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Smartwatch Executive Function Supports for Students With ID and ASD

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Abstract

This study examined the use of a wearable smartwatch-based intervention to support the executive functioning needs of college students with intellectual disability and autism spectrum disorders. The study was designed to address the universal design for learning guidelines and checkpoints for Provide options for Executive Functions. Three students with intellectual disability, two on the autism spectrum, participated in this multiple-probe across participants with an embedded ABAB design to determine whether a causal relationship exists between the smartwatch intervention and the percentage of tasks completed independently. Students were taught to use a wearable smartwatch device to enter novel appointments for the coming week and the associated tasks. All students self-operated the wearable device to enter appointments, attend appointments on time, and complete associated tasks. Results are discussed in the context of applying new technology applications to assist individuals with intellectual disability and autism to self-manage technological supports to learn new skills, set reminders, and enhance independence.

Keywords

executive function, universal design for learning, intellectual disability, autism spectrum disorder, wearable devices, mobile learning

The primary goals of educational and vocational programming for individuals with disabilities are essentially one and the same, to teach the skills one needs in order to live a fulfilling adult life. For most people, this means to be free from the constant direction of others and autonomous in daily life. For individuals with intellectual disability (ID) and autism spectrum disorder (ASD), difficulty in memory and executive functioning often results in dependence on other people and external supports to remind them to initiate and complete daily tasks and activities (L. Hume et al., 2009; Smith et al., 2012). Independent functioning in daily routines requires the ability to complete designated tasks from one activity to the next. Executive functioning and self-management of activities, appointments, schedules, and to-do lists are critical to independence in adulthood and continues to be an area of interest and concern in the research literature (Carnahan et al., 2012; Mechling, 2007). Additionally, providing options for executive functioning is one of the nine specific guidelines identified by the research-based framework of universal design for learning (UDL; CAST, 2018). This study examines using a context-aware smartwatch as an UDL inspired intervention to support executive functioning relating to goal setting, planning, and progress monitoring of completed tasks for students with ID and autism.

Individuals with ID and ASD often experience significant challenges involving executive functioning skills, but there are established interventions to support these learners. Systematic prompting procedures can be implemented to initially assist students with task completion. Prompting procedures refer to any type of assistance provided to help an individual perform a given skill or task and can be provided through adult assistance or assistive technologies such as mobile devices (Ayres et al., 2013). However, in many instances, prompting must be systematically faded over time in order to prevent dependency, which has been demonstrated as a challenge for students with ID and ASD (K. Hume, 2004). Prolonged prompt dependency results in limited future opportunities for students, including restrictions in possible career options (L. Hume et al., 2009). The use of prompting procedures often requires additional supports or self-management strategies to increase the probability that an individual will learn skills and tasks correctly and with

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the greatest level of independence possible (Lancioni & O'Reilly, 2001).

Visuals are commonly used as additional supports to supplement prompting procedures. Visual supports refer simply to any type of graphical presentation of information as a tool to assist an individual in completing a given skill, task, routine, or activity (Knight et al., 2015). Picture or object cues, written words and checklists, environmental arrangements, maps, schedules, and scripts are all considered visual supports and are used by everyone throughout daily life. Activity schedules are visual supports for completing daily routines and can be comprised of actual objects, photographs, icons, and/or text to symbolize a sequence of activities or the steps of a routine (Banda & Grimmett, 2008). Visual supports to assist transitioning from one activity to the next are referred to as between-activity schedules, and those providing directions for actions to be completed during an activity are called within-activity schedules (i.e., to-do list; Banda et al., 2009; Lee & Sturmey, 2006).

Self-management strategies are used to teach individuals with ID and ASD to direct their own actions and manage their own behaviors across settings and situations (Neitzel & Busick, 2009). As familiarity and understanding of the self-management routine is gained, the amount of responsibility for implementation of the routine is also systematically increased away from person-support assistances (e.g., teacher, job coach) to the individual themselves. One type of self-management strategy is the use of self-operated prompting systems, which are a type of antecedent self-management that involves independent operations by persons with I/DD as strategies to increase independence and decrease reliance on external prompts delivered by adults or peers (e.g., Hughes et al., 2006; Taber et al., 1999). Previous research has shown these systems to be highly effective in prompting the completion of between-activity schedules such as a daily schedule and within-activity schedules or chained tasks such as following the steps of a recipe (MacDuff et al., 1993).

