, Chunta and DuPaul (2022) found that teacher self-efficacy contributed to teachers' degree of intervention endorsement regardless of students' disability category. However, regardless of teachers' degree of self-efficacy, the researchers also found that even when children have identical academic needs, teachers were also more likely to endorse academic interventions for children with a specific learning disability over children with ADHD. It is also important to note that other researchers have delivered mixed findings about the relationship between teachers' self-efficacy and their preferences or intentions related to using classroom interventions. For example, although some researchers have found that teacher self-efficacy plays an important role in teachers' plans to use interventions in the classroom (e.g., Gregus et al., 2017), other researchers have found that self-efficacy has no meaningful effect on teachers' intervention preferences (e.g., Girio, 2009). Considering findings from past research, it may be the case that teacher self-efficacy is related to teacher intervention preferences contingent on the presence of additional contextual variables like disability type or intervention category.

Finally, although cognitive load was expected to meaningfully account for some of the variance in intervention acceptability ratings, cognitive load had no significant relation with teachers' intervention acceptability ratings in the present study. The hypothetical nature of the experimental conditions in the present research, the limitations of single-item measures, and the limitations of cognitive load as a construct are among some of the reasons that may account for why cognitive load was not meaningfully associated with participants' intervention acceptability scores. First, there is the possibility that the cognitive load measure itself was not problematic. Rather, the situation in which the measure was used could have been problematic. Namely, it may have been the case that the cognitive load participants reported after reading about the vignette and intervention procedures lacked ecological validity given that the scores were associated with hypothetical scenarios.

Typically, cognitive load is a measure of mental effort that is assessed either during or directly after participation in a given task (Chen et al., 2016). In fact, researchers have pointed out that a core component of the definition of cognitive load is that it is a multidimensional and dynamic construct that represents the demands on working memory *during* task performance, which can vary greatly within the task itself (Chen et al., 2016). However, in the present research, participants responded to a cognitive load measure after completing a reflection-based task that relied solely on hypothetical thinking rather than actual task completion. More specifically, the participants in the present research did not actually practice carrying out a self-monitoring intervention in a real-world classroom setting; instead, participants were merely asked to read a description of a student with ADHD-consistent symptoms and were subsequently asked to imagine supporting this student by using a self-monitoring intervention described through text and visual examples.

Although there is not any published research that has explicitly explored the differences between individuals' cognitive load in hypothetical scenarios and analogous real-time scenarios, some researchers have indicated that measuring cognitive load in real-time scenarios is more accurate than measuring cognitive load in simulated scenarios designed to closely match reality. For example, Engström et al. (2005) measured the effects of visual demands on cognitive load on driving performance in both real and simulated scenarios. Although their simulated driving environment required participants to engage in the actions of driving by engaging with an authentic driving interface, the researchers found that indicators of stress response (e.g., heart rate) and increased effort were more pronounced in actual driving scenarios compared to simulated driving scenarios. In the present research, given that participants merely imagined implementing an intervention with a student with executive functioning and attention difficulties, it is possible that the cognitive load they experienced during the task was not as pronounced as it may have been in a simulated or real-world scenario that requires the actual implementation of an intervention.

Next, there is the possibility that the cognitive load measure used in the present study was problematic, especially since it was a single-item measure. Researchers, such as Diamantopoulous et al. (2012), have demonstrated that single-item measures are often inferior to multiple-item measures with respect to predictive validity. They also found that the use of single-item measures is appropriate only in certain scenarios, such as when a small sample size is used ($N < 50$), when inter-item correlations are weak ($\alpha < .30$), or when analogous multiple-item measures are either very homogeneous or semantically redundant. Therefore, despite the fact that Paas' (1992) measure of cognitive load is one of the most common measures that researchers use to assess cognitive load in educational settings (Anderson & Makransky, 2020), the fact that it is a single-item measure implies that it may lack key components of validity, such as construct validity and predictive validity. Indeed, Diamantopoulous et al. showed that when single-item measures were used in scenarios not circumscribed within the appropriate use scenarios outlined above, the predictive validity of single-item measures fell short in comparison to that of comparable multiple-item measures.

Even so, there are several other cognitive load measures that have been established in the research literature that may be preferable for use in future research. In their handbook on the measurement of cognitive load, Chen et al. (2016) provided in-depth reviews of a number of methods by which cognitive load can be assessed. Examples of cognitive load measures included subjective self-report scale, physiological measurement methods (e.g., pupillary response, galvanic skin response), methods based in assessing linguistic features (e.g., word counts, use of swear words, use of certainty and uncertainty words), and multimodal measures. However, an alternative measure of cognitive load that is germane to the present research may be Leppink's (2013) Cognitive Load Scale (CLS). The CLS is a multiple-item cognitive load measure that is appropriate for use in educational settings and learning situations. Importantly, unlike Paas' (1992) single-item scale that assesses overall cognitive load, the 10-item CLS was developed using confirmatory factor analysis (see Leppink et al., 2013) and can assess multiple dimensions cognitive load, including intrinsic load, extraneous load, and germane load (Andersen & Makransky, 2020). Therefore, in future studies concerning whether cognitive load is related to educators' use of classroom interventions, it may be preferable to use Lepink et al.'s (2013) multidimensional measure over Paas' single item measure.

Additional Limitations and Future Directions

In addition to the limitations previously outlined, there are other limitations that should additionally inform the research design and participant selection approaches used in future intervention acceptability research. Specifically, limitations related to participant attrition and study design may have challenged validity outcomes associated with the present study. With respect to participant attrition, most participants' data could not be included in the final analyses due to failure to pass a validity check. In fact, data from only 26.5% of participants could be included in the final analyses. The remaining 73.5% of participants' responses were omitted from analyses for inadequate time spent engaging with the experimental stimuli (i.e., vignette description, intervention description).

Overall, the magnitude of participant attrition in the present research was problematic in many respects and ultimately may have biased the overall results. Statistically speaking, the high degree of response omission resulted in an overall sample that did not meet the minimum ten to one participant to predictor ratio that statisticians recommend for multiple regression models (e.g., Jenkins & Quintana-Ascencio, 2020; VanVoorhis & Morgan, 2007). Consequently, having fewer than ten participants per predictor variable likely weakened the power of the present study's multiple regression model, resulting in a reduced probability related to correctly reject a false null hypothesis (VanVoorhis & Morgan, 2007). Beyond the statistical impacts of a reduced sample size, substantial attrition, such as what was incurred in the present study, can introduce unintended sampling bias. Remotely sourcing data (i.e., through web or email invitation) is particularly susceptible to high rates of participant attrition by way of dropout or incomplete participation, which in turn can contribute to unexpected outcomes or misleading results (e.g., Zhou and Fishbach, 2016). Although it is not possible to draw any definitive conclusions about the ways in which the final sample used in the present study was compromised due to attrition, there are several ways in which the final sample may have not been representative of the average secondary school teacher population.

To begin, the majority of participants who met criteria to be included in the final analyses were highly educated with nearly 70% of teachers reporting earning either a master's degree or higher. In addition, participants' years of teaching experience was positively skewed, with the majority of participants being relatively new teachers with 7 or fewer years of teaching experience. Considering these characteristics, it is possible that the participants who were more likely to follow directions were also those who were more likely to have postbaccalaureate educational attainment; if educational attainment was then biased in the final participant pool, it is probable that their responses to the experimental stimuli were not representative of the population that was intended to be sampled (i.e., US secondary school teachers). Furthermore, the participants whose responses were included in the final analyses had fewer years of teaching experience than the national average years of teaching experience (see National Center for Education Statistics [NCES]). These teachers' relative inexperience may have been associated with a greater likelihood to be open to and accepting of a new classroom intervention, regardless of intervention modality, than the average secondary school teacher with more years of teaching experience. This postulation is consistent with previous research that has shown that novice teachers tend to be open-minded about trying out evidence-based practices (e.g., Elik et al., 2010).

