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The Necessity of Advancing Our Knowledge on Assistive Technologies To Better Support Students With Attention Deficit Hyperactivity Disorder

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Abstract

Individuals with ADHD may benefit from assistive technologies (ATs). ATs include FM systems, MontivAIDR, Time Aids, iSelfControl and Kurzweil. Eligibility for acquiring these ATs is discussed first. The importance of eligibility is highlighted because the review of the literature suggests that these ATs may promote academic success among students with ADHD. Unfortunately, most of the research on the efficacy of ATs is directed at learning disabilities. Consequently, a review of ATs that support students with learning disabilities is provided with the overarching goal to encourage researchers to determine how ATs that support students with learning disabilities may also support students with ADHD. Finally, we discuss the ways in which ATs can maintain their efficacy over time for students with ADHD through the implementation of a Response to Intervention (RTI) framework. Concluding remarks will follow.

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Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a persistent and pervasive neurological disorder affecting approximately 5% of students [1]. The symptoms include inattention and/or hyperactivity/ impulsivity which may result in academic underachievement or failure [2] [3] [4]. Interventions that may promote academic achievement among students with ADHD include assistive technologies (ATs). ATs is defined as "any item, piece of equipment, or product system, whether acquired commercially or off the shelf, modified or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability" [5] (pp. 1-2).

ATs do not replace accommodations or interventions implemented to support students with ADHD, rather they compliment them. For instance, Bussing et al. (2016) and Evans, Langberg, Egan & Molitor (2014) highlight common accommodations and supports for students with ADHD, these include allowing for movement in the classroom, facilitating methods to ensure students are kept busy, limiting distractions, using reminders, re-formatting tasks perceived to be difficult, extending time allotted for tests and assignments, reducing the length of assignments, and providing teacher or peer prepared notes [6] [7].

Richardson et al. (2015) reviewed non-pharmacological interventions for students with ADHD and identified two domains of interventions: reward and punishment (e.g., contingency management) and skills training and self-management. Skills training and self-management involves facilitating motivational beliefs (e.g., the notion that working hard and putting forth effort will lead to academic success) [8]. On the other hand, academic and study skills training involves learning and practicing strategies that promote academic success in specific areas such as, reading or writing. Importantly, many of the interventions and supports provided to students with ADHD that do not explicitly call for an AT can be supported by ATs and vice versa. For instance, academic and study skills are supported using ATs. Therefore, having open discussion about their use is essential, particularly in the current technology driven era. This can equalize the access to the curriculum between students with ADHD and their typically developing peers [9] [10] [11] [12] [13]. Unfortunately, while there has been research support for the usefulness of ATs for individuals learning disabilities there has been limited research on the usefulness of ATs for students with ADHD [14] [15] [16]. Thus, the overarching goal of this paper is to explore the usefulness of ATs for students with ADHD specifically.

First, eligibility for ATs among students with ADHD is discussed. Second, the research on the ATs that have been demonstrated to benefit students with ADHD will be reviewed. Third, directions for future research in ATs and ADHD will be investigated. Finally, through a Response to Intervention (RTI) framework the ways in which ATs can maintain their efficacy over time for students with ADHD will be outlined.

Eligibility for Assistive Technology

ADHD under the Individuals with Disabilities Education Act (IDEA) is not considered a specific educational disability [17]. However, the US Department of Education put forth a policy memorandum declaring that youth with ADHD are entitled to special education resources under the category "Other Health Impairment" in the circumstance that symptoms of diminished alertness lead to academic difficulty [18].

Furthermore, students with ADHD may be eligible to receive ATs through Section 504 of the Rehabilitation Act of 1973, contingent on the form of impairment at school. Nevertheless, a recent study examining characteristics and prevalence of school services offered to high school students with ADHD revealed that the majority had an Individualized Education Plan (IEP) which can only be accessed through the identification of a specific educational disability [19]. This likely reflects the fact that many students with ADHD are served through the fulfillment of the requirements for a disability in other domains [20]. Nevertheless, in a recent study by Murray et al. (2014) only approximately 11% of youth with ADHD who had an IEP reported using an AT (not one youth with ADHD without an IEP reported using an AT) [20].

This number seems relatively low given that Congress passed the Assistive Technology Act of 2004 [21], a revision and update from the Assistive Technology Act of 1998. The legislation stated that

there needs to be an increase in: 1) the funding, training access, awareness and availability regarding AT services and devices; 2) the capability of individuals who have a disability to be able to access ATs in order to promote their functioning on a day-to-day basis across contexts; 3) the ability of both private and public agencies to deliver and supply ATs and 4) facilitating the involvement not only among individuals with disabilities but also those that support them to help in make decisions regarding the use of the AT. However, there is a paucity of research examining the efficacy ATs may have for students with ADHD.