Traditionally, self-operated prompting systems for completion of daily routines have relied on visual materials (Lancioni et al., 2001; Mechling, 2007) to represent the tasks and task steps in a sequential arrangement on either a paper-based (i.e., notebook, strip) or a computer-based display (Banda & Grimmett, 2008). The common procedures for teaching these visual systems typically include (a) student views a static image representing a step of a task, (b) completes the step, (c) marks the step as complete (i.e., cross off, flip page or card, and remove card), and (d) proceeds to the next picture until all steps are completed. However, the recent advancements in and increased availability of mobile technology have allowed researchers to expand established methods beyond the use of static, printed visuals to include mobile devices as self-operated prompting systems for both between-activity and within-activity schedules. For example, Cihak et al. (2008) used a portable digital assistant (PDA) as a handheld prompting system to increase independent transitioning between tasks in vocational settings. Students with ID were provided a PDA device that was preloaded with picture sequences prompting the completion of vocational tasks (within-schedule). The final picture in each sequence provided a visual directive to transition to the next vocational task (between-schedule). Results indicated that students were able to use the PDA device successfully to complete each task and transition between tasks independently.

Purpose

Mobile devices such as mobile phones and tablet computers such as iPads are also resources to provide UDL features for diverse learners (Bacca et al., 2015; McMahon & Walker, 2014). In addition to phones and tablets, the field of mobile devices is growing to include wearable devices such as smartwatches and smartglasses that are becoming new platforms for UDL interventions. UDL is also a complex topic that can be challenging to implement at scale while measuring outcomes (Edyburn, 2010, p. 40). The UDL Implementation and Research Network published UDL reporting criteria for focused research (Rao et al., 2018). One method of expanding UDL research is to have studies address the application of UDL guidelines and checkpoints and examine them through applied research for modular elements and interventions. This study addresses the UDL reporting criteria by addressing UDL in (1) Learner Variability and Environment, (2) Proactive and Intentional Design, and (3) Implementation and Outcomes. For example, examining how an intervention on a wearable device can support a specific UDL guideline (CAST, 2018) such as (6) Provide options for Executive Functions by addressing some of the guideline's detailed checkpoints such as guide appropriate goal setting (6.1), planning and strategy development (6.2), facilitating managing information and resources (6.3), and enhancing capacity for progress monitoring (6.4).

Context-aware and wearable technologies have the potential to compensate for some of the cognitive executive functioning challenges associated with ID and to further increase independent living and post-school outcomes. The flexibility of wearable devices can be illustrated by the use of a context-aware checklist and reminder application. Electronic reminders and checklists that are contextually aware are only displayed when relevant to the current environment and useful to the user's situation. Notifications and reminders occur based on the user's context and needs. The major advantage of contextual awareness is that the user can be notified automatically without having to remember anything, such as keeping up with written notes and appointment books or check a schedule. This capability is of particular importance for individuals with I/DD who experience poor short-term memory (e.g., Jarrold et al., 2000; Jarrold & Towse, 2006). For example, information remembered on Monday may not be able to be recalled on Tuesday. Context-aware executive functioning tools may reduce the need to bring a written checklist or remember to refer to it periodically throughout the day to remain informed of scheduled appointments and task reminders. Therefore, the ability to automatically receive contextually aware reminders on a wearable device may enhance independence in self-prompting completion of daily routines.

Table 1. Demographic Characteristics of Participants.

Student	Age	Disability [a]	IQ [b] (SS)	Adaptive [c] (SS)	ASD Index [d] (SS)	Basic Reading [e]	Understanding Directions [f]
Jackson	19	ASD/ID	61	51	104	80	53
Colby	21	ID/CCN	64	73	—	17	41
M.J.	20	ASD/ID	67	77	102	77	88

[a]ASD = autism spectrum disorder, ID = intellectual disability, CCN = complex communication needs. [b] Wechsler Intelligence Scale for Children–III (Schrank et al., 2001). [c] Vineland Adaptive Behavior Scales, Second Edition (Sparrow et al., 2005). [d] Gilliam Autism Rating Scale, Second Edition (Gilliam, 1995). [e] Woodcock-Johnson III Tests of Cognitive Abilities: Basic Reading Skills Subtest (Woodcock et al., 2001). [f] Woodcock-Johnson III Tests of Cognitive Abilities: Understanding Directions Subtest (Woodcock et al., 2001).