As previously stated, it is likely that a major contributing factor to the degree of attrition in the present study was the study design itself. Namely, the remotely-completed, survey-based study format likely allowed the majority of participants to avoid spending adequate time engaging with the vignette and intervention procedure. Therefore, it is important that future research is designed to limit attrition as much as possible. One way in which this can be accomplished is through having individuals complete the online survey in-person. However, a tradeoff of this approach is likely a reduced overall sample size. Alternatively, participant attrition in vignette-based intervention acceptability research might be curbed by delivering vignette and intervention descriptions in a modality that requires less cognitive effort for participants. Delivery of information through video, and particularly through picture-in-picture video (where an instructor is filmed narrating a separate illustrative or demonstrative video that is displayed in the same screen), seems to be a promising approach. In fact, researchers have shown that picture-in-picture videos are associated with stronger learning and retention outcomes, regardless of individuals' degree of sustained attention, than other information delivery modalities, such as voiceover video and written text (Kokoç et al., 2020).

An additional benefit of using video-based stimuli to convey a vignette scenario and intervention procedures is that the approach arguably requires less cognitive effort, and is therefore easier for participants to engage with, compared to reading through the same information delivered via written text. Moreover, video-based delivery of information would allow researchers to control the amount of time each participant spends with the video-delivered stimuli such that participants are not able to skip over the information as they did in the present study. However, it is worth noting that conveying information via video still does not control for the extent to which participants are actively attending to the stimulus.

It is also important to emphasize that the present research revealed that survey- and vignette-based research is likely not the best approach to investigating teachers' perceptions of classroom interventions. Therefore, researchers who seek to further investigate the acceptability of analogous interventions delivered in separate modalities should ideally aim to conduct ecologically valid research in which teachers actually use the given intervention in their own classroom setting. Furthermore, those who seek to contribute to comparative research on intervention acceptability should make an effort to move away from single-subject design (SSD) research given that the majority of extant ADHD intervention research outcomes are based on SSD studies (e.g., Gaastra et al., 2016). Although SSD research is valuable when it comes to gathering detailed information about how students and teachers respond to interventions, the approach is prone to internal validity concerns; this is especially true if a repeated-measures approach is used (which is often the case in intervention research) since data collected through repeated-measures are vulnerable to maturation and history effects (Kratochwill et al., 2021).

It is critical that future researchers strive to continue to investigate the acceptability and efficacy of nonpharmacological ADHD interventions by using rigorous research methodologies that promote the internal and ecological validity of the data collected. Despite the range of nonpharmacological interventions that have been developed and despite the promising findings related to the potential benefits of nonpharmacological interventions, very few nonpharmacological ADHD interventions have garnered empirical support; this lack of empirical support is due, in part, to an ongoing lack of rigorous research methodologies in the literature. Trout et al. (2007) was one of the first research teams to shed light on the methodological issues common to nonpharmacological ADHD intervention research. In their review of 41 empirical studies conducted between 1980 and 2002, some of the most pervasive methodological issues were that over half of the studies were single-subject design studies, nearly 60% of the studies omitted measures of social validity (e.g., teacher acceptability, student acceptability), 50% of the studies failed to report whether participants were taking concurrent medication, and nearly 90% of the studies focused only on male participants.

Moreover, the majority of the research reviewed by Trout et al. involved interventions that were administered for only an abbreviated period of time (< 1 month) and did not involve assessment of long-term outcomes. According to researchers who have conducted meta-analytical studies on nonpharmacological ADHD interventions using a more contemporary pool of research (i.e., conducted in the past 10 to 15 years; e.g., Gaastra et al., 2016; Lambez et al., 2020; Miller & Lee, 2013; Moore et al., 2019; Richardson et al., 2015), similar methodological problems continue to persist. In the case of self-monitoring interventions for ADHD, researchers' use of rigorous research methodologies is particularly pressing because although results from SSD studies show the effectiveness of self-monitoring interventions and show that teachers find such interventions to be socially acceptable, teachers also report that self-monitoring intervention procedures are impractical or infeasible for everyday use (Amato-Zech et al., 2006). Thus, the gap between intervention efficacy and teachers' tendency to not use effective interventions in the classroom persists. Consequently, it remains important for researchers to find ways to help teachers deliver effective interventions in their classrooms with fidelity and consistency.

Overall, the present research was designed in order to address some of these shortcomings in a variety of ways (e.g., gathering intervention acceptability data from a large sample, and using vignettes and intervention descriptions to control for potentially confounding variables present in classroom-based SSD research). However, the drawbacks of the present research, especially with respect to participant attrition and results that are not consistent with the literature on teachers' intervention preferences, suggest that survey-based research on intervention acceptability has considerable drawbacks. Namely, the present study was prone to sampling bias and likely lacked ecological validity. Therefore, future intervention researchers should avoid using survey-only methodologies and promote ecological validity by having participants actually use the interventions being investigated. However, future intervention researchers should still aim to gather data from an adequately large sample in order to minimize the risks associated with SSD studies, and they should also have measures in place to minimize participant attrition.

Conclusion

Historically, nonpharmacological classroom interventions for ADHD have been characterized by myriad limitations that include wide-ranging research quality and a lack of consideration for implementation barriers, such as teachers' time constraints and cognitive bandwidth. Of the interventions that researchers have proven to be efficacious in reducing the core symptoms of ADHD, nonpharmacological interventions have been limited to analog, multi-step approaches that do not likely translate well to sustained classroom use. Indeed, evidence-based approaches that are associated with the largest effect sizes often require teachers to keep track of various intervention components and require a degree of background knowledge without providing requisite psychoeducation. As such, extant evidence-based interventions do very little to minimize the effect of barriers that disrupt teachers' ability to implement interventions with fidelity and engage in long-term intervention use, especially at the secondary level.

The results of the present study suggest that digitizing classroom interventions for ADHD is a potentially viable approach to simultaneously making evidence-based interventions more accessible to secondary school teachers and reducing barriers to intervention implementation in middle and high school classrooms. However, further research is needed to build a more robust body of evidence concerning what intervention strategies can most effectively facilitate secondary school teachers' use of evidence-based ADHD interventions. Overall, digital ADHD interventions represent a potentially promising direction. However, to fully investigate the value of digital interventions in the secondary school context, both in terms of efficacy and teacher use, future research will continue to require large-scale, randomized control trials. Importantly, research will also benefit from conducting such trials in real-world, classroom settings in which teachers and students can actually use digitally based ADHD interventions prior to evaluating such interventions on key metrics like acceptability and use likelihood.

Given that ADHD is a chronic condition that persists into adolescence and beyond, students with ADHD need and deserve to receive effective supports at each stage of their schooling. Considering that intervention supports for most students with ADHD drop off steeply once students enter secondary school, it is incumbent on researchers to identify intervention strategies are not only effective, but are also feasibly implemented by their teachers. Otherwise, adolescent students with ADHD are at risk of continuing to be overlooked and under supported in the school setting.