Beyond the United States, the primary initiative of the Global Cooperation on Assistive Health Technology, established by the World Health Organization, is to increase the availability of ATs that are high quality and affordable across the world [22]. Irrespective of living in high, middle or low-income countries there is a need for ATs to be robust, affordable and readily available [22]. We are continually making progress to ensure the needs of those with disabilities are being met, including the needs of those with ADHD, but significantly more progress needs to be made at an international level to help ensure those with ADHD receive the supports they need to succeed academically. The next section describes how the literature for this present paper on ATs was selected.

Assistive Technologies

Personal Frequency Modulation (FM) Systems

FM systems resemble small radio stations that operate on special frequencies and include a transmitter and receiver. Their function is to amplify sound and they are commonly used in classrooms for students with hearing impairments. The sound from the transmitter, worn by the teacher, is heard from the receiver, which is in the possession of the student. It is necessary for teachers to be cognizant of the following points when their student(s) are using FM systems: 1) For proper use the teacher speaks into a wireless microphone transmitter, worn on the lapel approximately 7 inches from the mouth; 2) The teacher needs to continually be aware of noise levels within the classroom because the microphone can pick up extraneous sounds and 3) The teacher can select different channels to be synced with individual students. Schafer et al. (2013) found that through the use of FM systems on-task behavior increased among students with ADHD. Further, during trial periods using the FM system, teachers reported improvements in students listening [11].

Importantly, auditory processing disorders are common among students with ADHD. Research has demonstrated that students with ADHD and suspected auditory processing disorders benefited from FM systems [23] [24]. Specifically, compared the control group, the experimental group performed at a higher level on specific measures of auditory function. Further, parents as well as teachers reported improvement among the experimental group in speech understanding and greater overall academic performance as well as improvements in behaviour [24]. Through a systematic review of FM systems effectiveness Reynolds, Kuhaneck and Pfeiffer (2016) found that this form of AT resulted in students with auditory processing impairments being better able to listen and attend in classroom settings [25]. Irrespective of an auditory processing deficit, given that one of the primary deficits demonstrated by students with ADHD is listening and sustaining attention, FM systems are likely to benefit this group of students [2] [26].

MotivAIDER

MotivAIDER resembles a pager and can fit on a belt or be carried in the user's pocket. To use the device the student first selects a message such as an image, phrase, or word reminding and motivating them to remain focused. Next, the student sets the device to vibrate at specific time intervals, and when it does the student is reminded of his/her motivational message. The student can set the device to vibrate as frequently as desired to help him or her remain focused on the task at hand; this facilitates focus and leads to greater productivity among students with ADHD [10]. Steps and Tips when using MotivAIDER are outlined in Table 1.

Next, as described by McDougall et al. (2012) the student can monitor his or her own on-task behavior by making a note of whether he or she is on-task at various points in a given school day when they received the messages [10]. The rationale for using MotivAIDER in combination with a fillable on-task form (See Table 2 for sample form) is that the student will begin to develop greater levels of self-awareness promoting on-task behavior and accountability.

Table 1: Steps and Tips for MotivAIDER as cited in McDougall et al. (2012)
Steps and Tips for Training Teachers to help Students Promote their Academic Achievement through Tactile Cued Self-Monitoring (TCSM)

Steps	Tips
1) The rationale for TCSM and improving target behaviour is explained by the teacher.	The teacher works independently with the student to highlight the target behaviour and how TCSM would promote their academic achievement. The interaction between teacher and student needs to be neutral (e.g. not in the context of the student in trouble).
2) Examples of non-examples are mod-eled by the teacher.	Examples of non-examples are those behaviours that have previously transpired. The student needs to be aware of the target behavior and have an understanding that the teachers are cognizant that students understand the specific target behaviour.
3) Students observe the use of TCSM by their teacher; both the teacher and students self-record independently.	Demonstrate examples and non-examples of the target behavior. Self-reporting should be out of others' view. Students may react to non-examples identified by the teacher. For example, they may laugh.
4) Students observe the use of TCSM by their teacher; both the teacher and students self-record independently	Direct students to target behavior and accurately self-report; return to previous task following completing the self-recording form.
5) Agreement is checked	There needs to be 100% agreement. Following training teachers need to have TCSM applied in everyday settings. Remind students of the benefit of TCSM and the importance of self-report. It will help them to become more aware of disengaging from the task and promote their academic achievement.

Steps from cognitive-behavioural training procedures aiming to promote self- monitoring [27]. Tips are adapted using a DVD centering on behavioural self-management training [28].