The purpose of this study was to examine the effects of the use of a context-aware application and a wearable device as system to support executive functioning to enhance independent task completion. By teaching college students with ID and ASD the skills needed to (a) access the necessary technology, (b) enter their own appointments as new alarms, (c) select the correct appointment formula, and (d) utilize the wearable device to access the information needed to complete the task, context-aware smartwatch applications may increase their independence in a college setting.

This study examined the following research questions.

Research Question 1: What are the effects of using a wearable device as a self-operated executive function support option for prompting on independent task completion by college students with ID and ASD?

Research Question 2: Do college students with ID and ASD report their experience using the wearable device as an executive function support system to be beneficial and socially acceptable?

Method

Settings

All students attended a postsecondary education program (PSE) specialized for students with ID and ASD located at a large, southeastern public university. Each student attended traditional university courses for audit credit and participated in a work-based internship for approximately 4–8 hrs weekly. In addition, all students progressed through a series of courses specially designed for college students with ID and ASD each semester as part of the PSE program. These program-specific course sequences included independent living skills, career development, and digital literacy. All three students were full-time students in the PSE program and were enrolled in the same digital literacy class. The digital literacy class was held in a general student computer lab and occurred 3 times per week for 50-min class sessions. All distribution of printed student checklists and entering the appointments into the watch as part of the baseline, pretraining, and intervention sessions took place during the digital literacy class sessions. Appointments and tasks took place at different locations on and off campus, depending on each student's weekly schedule.

Data were collected within an inclusive campus and workplace environments including common areas and a computer lab. Baseline data collection, pretraining sessions, and all occurrences of entering appointments using the smartwatch occurred at the beginning of the digital literacy class on Monday mornings. Intervention data collection occurred during student internship placements, a shared office space, and the robotics lab located across campus in both morning and afternoon time periods. The data collection environments were typically occupied by 3–10 other university students with and without disabilities.

Participants

All three participants were male and ranged from 19 to 21 years of age. Pseudo names (Jackson, Colby, and M.J.) were used to maintain confidentiality. Selection of participants was based on the following criteria (a) diagnosis of an ID, (b) participation in a PSE, (c) adequate physical ability to perform the actions involved in the study procedures, and (d) consent to participate in the study. Additionally, the participants' current levels of functioning with respect to the self-management of schedules were a consideration in selection for participation in this study.

Participants' full-scale IQ scores ranged from 61 to 67, all of which fall more than two standard deviations below the mean as seen in Table 1. Academic achievement measures had been conducted for all three participants within the past year from the date of initial data collection for this study using selected subtests from the Woodcock-Johnson III Normative Update Tests of Cognitive Abilities and Tests of Achievement (Woodcock et al., 2007).

All students received special education services under ID and/or autism eligibility during K–12 school years as a part of their individual education plan. Additionally, all students met the eligibility guidelines for admission to the PSE program. All three of the participants were enrolled in their final semester of the PSE program at the time of this study and therefore had already completed three semesters of the program-specific digital literacy skills and other courses prior to the onset of the study. All three participants were highly familiar with campus locations and able to independently and easily navigate anywhere on campus.

Jackson. Jackson was a 19-year-old student diagnosed with ID and autism. Jackson's IQ score was measured to be 61 by the Wechsler Intelligence Scale for Children (WISC-III). Jackson received an Autism Index standard score of 104 on the Gilliam

Autism Rating Scale, Second Edition (GARS-2), which indicated the probability of an ASD to be "very likely." Jackson's Basic Reading Skills subtest score was 80, which indicated mildly delayed development, and his Understanding Directions subtest score was 53, which indicated moderately delayed development on the WJ-III Tests of Achievement.

Colby. Colby was a 21-year-old student diagnosed with ID and complex communication needs. Colby's IQ score was measured to be 64 when evaluated by the WISC-III. Colby received an adaptive behavior composite standard score of 73 on the Vineland Adaptive Behavior Scales, Second Edition (Sparrow et al., 2005). Academically, Colby's Basic Reading Skills subtest score was 17, which indicated negligible proficiency, and his Understanding Directions subtest score was 41, which indicated very limited proficiency as measured by the WJ-III Tests of Achievement.