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Table 1
Frequencies of Demographic Variables

Variable	Subgroup	*Total*	*Percent Total*
Race	White	66	74.16
	American Indian/Alaska Native	8	8.99
	Hispanic/Latino	5	5.62
	Black/African American	4	4.49
	Multiple races		
	Asian	4	4.49
		2	2.25
Age	20-29	19	21.35
	30-39	37	41.57
	40-49	18	20.22
	50-59	8	8.99
	60-69	4	4.49
	70+	3	3.37
Gender	Female	57	64.04
	Male	29	32.58
	Prefer not to say	2	2
	Non-binary	1	1
Education	Bachelor's	28	31.46
	Master's	51	57.30
	Doctoral	7	7.87
	Multiple Degrees	3	3.37
Teaching Status	Current Teacher	61	68.54
	Former Teacher	28	31.46
Grade Levels Taught	Middle School	36	40.45
	High School	35	39.33
	Middle & High School	18	20.22
Experience Teaching Students with ADHD	Has Experience	84	94.38
	Does Not Have Experience	1	1.12
	Unsure	4	4.49

Table 2

Means and Standard Deviations of Intervention Acceptability Ratings by Intervention Type

Intervention Group		Intervention Acceptability	Cognitive Load	ADHD Knowledge	Computer Anxiety	Teacher Self-Efficacy
Analog Intervention						
	M	3.34	5.50	20.58	42.08	6.75
	SD	0.47	1.57	6.85	11.31	0.97
Digital Intervention						
	M	3.50	5.13	18.026	43.49	6.53
	SD	0.37	1.92	6.94	12.82	1.093

Table 3

Correlations of Intervention Acceptability Ratings with Continuous Covariates

Intervention Modality	1	2	3	4	5
1. Intervention Acceptability					
2. Cognitive Load	0.064				
3. ADHD Knowledge	0.044	0.17			
4. Computer Anxiety	-0.0061	-0.0010	-0.33*		
5. Teacher Self Efficacy	0.035	0.15	0.18	-0.43*	
M	3.40	5.34	19.46	42.70	6.66
SD	0.43	1.73	6.96	11.94	1.027

*p < 0.05

Table 3

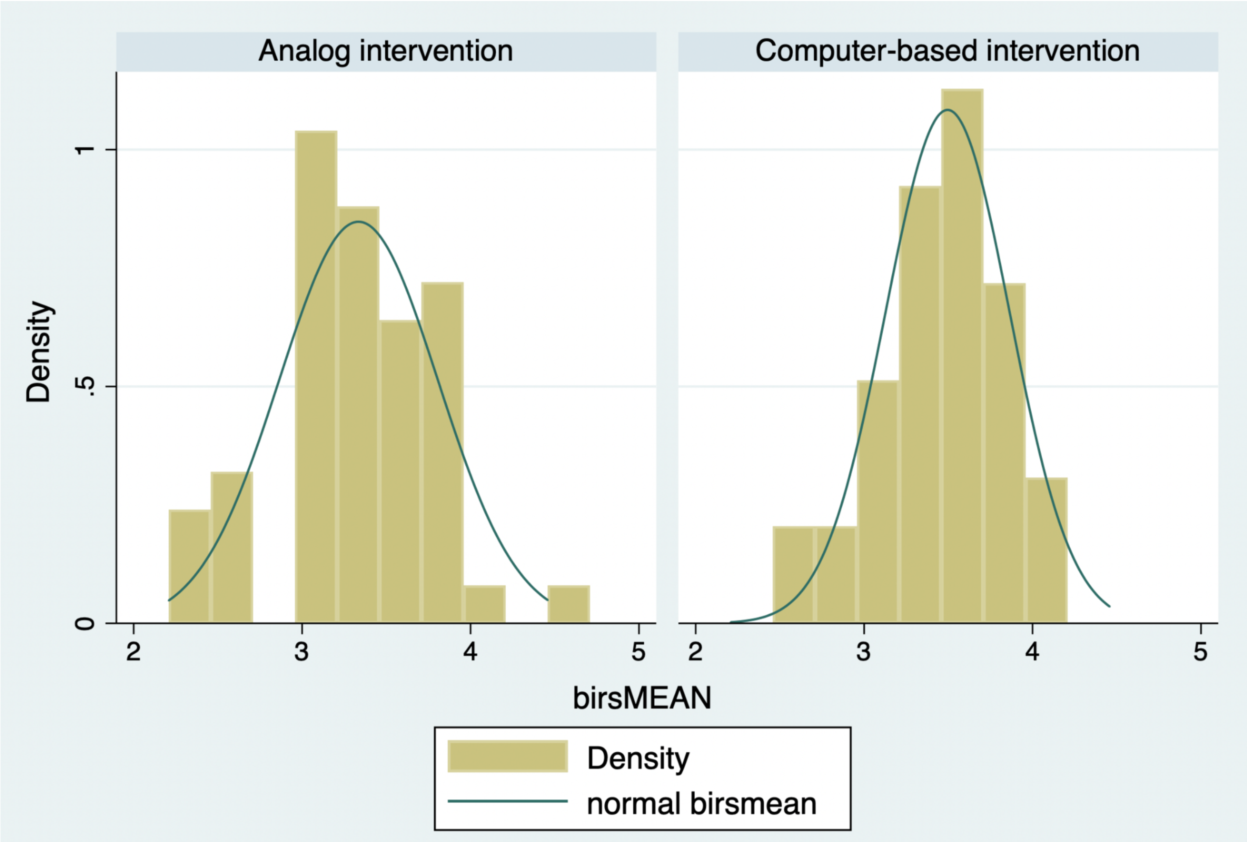
Level-1 and Level-2 Coefficients of the Random Intercept Model

				95% CI	
	Coefficient	*SE*	*Probability*	*LL*	*UL*
Intercept	2.75	0.10	0.000	1.59	3.92
iPad Intervention	0.18	0.29	0.069	-0.015	0.38
Cognitive load	0.018	0.0077	0.54	-0.040	0.075
ADHD knowledge	0.0043	0.0050	0.58	-0.011	0.020
Computer anxiety	0.00067	0.0056	0.89	-0.0092	0.011
Teaching self efficacy	0.0086	0.0070	0.88	-0.10	0.12
Age	0.0089	0.031	0.21	-0.0050	0.023
Race/Ethnicity	0.0064	0.065	0.84	-0.056	0.069
Grade Level Taught	0.038	0.11	0.56	-0.091	0.17
Teaching Status (current or former)	0.13	0.10	0.91	-0.20	0.22
Years Experience	-0.0084	0.58	0.42	-0.029	0.012

* $p < 0.05$

Figure 1

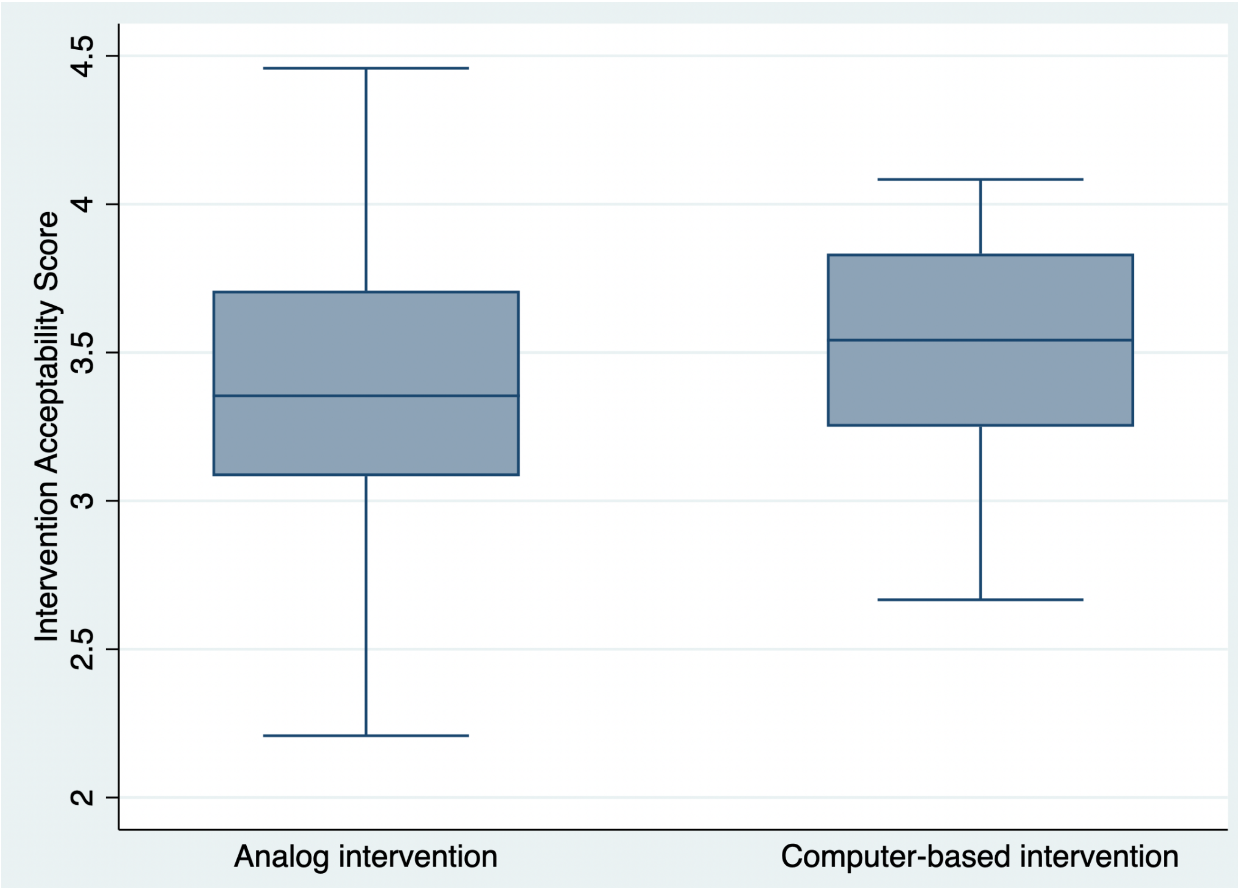
Histograms of Intervention Acceptability Scores Plotted by Intervention Modality