Table 2: On-Task Behaviour Facilitated by the MotivAIDER

On-Task	12:00PM	12:10:PM	12:20PM	12:30PM	12:40PM	12:50PM	1:00PM
YES or NO							

Time Aids

Time aids are designed to make the passage of time more understandable and concrete for individuals impaired in time perception. Time rule is one example of this. Time rule displays a row of light diodes where an increasing number of lit rows indicates the passages of time. In other words, few light diodes indicate a short period of time whereas many light diodes indicate a longer period of time [29]. Further examples of time aids include quarter hour watches and adapted calendars promoting orientation in the year, month, week, and time of day (Janeslätt et al., 2014). Finally, time management can be improved using time aids such as a personal digital assistant (PDA) and/or using an adapted Filofax [9]. Janeslätt et al. (2014) found that among individuals with ADHD time aids facilitated the development of their time perception, time orientation and time management [9]. Table 3 outlines steps that the teacher will have to foresee which may interfere with students with ADHD benefiting from time aids and how teachers can, in turn, help them overcome these challenges through the tips highlighted.

iSelfControl

iSelfControl is a web-based application for tablets. It is designed to promote self-regulation within the classroom among children with ADHD. Schuck et al.'s study (2016) examined the use of iSelfControl in which students were prompted by the application to rate their classroom behaviour evaluating their performance in various domains every 30 minutes [12]. This is similar to MotivAIDER in the sense that students are prompted to evaluate their behaviour by an external device at specific time intervals. However, unlike MotivAIDER, adaptive behaviours earn points while maladaptive behaviours lose points.

The teacher simultaneously evaluates the students' behaviour over the course of the same period of time on a different tablet. Students are then able to see whether their self-reports are consistent with their teacher-reported scores and are able to keep track of their performance during the day by viewing charts on the tablet. According to Schuck et al., (2016) the three central goals of implementing iSelfControl were to establish whether students with ADHD were better able to: 1) focus their attention on the present moment to monitor their behaviour; 2) assess their behaviour and 3) make corrections to their behaviour if they deemed it was necessary [12]. Further, it was expected that collection of the data from the application could be used to inform intervention that is individualized in the classroom. During the period of the study, iSelfControl facilitated self-reflection, complementing traditional cognitive behavioural therapy directed at students in the classroom [12]. As a result, it was positively accepted by most students (70%) along with their teachers [12].

Kurzweil

Text-to-speech programs, such as Kurzweil 3000 reads aloud digital, web-based and scanned print material. Kurzweil 3000 can also convert web-based digital and scanned information into mp3 to provide audio files for the user to then listen to at their convenience. This program may benefit students with ADHD who have difficulty with reading comprehension [14] [16]. This is because reading comprehension impairments may be more common among individuals with ADHD compared to their peers without ADHD [30] [31]. Text-to-speech programs circumvent this problem by reading aloud printed text for the student rather than the student having to read the text themselves. For example., Weiland (2008) also found that among

Table 3: Steps and Tips Leading to the Success of Time Aids

Steps	Tips
1) The teacher foresees that the time aid may be misplaced or used at the sporadic discretion of the student.	Encourage consistent integration of the time aid in school and home life.
2) The teach foresees that the time aid does not produce instantaneous benefits and is quickly discarded.	Support the use of the time aid and lead the student to experience immediate success.
3) The teacher foresees that the time aid is perceived to have stigma associated with it and negative perceptions of the time aid develop.	Maintain a positive attitude. Encourage parents to maintain a positive attitude. Highlight to all students the value of the time aid(s).
4) The teacher foresees that the student, despite the time aid, relies on the teacher to manage his or her time.	Continually re-enforce the notion that through the use of the time aid the student's sense of control and independence will develop.

students with ADHD, Kurzweil 3000 promoted their reading speed and comprehension [13]. Finally, individuals with ADHD also frequently have a co-occurring reading disability and Kurzweil through reading aloud printed text may ameliorate difficulties in reading [32] . In a study by Cullen, Keesey, Alber-Morgan and Wheaton (2013) it was found that Kurzweil 3000 helped a student with ADHD develop their sight word reading abilities [33].

Expanding the Scope of Research on ATs for Students with ADHD

Despite ADHD being a risk factor for academic underachievement, the empirical research on ATs to support students with the disorder has been limited and to our knowledge includes only FM systems, MotivAIDER, time aids, iSelfControl and Kurzweil 3000. On the other hand, research supporting the use of ATs for students with learning disabilities is further developed [14] [15] [16]. It is necessary for the research examining the efficacy of ATs for students with learning disabilities to expand in order to examine whether these same ATs similarly benefit those with ADHD. What follows describes ATs which support writing, attention and executive functions; domains that are frequently impaired among individuals with ADHD [2] [34] [35] [36] [37].