M.J. M.J. was a 20-year-old student with ID and autism. M.J.'s IQ score was measured to be 67 by the WISC-III. M.J. received an Autism Index standard score of 102 on the GARS-2, which indicated the probability of an ASD to be "very likely." Results from the WJ-III showed a score of 77 on the Basic Reading Skills subtest, which indicated very limited proficiency, and a score of 88 on the Understanding Directions subtest, which indicated limited to average proficiency.

Materials

Smartwatch. The smartwatches used in this study were Samsung Gear Live models, which are compatible with the GuruWear and MoveUp! applications and run the Android Wear operating system. These smartwatches feature the ability to provide both visual and tactile (vibration) notifications to the user based on the time, day, or recognition of activity as specified through the GuruWear application and allow direct user input through either voice commands or the touchscreen of the watch face. Each smartwatch was paired with a smartphone for the initial watch setup and to install GuruWear formulas. The smartphones were used by the researcher for smartwatch settings configuration and to push the created and revised formulas to the smartwatches.

Student checklists. Student checklists were created by the researcher and included three sets of appointments and four associated tasks to be completed by the student during the coming week. The appointments (locations) were selected according to each student's weekly schedule in order to ensure the locations and tasks were relevant to the student while simultaneously avoiding direct overlap with their daily school schedules. At least three locations were determined for each student. For each location, 10 discrete tasks were identified as relevant to that location and skills the student could already complete independently. Each week, three tasks were selected randomly from the 10-item list to be assigned for each location. A printed copy of the checklist was provided to each student each Monday morning for the duration of the study, a copy of this checklist is provided in Table 2.

Table 2. Example Printed Student Checklist.

Computer Lab [a]	Bookstore	Library	Robot Lab
9:00 a.m. on Mon.	Wed. @ 1:45 p.m.	3:00 p.m. on Thurs.	Noon on Fri.
Post to blog	Buy scantron form	Find store hours	Deliver envelope
Complete lesson	Ask for receipt	Checkout headphones	Choose robot activity
Daily question	Deposit in envelope	Take a picture	Schedule next session

[a]Pretraining practice session.

GuruWear application. GuruWear is a free application by w9 software that was made available for download in 2015. GuruWear offers users the ability to create visual formulas, procedures, or recipes that are specifically designed to be accessed on wearable devices. Each formula consists of individual steps, and each step is displayed as a separate screen view. Formula steps can also involve interactive features to engage the user during the times the formula is executed on the wearable device, such as marking to-do items as complete on a checklist, set pedometer measures, or automatically started timers to measure the duration of the step. Creation of a new formula can be done through the GuruWear website or the mobile application. Execution of formulas on a wearable device requires one of the companion applications offered by GuruWear, which are all standalone apps for the wearable platform. The companion application used in this study was MoveUp! Alarm. The GuruWear and MoveUp! applications are available for free through the Google Play store.

The web-based GuruWear platform was used only by the researcher to create new formulas and checklists, and modifications to the formulas were done through the GuruWear application installed on the smartphone paired with each smartwatch. The created formulas and checklists were then downloaded to the smartwatches by the researcher so that each student had three formulas to choose from at all times when entering appointments on the smartwatch. Once the first task was complete, the student tapped "next" or "done" to continue to the next task until all four tasks were completed. The final card in all formulas featured a checklist summarizing each step that had been shown separately, and students were instructed to mark each step on the checklist as complete by tapping the checkbox as self-evaluation and review. An example screenshot view of the GuruWear application is provided below in the top two images of Figure 1.

MoveUp! Alarm application. The MoveUp! Alarm application was only available on the smartwatch device and was used by the students to enter the appointment information, select the appointment's corresponding formula, and save the