Note. This figure depicts a histogram of the dependent variable, intervention acceptability score, plotted for each of the intervention modalities and includes a fitted curve.

Figure 2

Histograms of Intervention Acceptability Scores Plotted by Intervention Modality



Appendix A
Summary of Demographic Items

I am currently teaching students in grade…	• 6 • 7 • 8 • 9 • 10 • 11 • 12
Years of teaching experience	☐ ________ [participant enters years]
Age	☐ ________ [participant enters age]
Education	• Bachelor's degree • Master's degree • Doctoral degree • Other _______
I have instructed at least one student with an ADHD diagnosis and/or executive functioning difficulties	• True • False • Unsure
Gender	• Female • Male • Non-binary • Prefer to self-describe:________________ • Prefer to not answer
Race/Ethnicity	• American Indian or Alaska Native (includes Cherokee, Navajo, Latin American Indian, Choctaw, etc.; Northwest Coast Indians, Yupiks, Aleuts, Athabascans, etc.) • Asian (includes Chinese, Indian, Filipino, Vietnamese, Korean, Japanese, etc.) • Black or African American (includes Jamaican, Haitian, Nigerian, Ethiopian, Somali, etc.)

- Hispanic or Latino (includes Mexican, Puerto Rican, Cuban, Salvadorian, Dominican, Colombian, etc.)
- Middle Eastern or North African (includes Lebanese, Iranian, Egyptian, Syrian, Moroccan, Algerian, etc.)
- Native Hawaiian or Other Pacific Islander (includes Native Hawaiian, Samoan, Chamorro, Tongan, Fijian, Marshallese, etc.)
- White (includes German, Irish, English, Italian, Polish, French, etc.)
- Multiracial
- Race/ethnicity not listed: ________
- Prefer not to answer

Appendix B
Intervention Acceptability Questionnaire

1. This would be an acceptable intervention for the child's problem behavior.	1 2 3 4 5
2. Most teachers would find this intervention appropriate for behavior problems in addition to the one described.	1 2 3 4 5
3. The intervention should prove effective in changing the child's problem behavior.	1 2 3 4 5
4. I would suggest the use of this intervention to other teachers.	1 2 3 4 5
5. The child's behavior problem is severe enough to warrant use of this intervention.	1 2 3 4 5
6. Most teachers would find this intervention suitable for the behavior problem described.	1 2 3 4 5
7. I would be willing to use this in the classroom setting.	1 2 3 4 5
8. The intervention would result in negative side-effects for the child.	1 2 3 4 5
9. The intervention would be appropriate intervention for a variety of children.	1 2 3 4 5
10. The intervention would be consistent with those I have used in classroom settings.	1 2 3 4 5
11. The intervention would be a fair way to handle the child's problem behavior.	1 2 3 4 5
12. The intervention would be reasonable for the behavior problem described.	1 2 3 4 5
13. I like the procedures used in the intervention.	1 2 3 4 5
14. This intervention would be a good way to handle this child's behavior problem.	1 2 3 4 5
15. Overall, the intervention would be beneficial for the child.	1 2 3 4 5
16. The intervention would quickly improve the child's behavior.	1 2 3 4 5

17. The intervention would produce a lasting improvement in the child's behavior. 1 2 3 4 5

18. The intervention would improve the child's behavior to the point that it would not noticeably deviate from other classmates' behavior. 1 2 3 4 5

19. Soon after using the intervention, the teacher would notice a positive change in the problem behavior. 1 2 3 4 5

20. The child's behavior would remain at an improved level even after the intervention is discontinued. 1 2 3 4 5

21. Using the intervention should not only improve the child's behavior in the classroom, but also in other settings (e.g., other classrooms, home). 1 2 3 4 5

22. When comparing this child with a well-behaved peer before and after use of the intervention, the child's and the peer's behavior would be more alike after using the intervention. 1 2 3 4 5

23. The intervention should produce enough improvement in the child's behavior so the behavior no longer is a problem in the classroom. 1 2 3 4 5

24. Other behaviors related to the problem behavior also are likely to be improved by the intervention. 1 2 3 4 5

Note. The questionnaire was adapted from the Behavior Intervention Rating Scale validated by Elliott and Treuting (1991). The directions for completing the questionnaire are as follows: "You have just read about a child with a classroom problem and a description of an intervention for improving the problem. Please evaluate the intervention by circling the number which best describes your agreement or disagreement with each statement. Please answer each question."

Appendix C
Computer Anxiety Rating Scale (CARS)

1. I feel insecure about my ability to interpret and use new computer applications	1 2 3 4 5
2. I look forward to using a computer on my job	1 2 3 4 5
3. I do not think I would be able to learn a new computer language	1 2 3 4 5
4. I am confident I can learn computer skills	1 2 3 4 5
5. Anyone can learn to use a computer if they are patient and motivated	1 2 3 4 5
6. Learning to operate a computer is like learning any new skill – the more you practice the better you become	1 2 3 4 5
7. I am afraid that if I begin to use computers I will become dependent on them and lose some of my reasoning skills	1 2 3 4 5
8. I am sure that with time and practice I will be as comfortable working with computers as I am working with basic word processing software	1 2 3 4 5
9. I feel that I will be able to keep up with the advances happening in the computer field	1 2 3 4 5
10. I dislike working with machines that are smarter than I am	1 2 3 4 5
11. I feel apprehensive about using computers	1 2 3 4 5
12. I have difficulty understanding how a computer works	1 2 3 4 5
13. It scares me to think that I could cause the computer to destroy a large amount of information by hitting the wrong key	1 2 3 4 5
14. I hesitate to use a computer for fear of making mistakes I cannot correct	1 2 3 4 5
15. You have to be a genius to understand all the special commands contained in most computer software	1 2 3 4 5
16. If given the opportunity I would like to learn about and use computers	1 2 3 4 5

17. I have avoided computers because they are unfamiliar and somewhat intimidating to me	1 2 3 4 5
18. I feel computers are necessary tools in both educational and work settings	1 2 3 4 5
19. The challenge of learning computers is exciting	1 2 3 4 5
20. I feel that understanding computers will make me a more productive individual	1 2 3 4 5

Note. The CARS is a 20-item instrument which was adapted from the most recent scale used by Havelka & Beasley (2004). Each item is rated on a scale from 1 (strongly disagree) to 5 (strongly agree).