Assistive Technologies Supporting Writing

Dragon Naturally Speaking allows students to orally dictate words for the computer to then interpret leading to a written composition. Inspiration, on the other hand, guides students in the writing process by generating graphic organizers, mind maps, and by helping students to brainstorm and encouraging their creativity. Once the notes are visually displayed through such means, the program transforms them into an outline which facilitates students' ability to begin to write. Through this process, users can direct their focus within an expansive topic, organize their thinking, and make connections between the topics and ideas; this in turn facilitates memory [38]. Finally, Text Help, like text-to-speech programs, such as Kurzweil 3000, reads the text that the student has written aloud, allowing them to pick up on grammatical errors and structural or organizational flaws.

Assistive Technologies Supporting Attention

There have been several applications that aim to promote attention which may lead to greater levels of productivity. For instance, Attention Exercise is an application that allows the user to doodle. This application, allows the users to simultaneously draw a vertical line with their right hand and a circle with their left hand. Research has found that doodling can promote the ability to focus [39]. Further, Focus@Will improves productivity through the use of phase-sequenced playlists of instrumental music whereby users choose from various channels (e.g. classical) and skip tracks found to be a distraction. Also included within this application is a productivity tracker and timer function. Research suggests that enjoying what is listened to is related to test-taker attention performance and that compared to music with lyrics, music without lyrics enhances attention and performance [40] [41]. This is consistent with the Moderate Brain Arousal (MBA) model of ADHD which proposes that stimuli eliciting over-stimulation compromises performance [42]. Finally, research supports the notion that taking breaks allows individuals to ultimately stay focused for longer periods of time [43]. To this end, the application Time Out helps users to take regular breaks by slowly dimming the screen at time internals chosen by the user. The user can choose messages, such as "stretch" to be displayed on the screen during breaks. Once the break is finished (at a predetermined time set by the user) the computer screen fads back in and the user can begin working again. In another app, Focus Booster, breaks are earned by being on-task for 25-minute intervals which in turn improves focus. This is known as the Pomodoro Technique.

Assistive Technologies Supporting Executive Dysfunctions

There are also ATs designed to help students with ADHD which compensate for executive dysfunctions. Executive Function (EF) is defined as "a collection of interrelated cognitive and behavioral skills that are responsible for purposeful, goal-directed activity and include the highest level of human functioning such as intellect, thought, self-control, and social interaction" [44] (p. 42). Common executive dysfunctions among individuals with ADHD that compromise academic achievement may include planning/organization and working memory [45] [46].

Strategic planning and organization are necessary for successful homework completion and in turn academic achievement. Temple (2013) reported that applications for tablets or phones to ensure homework gets completed, including myHomework and iStudiezpro, are beneficial for some students with executive dysfunctions [38]. For example, myHomework can be used with different devices and allows the students to track assignments, homework, tests and classes. Similarly, iStudiezpro, allows users to keep track of grades and assignments as well as provides them with the ability to break down assignments through a schedule planner. Moreover, Soshiku.com, RemembertheMilk.com and Squareleaf are three websites that allow access to tools that assist with keeping track of assignments, saving notes, attaching files, collaborating, e-mail and managing tasks. These websites have also been shown to promote autonomy [47].

Working memory helps an individual simultaneously hold on to information in his or her mind and continually update the information to form a coherent mental model of what is being read or listed to. Limited working memory capacity directly impairs ability to take notes from a lecture, and similar to planning and organization deficits contributes to poorer written work [48]. An example of an AT that may compensate for poor working memory and/or poor handwriting, two common deficits among individuals with ADHD [26] [49], is the Livescribe Pen (LSP). The LSP records audio and simultaneously takes pictures of hand written notes with the LSP. Once uploaded to a computer, the notes and pictures can become synchronized such that the user can replay portions of the audio by tapping on the notes that were taken at the time the recording was made. In other words, students using this pen would not miss information provided orally by the teacher even if they did not make a note of it during the lecture. While it has been found that students with learning disabilities in reading benefited from the LSP [15], it is likely that those with ADHD would also benefit from its use. Thus, it is necessary for future research to assess the relative benefit of LSP use for students with ADHD.