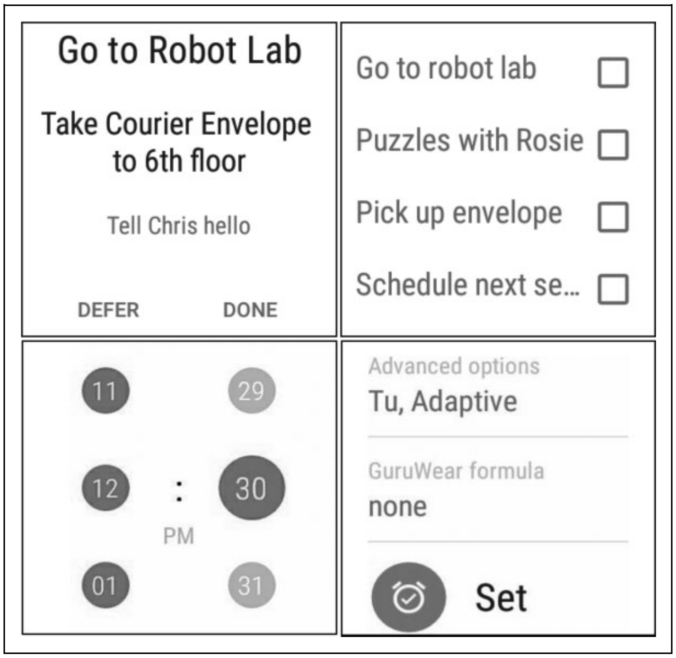

Figure 1. Example screenshots of initial and final formula steps as displayed on the smartwatch platform are the top two images. Lower two images are screenshots of the MoveUp! alarm application alarm configuration view on the smartwatch. *Source:* Author.

appointment information as a new alarm. Example screenshots of the MoveUp! Alarm creation screen are shown in the bottom two images of Figure 1. The wheel to select the appointment time is shown in the image on the left. The image on the right displays the selected day of the week and the area where the corresponding formula is selected.

Variables and Data Collection

The systematic implementation of the reminder intervention on a wearable smartwatch device served as the independent variable in this study. The dependent variable was the completion of the appointment and four associated tasks as scheduled. An independent response for appointment completion was defined as arrival at the correct time, on the correct day, and at the correct location as specified in the appointment. An independent response for completion of the four tasks associated with the appointment was defined as completion of all four tasks within 20 min of the appointment start time. Students were given a list of three appointments consisting of four discrete tasks each week. The set of three appointments consisted of and were always presented in the following order (a) appointment name (location), (b) appointment time and day, and (c) the list of four discrete tasks to be completed during the appointment. For example, the appointment name informed the students to go to a specific location (e.g., bookstore) during a specific time (e.g., Friday at 2:15 p.m.) and the four discrete tasks described what they needed to do when they got there (e.g., purchase a scantron form, ask the cashier for a receipt, deposit purchase and receipt in the student's courier envelope, and then deliver the courier envelope to a specified location). The four discrete tasks were randomly assigned for each appointment location. Event recording procedures were used to record the number of task-analyzed steps completed independently or the level of assistance required. Data were collected through the use of a data sheet designed to record the presentation of task analyzed chains. The number of tasks completed independently was divided by the five opportunities for correct responses (going to the location and completing the four discrete tasks) to calculate a percentage of tasks completed independently. The percentage of steps completed independently was graphed for visual analyses. The list of appointments and task bank for Jackson is provided in Table 3.

Experimental Design

A multiple-probe across participants with an embedded ABAB design (Gast, 2010) was employed to determine whether a causal relationship exists between the smartwatch intervention and the percentage of tasks completed independently (Horner et al., 2005). This study began with a minimum of sessions during the baseline phase for all students. The smartwatch intervention was then introduced to the first participant when baseline stability was established, while the remaining students continued to participate in the baseline phase. Baseline (A1) stability was defined as a minimum of 80% of the data points not varying more than 20% from the baseline mean for three minimum consecutive sessions. For the initial smartwatch intervention phase (B1), the criterion for changing the phase was defined as 100% independent task completion for three consecutive days. For the withdrawal phase (A2), the criterion for changing the phase was defined as a descending trend. Finally, a criterion of 100% independent task completion for three consecutive days was established during the reintroduction of the smartwatch intervention (B2). When the first participant started the intervention reintroduction phase (B2), the next student was introduced to the smartwatch intervention phase (B1), followed by the withdrawal phase (A2), and, finally, the reintroduction of the smartwatch intervention (B2). The process continued until all students participated in all study phases.

Experimental Procedures

Baseline. Baseline data were collected for a minimum of three sessions or until stability was achieved. A session was one school day. On Monday, students were given a novel list of three appointments each with four discrete tasks that needed to be completed during the week. The list was created by the researcher and based on each student's weekly schedule but was not part of the student's schedule created and synced by the PSE program staff. The list was printed and provided to the students prior to the beginning of their first Monday scheduled class or activity and asked to complete the tasks by Friday. The list included a specific day, time, location, and four discrete tasks to be completed. No additional feedback was provided.

Table 3. Appointments and Tasks for Jackson.