Appendix D
The Ohio State Teacher Efficacy Scale (OSTES)

How much can you do to control disruptive behavior in the classroom?	1 2 3 4 5 6 7 8 9
How much can you do to motivate students who show low interest in school work?	1 2 3 4 5 6 7 8 9
How much can you do to get students to believe they can do well in school work?	1 2 3 4 5 6 7 8 9
How much can you do to help your students value learning?	1 2 3 4 5 6 7 8 9
To what extent can you craft good questions for your students?	1 2 3 4 5 6 7 8 9
How much can you do to get children to follow classroom rules?	1 2 3 4 5 6 7 8 9
How much can you do to calm a student who is disruptive or noisy?	1 2 3 4 5 6 7 8 9
How well can you establish a classroom management system with each group of students?	1 2 3 4 5 6 7 8 9
How much can you use a variety of assessment strategies?	1 2 3 4 5 6 7 8 9
To what extent can you provide an alternative explanation or example when students are confused?	1 2 3 4 5 6 7 8 9
How much can you assist families in helping their children do well in school?	1 2 3 4 5 6 7 8 9
How well can you implement alternative strategies in your classroom?	1 2 3 4 5 6 7 8 9

Note. This version of the OSTES is the 12-item short form, validated by Tschannen-Moran and Woolfolk Hoy (2001). Each item is rated on a scale from 1 (nothing) to 9 (a great deal). The directions for completing the questionnaire are as follows: “Please indicate your opinion about each of the statements below.”

Appendix E
Test of ADHD Knowledge (TOAK)

1. Hereditary factors play a major role in determining if someone will develop ADHD.	Agree	Disagree	Not Sure
2. Children with ADHD maintain grade point averages comparable to students without ADHD.	Agree	Disagree	Not Sure
3. Adults with ADHD are often late or forget to keep appointments.	Agree	Disagree	Not Sure
4. The most common side effects of stimulant medications are decreased appetite and sleep difficulties.	Agree	Disagree	Not Sure
5. As compared to students without ADHD, students with ADHD are more likely to drop courses or withdraw from courses.	Agree	Disagree	Not Sure
6. Biofeedback is not a well-established or proven treatment for ADHD.	Agree	Disagree	Not Sure
7. Most children with ADHD will no longer have problems once they are finished with school.	Agree	Disagree	Not Sure
8. ADHD seldom impacts relations with friends or romantic partners.	Agree	Disagree	Not Sure
9. Children with ADHD display symptoms of inattention, impulsivity, and/or hyperactivity.	Agree	Disagree	Not Sure
10. Students with ADHD graduate from college at about the same rate as do students who do not have ADHD.	Agree	Disagree	Not Sure
11. Most children with ADHD who take stimulant medication benefit from its use.	Agree	Disagree	Not Sure
12. Children with ADHD are more likely than children without ADHD to be aggressive.	Agree	Disagree	Not Sure
13. To confirm a diagnosis of ADHD, it is usually necessary to conduct neurological testing.	Agree	Disagree	Not Sure
14. The driving behavior of adults with ADHD is no different than that of adults without ADHD.	Agree	Disagree	Not Sure

15. College students with ADHD are at increased risk for smoking cigarettes.	Agree	Disagree	Not Sure
16. Medication is the only treatment necessary for most individuals with ADHD.	Agree	Disagree	Not Sure
17. Adults with ADHD change jobs more frequently than adults without ADHD.	Agree	Disagree	Not Sure
18. Students with ADHD take longer to complete college than do students without ADHD.	Agree	Disagree	Not Sure
19. Low levels of the brain chemical, serotonin, are a major cause of ADHD.	Agree	Disagree	Not Sure
20. Divorce rates among adults with ADHD are no different than those for adults without ADHD.	Agree	Disagree	Not Sure
21. Many children with ADHD display poor organizational skills and time management difficulties.	Agree	Disagree	Not Sure
22. Clinical interviews and behavior rating scales are important tools in assessing ADHD.	Agree	Disagree	Not Sure
23. ADHD is a condition that typically arises in early childhood and persists across the life span.	Agree	Disagree	Not Sure
24. Adults with ADHD commonly have problems managing their money.	Agree	Disagree	Not Sure
25. Anxiety problems occur more often in those with ADHD than they do in non-ADHD individuals.	Agree	Disagree	Not Sure
26. As compared to non-ADHD adults, adults with ADHD are more likely to have a child with ADHD.	Agree	Disagree	Not Sure
27. A diagnosis of ADHD is appropriate for any student reporting severe concentration problems.	Agree	Disagree	Not Sure
28. Children with ADHD often have difficulty planning ahead and remembering things.	Agree	Disagree	Not Sure
29. Teachers are obligated to give easier exam questions to students with ADHD.	Agree	Disagree	Not Sure
30. Adults with ADHD are at increased risk for getting into	Agree	Disagree	Not Sure

trouble with the law.

31. Cognitive-behavioral interventions have been shown to be effective in treating individuals with ADHD.	Agree	Disagree	Not Sure
32. Children with ADHD experience depression at about the same rate as children without ADHD.	Agree	Disagree	Not Sure
33. In-class use of an audio/tape recorder and priority seating are examples of accommodations that students with ADHD may receive.	Agree	Disagree	Not Sure
34. To be effective, stimulant medications must build up in the bloodstream over a period of many days.	Agree	Disagree	Not Sure
35. Students with ADHD may benefit from receiving classroom accommodations.	Agree	Disagree	Not Sure
36. There currently are no agreed upon criteria for diagnosing ADHD among children.	Agree	Disagree	Not Sure
37. Certain non-stimulant medications (e.g., Strattera) can be effective in reducing ADHD symptoms.	Agree	Disagree	Not Sure
38. An underactive inhibition center in the brain may cause ADHD.	Agree	Disagree	Not Sure
39. Students with ADHD are just as likely to engage in risky sexual behavior as students without ADHD.	Agree	Disagree	Not Sure

Note. The version of the TOAK-40 used for the present study was adapted and updated from the original 40-item TOAK validated by Anastopoulos et al. (2021). The directions for completing the questionnaire are as follows: “After each statement, please indicate whether you ‘agree,’ ‘disagree,’ or are ‘not sure.’”

Appendix F

Cognitive Load

If I were to implement the previously described ADHD intervention, I anticipate that I would invest…	● 1. very, very low mental effort ● 2. very low mental effort ● 3. low mental effort ● 4. rather low mental effort ● 5. neither low nor high mental effort ● 6. rather high mental effort ● 7. high mental effort ● 8. very high mental effort ● 9. very, very high mental effort

Note. This single-item measure of mental effort was adapted by the measure validated and published by Paas (1992). The prompt in Paas' measure is as follows, "In solving or studying the preceding problem I invested…"

Appendix G
ADHD Psychoeducation

ADHD prevalence and symptoms.

***Prevalence*.** Attention-deficit/hyperactivity-disorder (ADHD) is a neurodevelopmental disorder that impacts an estimated 9.5% of school-aged children in the United States. ADHD is characterized by a persistent pattern of inattention, hyperactivity, and/or impulsivity, which interferes with the individual's day-to-day functioning and development.

***Symptoms*.** There are three diagnostic categories of ADHD based on three different symptom profiles: primarily inattentive, primarily hyperactive and impulsive, and combined (DSM-5). Examples of symptoms of inattention include becoming off task, lacking persistence, and having difficulty sustaining focus. Examples of symptoms of hyperactivity include excessive fidgeting, tapping, and talkativeness. Finally, examples of symptoms of impulsivity include a desire for immediate rewards, great difficulty delaying gratification, social intrusiveness, and not considering the long-term consequences of one's actions.

***Developmental features*.** In addition to the core symptoms, ADHD symptom profiles tend to change as children age. Typically, younger children experience greater symptoms of hyperactivity and impulsivity. Older children and adolescents tend to experience greater symptoms of inattention.

When and where do symptoms occur?