Furthermore, if ability to take clear and accurate notes is compromised due to poor working memory capacity or handwriting impairments, software programs such as MyScript by Vision Objection may be beneficial [47]. This program learns the user's handwriting and converts his or her notes into a rich text format file which can be edited and printed by exporting it to a word processing program. For less expensive options designed for note taking Schwartz (2014) also cites Notability, Evernote, eNotebook, Note Taker HD, and Penultimate which are applications designed for smart phones or tablets [47]. While these popular programs are used by students with ADHD, to the best of our knowledge, there is no research to support their efficacy among this group. Future research should examine the impact of these note taking software's on the note taking skills, test scores, and recall of individuals with ADHD.

Monitoring the Efficacy of ATs

"RTI has been broadly described as a process in which students are provided quality instruction, their progress is monitored, those who do not respond appropriately are provided additional instruction and their progress is monitored, and those who continue to not respond appropriately are considered for special education services" [50] (p. 159) cited by Bradley, Danielson & Doolittle (2005) [51]. Once in special education, within an RTI framework, students with ADHD need to be taught to self-monitor [52]. Haraway (2012) suggests that one way to achieve this is for students to complete daily monitoring forms, designed to assess the efficacy of the AT use [52].

Filling in the monitoring forms allows teachers to: 1) Assess progress on a day-to-day, week-to-week and/or month-to-month basis; 2) Decide on consequences and recognize when progress should be rewarded; 3) Recognize when progress begins to plateau and make needed modifications and 4) Help the student to make the link between the use of their ATs and their academic achievement, promoting their motivation to continue to use them. Table 4 indicates what a monitoring form could look like. However, it is important to recognize that monitoring the efficacy of ATs may be compromised if a student is unmotivated to utilize the AT and/or does not want to cooperate with their teacher and fill in the monitoring form. For instance, many students with ADHD have co-existing behavioral disorders, such as conduct disorder or oppositional defiant disorder that may lead to resisting the help offered by their teacher [53] [54] [55]. Thus,

Table 4: An Example of a Daily Monitoring Form that Assesses the Continual Efficacy of the Assistive Technologies Put in Place for the Student

Daily Monitoring Form				
	Yes	**No**	**Comments by the student**	**Comments by the Teacher**
Time Aid				
Did the Time Aid help in managing your time?				
Did you use your Time Aid more today than yesterday?				
Do you find your Time Aid easier to use compared to other forms of Time Aids such as clocks?				
Do you like using your Time Aid ?				
Personal Frequency Modulation (FM) System				
Did the FM system help you in hearing and nunderstanding the teacher?				
Could the teacher further help you listen to and understand him or her?				
Do you like using the FM system?				
iSelfControl				
Were you better able to focus?				
Did you understand what you were supposed to be doing throughout the day?				
Were you able to correct your behaviour for the most part, when needed?				

the interventions described and the monitoring forms may be only suitable for those students with ADHD who are willing to cooperate with their teachers. Importantly, most students with ADHD, despite a high prevalence of behavioural disorders do want to succeed academically. Consequently, the approaches outlined in this paper would likely be efficacious for many students with ADHD.

Concluding Remarks

Whether a student with ADHD is eligible for special education services, an educator's role is to teach their students how to compensate for their academic weaknesses by drawing on their strengths. This paper, suggests that certain ATs may be beneficial for students with ADHD in helping them to do just that. In order to select the appropriate AT for their students, teachers need to 1) identify students' relative academic strengths and weaknesses and 2) understand available ATs. However, many professionals self-report a need for additional AT training and a more collaborative approach between the teacher and other professionals to identify appropriate ATs for a particular student. This would result in teachers remaining current with the evolving technology and provide their students support in compensating for their academic weaknesses. Finally, teachers need to recognize the importance of the coordination of technology between school and home. Specifically, AT training most often occurs within the general education or special education classrooms (Dalton & Roush, 2010). However, it is important that ATs are not restricted to use within school as this could reduce generalizability and involvement by the family. Support needs to be ongoing and across the contexts in which students work [56].

Furthermore, the use of identical forms of ATs at home and at school will lead to less confusion and promote consistency, fidelity and effective use of the AT [47]. Finally, the greater degree of involvement a student has with AT promotes decision-making, positive perceptions of the device, greater engagement, and self-determination, all of which leads to further academic achievement [57] [58] [59].

In order for RTI to be implemented successfully for students with ADHD, more research is needed supporting the use of ATs among this group of students. ATs may be a key piece of support required by students with ADHD at each tier in the RTI framework. This paper described the existing, but limited, research on ATs that have been demonstrated to be efficacious for students with ADHD. However, future research needs to explore whether ATs that have been found to support, students with learning disabilities or are popularly used but do not have research support also promote the academic success of students with ADHD. It is possible that the combined use of ATs and monitoring forms will begin to put students with ADHD in a better position to succeed academically.

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