Task	Bookstore	Internship Site	Robot Lab
1	Purchase items	Check mailbox	Complete puzzle
2	Request receipt from cashier	Deliver envelope	Practice sequence
3	Pick up envelope	Vacuum floors	Take a picture with a robot
4	Deposit receipt in envelope	Clean tables	Pick up envelope
5	Deliver courier envelope	Pick up envelope	Deliver envelope
6	Mail a postcard	Mop floors	Schedule next session
7	Add stamp	Arrange furniture	Complete survey
8	Take a picture of the postcard	Dust	Count parts
9	Get currency exchange rate	Assemble train	Record number of parts
10	Text currency exchange rate	Clean bathroom	Choose a task

Table 4. GuruWear Application Task Analysis.

Step	Skill
1.	Tap the watch face to wake the device.
2.	Swipe left once (from home screen) to access the application menu.
3.	Scroll until the MoveUp! Alarm application icon is in view.
4.	Tap once on the MoveUp! Alarm icon to open the application.
5.	Scroll down to select "New Alarm."
6.	Enter appointment time.
7.	Enter appointment day.
8.	Select corresponding GuruWear formula for the appointment.
9.	Tap "Save."
10.	Swipe left to return to main menu.
11.	Repeat for the two remaining appointments.

Pretraining. Prior to implementing the intervention, the researcher provided three 20-min training sessions to each student individually. The pretraining sessions consisted of three parts: (a) discriminating between time-and location-based information; (b) using the GuruWear smartwatch application to enter the appointment time, day, and associated formula to set the reminder accurately; and (c) accessing the GuruWear formula on the smartwatch to complete the tasks assigned during the appointment time. A task analysis of the GuruWear application is provided in Table 4.

First, the relevant pieces of information in an appointment were defined, and each student was asked to identify the appointment name, location, time, day, and associated tasks of sample scenarios. Students were taught to review the defining criteria of each appointment type and ask, "What is the name of this appointment?" "What day do I go for this appointment?" "When does this appointment begin?" "Where do I go for this appointment?" and "What do I need to do during this appointment?" The students then analyzed the sample scenarios to identify the specific piece of information which answered each question by underlining the relevant words on a printed worksheet.

Second, the Model-Lead-Test procedures (Adams & Engelmann, 1996) were used to teach the steps of how to enter appointments and assign formulas as new alarms using the MoveUp! Alarm application on the smartwatch. The task analysis for entering appointments and assigning the formula on the smartwatch available on request from the researchers. The researcher modeled and then led the student through the process of entering the appointment information, assigning the corresponding formula, and saving as a new alarm. Finally, the researcher tested the students on the ability to enter the appointment, select the corresponding formula, and save as a new alarm.

Similarly, the Model-Lead-Test procedures were used to teach the operation of the smartwatch to access the formula, swipe left to view the next step, and mark the tasks as complete on the checklist card. An independent response was defined as initiating the first step in the task analysis within 10 s and completing each step within 10 s. Contingent upon a student error, the researcher implemented the system of least prompt procedures (Ault & Giffen, 2013). A 4-s delay occurred between each prompt level, which consisted of the following hierarchical levels: (a) verbal prompt (e.g., "[Name] what is the watch telling you to do?"), (b) gesture plus verbal explanation (e.g., pointing to the watch and saying "[Name] scroll down to expand the view"), and (c) physical assistance plus verbal explanation (e.g., researcher assists the participant to tap the watch face and says, "[Name] scroll down to expand the view"). Lastly, students were tested on their ability to enter the appointment, assign the corresponding formula, save the reminder, and follow the prompts to complete the associated tasks. During the assessment, students were given a novel list of three appointments to be completed during the week and asked to enter the appointments. The criteria for entering appointments were defined as opening the MoveUp! Alarm application; creating a new alarm; inputting the correct time, day, and associated formula; and saving the reminder with 100% independence for three consecutive sessions.

Context-aware smartwatch intervention. The intervention was implemented after the student reached pretraining criteria. Similar to baseline, on Monday, students were given a novel list of three appointments which included four discrete tasks that needed to be completed during the coming week. However, students were instructed to enter each appointment and select the corresponding formula on the smartwatch just as during the pretraining sessions. Students were reminded that these appointments and tasks needed to be completed during the current week. No additional feedback was provided. This phase continued until the student completed three consecutive appointments with 100% independence.