To receive an ADHD diagnosis, an individual must meet additional criteria beyond exhibiting symptoms consistent with one of the three symptom profiles. One such criterion is that the individual's symptoms must be present in more than one setting. Conversely, the symptoms may be minimal or absent during situations that involve engaging activities or constant external stimulation (such as with sports or video games), frequent rewards, close supervision, or in a one-on-one setting.

How can ADHD be treated?

In order to understand what treatments effectively reduce ADHD symptoms, it is first important to recognize that ADHD is a chronic disability. This means that although symptoms are reduced during treatment, treatments themselves do not result in long-term changes in symptoms. In other words, once treatment is stopped, the individual's symptoms return. Therefore, ADHD requires long-term, explicit, and consistent treatment. The two forms of effective treatment for ADHD that are strongly supported in the research literature are medication management and behavioral interventions.

***Medication management*.** One of the most effective and common treatments for ADHD is the use of stimulant medication. This mode of treatment effectively brings core symptoms to sub-clinical levels in an estimated 80% of school-aged children and teens. However, one drawback of relying on medication alone lies in the fact that 20 to 30% of those who receive pharmacological treatment are either non-responders or experience intolerable negative side effects and therefore cease pharmacological treatment.

***Behavioral intervention*.** One of the most effective non-medication-based treatment categories is behavioral intervention. There are several different types of behavioral interventions. An example of a research-supported approach is self-monitoring. Self-monitoring interventions always involve a small set of behaviors that the student self-monitors at regular intervals. Research shows that self-monitoring interventions are most effective when they are tightly structured, predictable, and involve an initial period of teacher monitoring of the student's target behaviors. Self-monitoring interventions are most effective when accuracy is the primary objective, as opposed to prioritizing a specific behavioral goal. Working toward a specific goal should be pursued after the student is monitoring their own behaviors accurately. Accuracy is typically determined by comparing the student's self-evaluation ratings to the teacher's ratings given in the same period.

Note. The above information about ADHD will be presented to participants in a self-guided slide show presentation.

Appendix H
Vignette

This year, you have a student in your class who is often distracted, especially during undesired activities, transitions, and independent work time. When distracted, they may “zone out,” engage in off-task socialization with their peers, or engage in other off-task activities (like doodling on their paper, or fidgeting with an object they brought to class). This student also has problems keeping their attention focused. They often fail to pay attention to details and make careless mistakes in their school work. In addition to being easily distracted, this student tends to blurt out answers before questions have been completed. They also have a difficult time waiting their turn and they tend to interrupt others.

Compounding these problems is the fact that this student often forgets to complete daily activities and loses things necessary for various assignments (e.g., pencils, books, homework, etc.). The student also leaves their seat at inappropriate times, which disrupts instruction. In one-to-one situations, this student can be frustrating to work with because they often do not seem to listen when spoken to directly and they have a difficult time organizing himself or herself in tasks and activities, even after being given reminders. Consequently, the student often has difficulty starting and finishing tasks.

After experiencing these difficulties in class for some time, you speak to one of the student’s parents and discover that this student also experiences these problems at home and has been like this since before they started school.

Appendix I
Intervention Descriptions

Digital ADHD Intervention Description

App-based self monitoring is one intervention that can be used to support students who have difficulties with focusing and sustaining attention. To use this intervention, the student is provided an iPad at the beginning of each class period. The iPad provides access to a self-monitoring intervention app. While the self-monitoring app is in use, the app blocks the student from accessing any other applications. A description of the self-monitoring app interface is provided below and is accompanied by example images of the app user interface (see Figures 1-3).

General Procedure:

When the student retrieves their iPad and is seated, they log into their account. Once logged in, they select the "self-monitor" icon. A message is then displayed to the student: "Do you want to monitor your on-task goal?" The message is accompanied by a "yes" and "no" option. When the student selects "yes," the student's percent-time-on-task goal is briefly displayed with the message, "Your goal is to stay on task __% of the time." The % time on task goal is individualized to each student and set by the teacher ahead of time. Then the self-monitoring session begins and the student places the iPad on the upper right-hand corner of their desk.

During the self-monitoring session the prompt, "Are you on task?" is displayed every 5 minutes. To direct the student's attention to the prompt, the iPad screen flashes for 3 seconds. The student then indicates whether they were engaging in on-task behavior at that moment by selecting "yes" or "no" in response to the prompt. The entirety of the self-monitoring session lasts for 60 minutes. Therefore, throughout the self-monitoring period, the student is prompted on 12 occasions to self-monitor their on-task behavior. After 60 minutes elapses, the app displays a message that notifies the student that the self-monitoring session has ended. The student then returns their iPad to the classroom teacher.

The Teacher's Role:

During week 1 of the intervention, the teacher's role is to promote the student's self-monitoring accuracy and help the student work toward their self-monitoring goal. Each day during week 1, the teacher uses a different iPad (or mobile device) to simultaneously monitor the target student's on-task behavior by responding to the same prompts at the same 5-minute intervals. At an agreed-upon time following each self-monitoring session during week 1, teacher and student meet briefly to discuss goal progress (% time on task) and self-monitoring accuracy.

To examine these results, the teacher and student navigate to the "Results" icon (which is available on both the student and teacher accounts). After selecting the results generated for that day, the app displays a split screen that shows goal progress (% time on task) and accuracy (student ratings compared to teacher ratings; see Figure 4). The left side of the split screen shows whether the student met their self-monitoring goal for the day. The right side shows how the student's self-monitoring results aligned with the ratings provided by their teacher.

The student is given positive verbal feedback for both goal progress and accuracy.

After the first week, the student continues to self-monitor daily (see Figure 5 for an example of how long-term progress is tracked). However, the teacher randomly chooses one day each week to monitor the student's on-task behavior. On this day, the teacher should meet briefly with the student to review results in order to continue to promote self-monitoring accuracy and goal attainment.

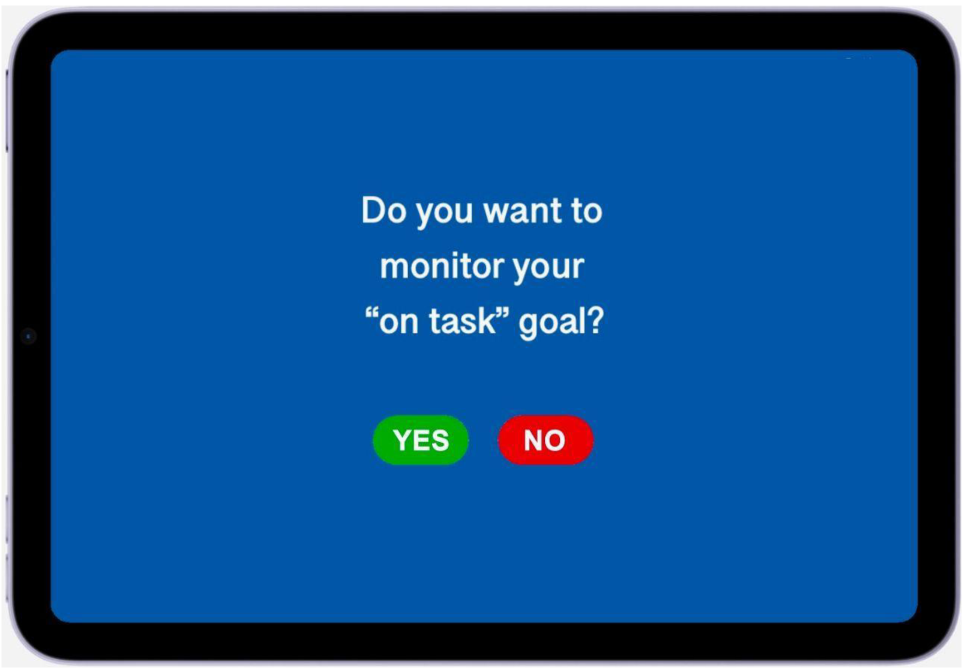


Figure 1. Example of interface that confirms student user's session for self-monitoring an on-task goal.

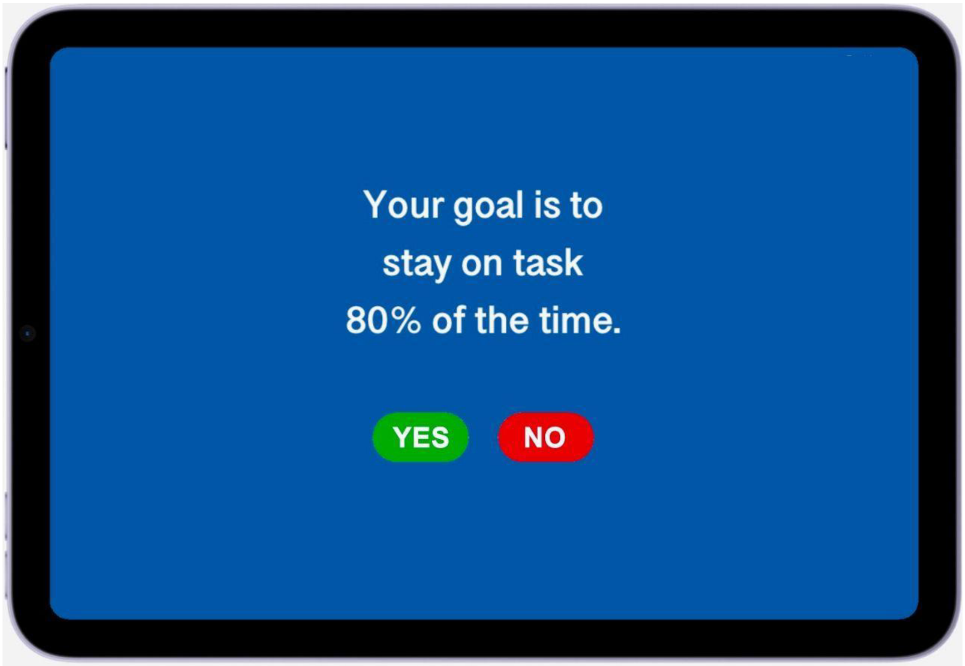


Figure 2. Example of interface that reminds the student user of the self-monitoring goal before they begin the 60-minute self-monitoring session.

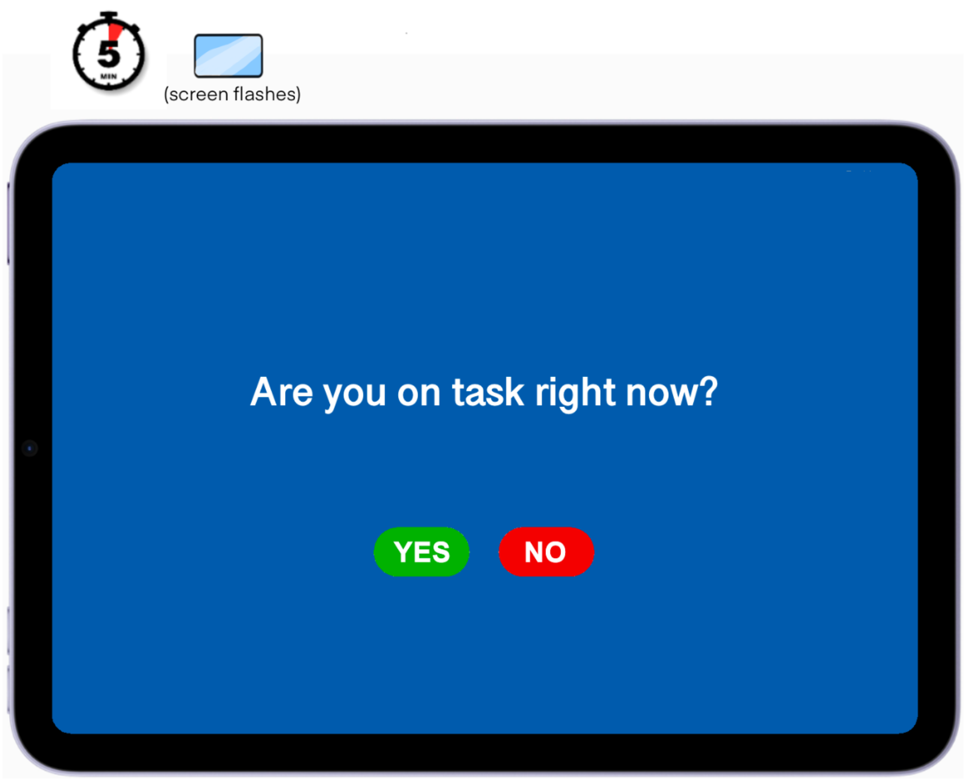


Figure 3. Example of self-monitoring interface of an on-task goal. After each 5 minute interval, the screen will flash, alerting the user to respond to the self-monitoring prompt.

Figure 4. Example of split screen interface that shows goal progress (% time on task) and accuracy (student ratings compared to teacher ratings).

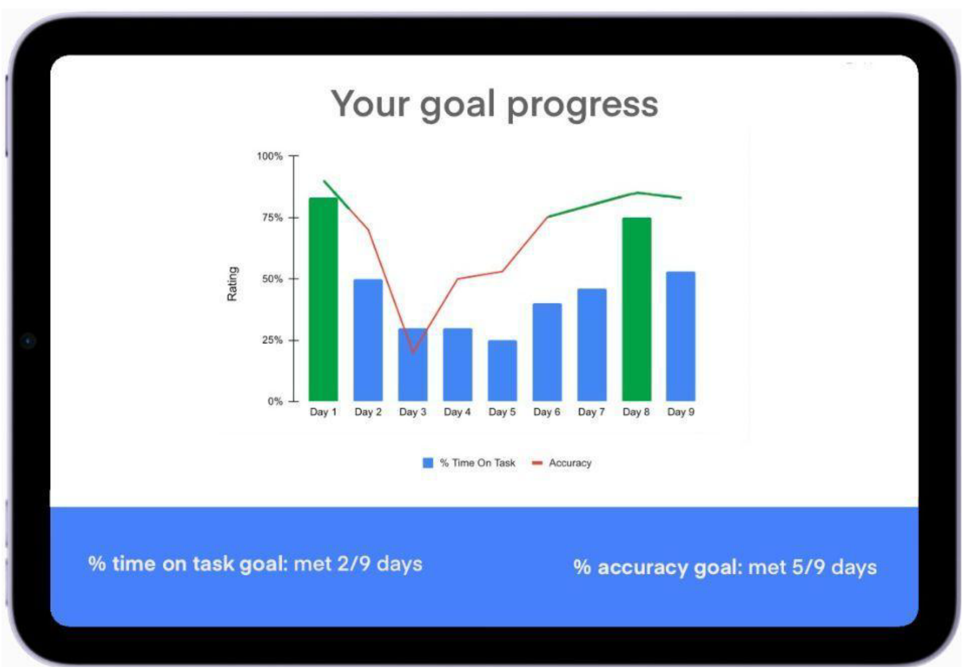


Figure 5. Example of interface that shows long-term goal progress (% time on task) and accuracy (student ratings compared to teacher ratings). Data are highlighted in green whenever the student's % time on task or accuracy goal is met.

Non-Digital ADHD Intervention Description

At the beginning of each class period, the student is provided an iPad (in order to use an interval timer app) and a self-monitoring handout that has a behavior goal printed on the top (e.g., Your goal is to stay on task 80% of the time.). The % time on task goal is individualized to each student and set by the teacher ahead of time. The interval timer app blocks the student from accessing any other applications. An example of the self-monitoring handout is shown below (see Figure 1).

General Procedure:

When the student retrieves their iPad and is seated, they open the timer app and start an interval timer. Once the timer is initiated, the student places the iPad and self-monitoring sheet on the upper right-hand corner of their desk.

At 5 minute intervals, the iPad screen flashes for 3 seconds in order to alert the student that it is time to self-monitor their on-task behavior. Each time the timer flashes, the student records on their self-monitoring sheet whether they were engaging in on-task behavior at that moment by checking "yes" or "no" in response to the question, "Am I on task right now?". The entirety of the self-monitoring period lasts for 60 minutes. Therefore, throughout the self-monitoring period, the student is alerted by the timer on 12 occasions to self-monitor their on-task behavior. After 60 minutes has elapsed, the self-monitoring period ends. The student returns their completed self-monitoring form and iPad to the classroom teacher.

The Teacher's Role:

During week 1 of the intervention, the teacher's role is to promote the student's self-monitoring accuracy and help the student work toward their self-monitoring goal. Each day during week 1, the teacher monitors the student's on-task behavior by filling out the same monitoring form at the same 5-minute intervals. At an agreed-upon time following each self-monitoring session during week 1, teacher and student meet briefly to discuss goal progress (% time on task) and self-monitoring accuracy.

To examine these results, the teacher and student turn the self-monitoring sheet over and fill out two boxes that are used to calculate goal progress (% time on task) and accuracy (teacher vs. student ratings; see Figure 2). The left box is used to calculate whether the student met their self-monitoring goal for the day. Goal progress is calculated by dividing the number of "yes" responses by the total number of intervals, and multiplying the result by 100. The right side shows how the student's self-monitoring results align with the ratings provided by their teacher. Accuracy is calculated by dividing the number of teacher and student responses that were the same by the total number of intervals, and multiplying the result by 100. The student is given positive verbal feedback for both goal progress and ratings that align with those provided by the teacher.

After the first week, the student continues to self-monitor daily (see Figure 3 for an example of how long-term progress is tracked). However, the teacher randomly chooses one day each week to monitor the student's on-task behavior. On this day, the teacher should meet briefly with the student to review results in order to continue to promote self-monitoring accuracy and goal attainment.

Name: Sample Student

Date: xx/xx/20XX

Your goal is to stay on task 80% of the time.

Time	Are you on task		Same rating as teacher? Complete this section with your teacher later
5 min	YES	NO	☑
10 min	YES	NO	☑
15 min	YES	NO	☑
20 min	YES	NO	☐
25 min	YES	NO	☑
30 min	YES	NO	☑
35 min	YES	NO	☑
40 min	YES	NO	☐
45 min	YES	NO	☑
50 min	YES	NO	☑
55 min	YES	NO	☑
60 min	YES	NO	☑

Figure 1. Example of handout for self-monitoring an on-task goal. After each 5 minute interval,

the user is alerted by an iPad timer to respond to the self-monitoring prompt, “Am I on task right now?”.

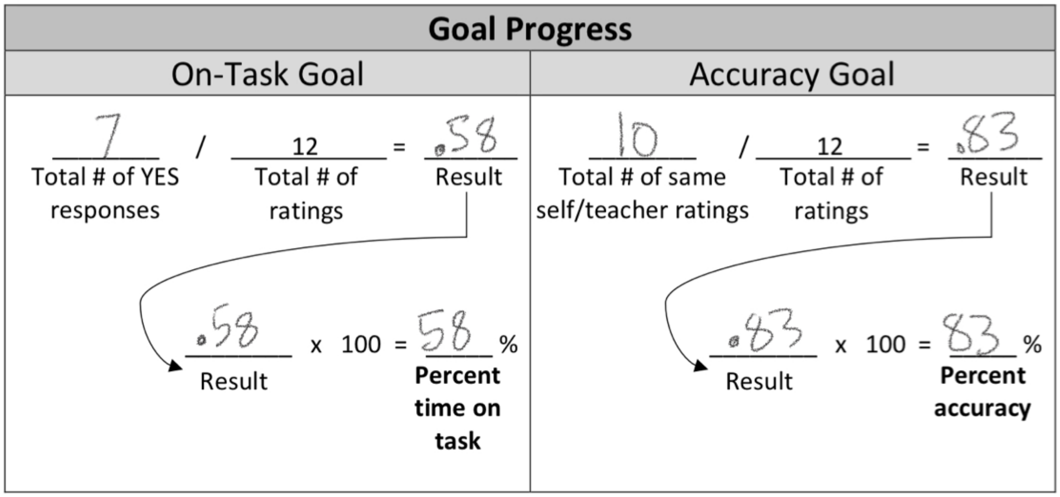


Figure 2. Example of space allocated on the back of the self-monitoring sheet that is used to track the given day’s goal progress (% time on task) and accuracy (student ratings compared to teacher ratings).

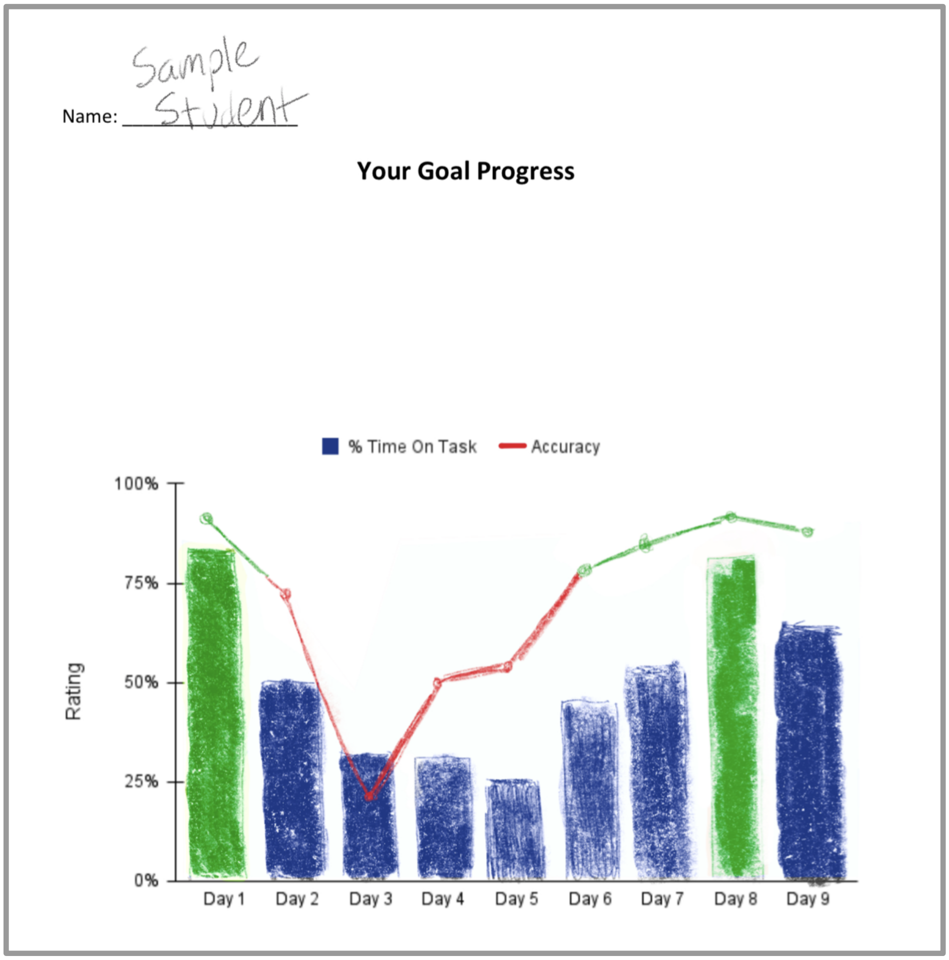


Figure 3. Example of worksheet where the student (in collaboration with their teacher) records long-term goal progress (% time on task) and accuracy (student ratings compared to teacher ratings). The teacher ensures that the student color codes the data appropriately. Blue is used to record % time on task with a bar graph, red is used to record % accuracy with a line graph, and green is used to record performance whenever the student's % time on task or accuracy goal is met.