No smartwatch intervention. Similar to the baseline phase, students were given a printed list of three novel appointments that included four discrete tasks that needed to be completed during the week. The list was provided to the students prior to the beginning of their first scheduled class or activity on Monday morning. The list included three sets of appointment locations, dates, times, and four discrete tasks that needed to be completed by Friday. Students were asked to complete the appointment tasks during the specified time and day. No additional feedback was provided. This phase continued until a descending trend was observed.

Reimplementation of the smartwatch intervention. In the initial intervention phase, on Monday, students were given a novel list of three appointments that included four discrete tasks and instructed to enter each appointment into the smartwatch. Students were reminded that the tasks needed to be completed this week, but no additional feedback was provided. This phase continued until the student completed three consecutive appointments with 100% independence.

Social Validity

Social validity measures were collected for all of the participants in the study. Students completed a 10-item Likert-type survey questionnaire related to the opinions and acceptability of using the smartwatch as a self-operated prompting system. All questions and response choices were read aloud to the students. Each survey item used a Likert-type scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Visual supports were added to each number on the response scale to support comprehension of the choices. The social validity survey also included two open-ended questions, to which the students' responses were scribed by the researcher.

Data Analysis Procedures

Visual analysis procedures were used to evaluate the results of the context-aware smartwatch application intervention. To assess intervention effects, six indicators were used to examine within-phase and between-phase data patterns: (a) level, (b) trend, (c) variability, (d) immediacy of the effect, (e) overlap, and (f) consistency of data patterns across similar phases (Kratochwill et al., 2010). Also, within-phase comparisons were evaluated to assess predictable patterns of data, data from adjacent phases were used to assess whether manipulation of the independent variable was associated with the change in the dependent variable, and data across all phases were used to document a functional relation (Gast, 2010).

Horner et al. (2005) indicated that a functional, or causal, relation is demonstrated after at least three occurrences of an effect over a minimum of three different points in time are observed. Percentage of nonoverlapping data (PND) was calculated between the baseline and intervention phases for each participant (Scruggs et al., 1987). Interpretational guidelines of PND, as suggested by Scruggs and Mastropieri (2001), were used to evaluate the effectiveness of the smartwatch intervention, which specify three different ranges for PND calculations: PND greater than 70% as highly effective, PND greater than 50% and less than 70% as questionably effective, and PND less than 50% to be considered an unreliably effective.

Agreement and Treatment Integrity

Interobserver agreement (IOA) and procedural reliability data were both independently and simultaneously collected by the researcher and a trained graduate assistant. The graduate assistant was provided training specific to the independent and dependent variables, and the data collection procedures. IOA data were collected during a minimum of 25% of sessions for each treatment condition for each participant. Observers recorded the number of tasks independently completed by the student both separately and simultaneously. IOA was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. Acceptable IOA was determined to be 90% or greater for each student across all phases of the study. If IOA was calculated to be below 90%, then the researcher and second observer met and reviewed IOA and data collection procedures. The mean IOR agreement for each student across phases was 95% for Jackson (range = 94%– 96%), 93% for Colby (range = 90%–96%), and 94% for M.J. (range = 92%–96%).

Procedural reliability data were collected during a minimum of 25% of all sessions, across pretraining and intervention phases for each participant. The researcher was required to provide participants with the necessary materials (e.g., Model-Lead-Test procedures, fully charged smartwatch, printed list of reminder items to be entered). A trained undergraduate assistant who was knowledgeable of the study, independent and dependent variables, and intervention instructional procedures observed the implementation of the pretraining and intervention procedures by the researcher. The observer was provided with a task analysis of instructional procedures for the treatment conditions and recorded if specific instructional procedures were observed. Procedural agreement level was calculated by dividing the number of observed behaviors by the number of planned behaviors and multiplying by 100. Acceptable procedural reliability was defined as 90% or greater for each student across all phases. If procedural reliability fell below 90%, then the researcher and observer reviewed the instructional procedures. Mean procedural reliability levels for each student across phases was 100% for Jackson, 94% for Colby (range = 92%–98%), and 94% for M.J. (range = 96%–100%).

Results

The number of appointments and tasks completed independently by each student during baseline, smartwatch, and no smartwatch phases is presented in Figure 2. Baseline measures indicated the students could not complete any of the novel appointments prior to intervention. No correct responses occurred during baseline.

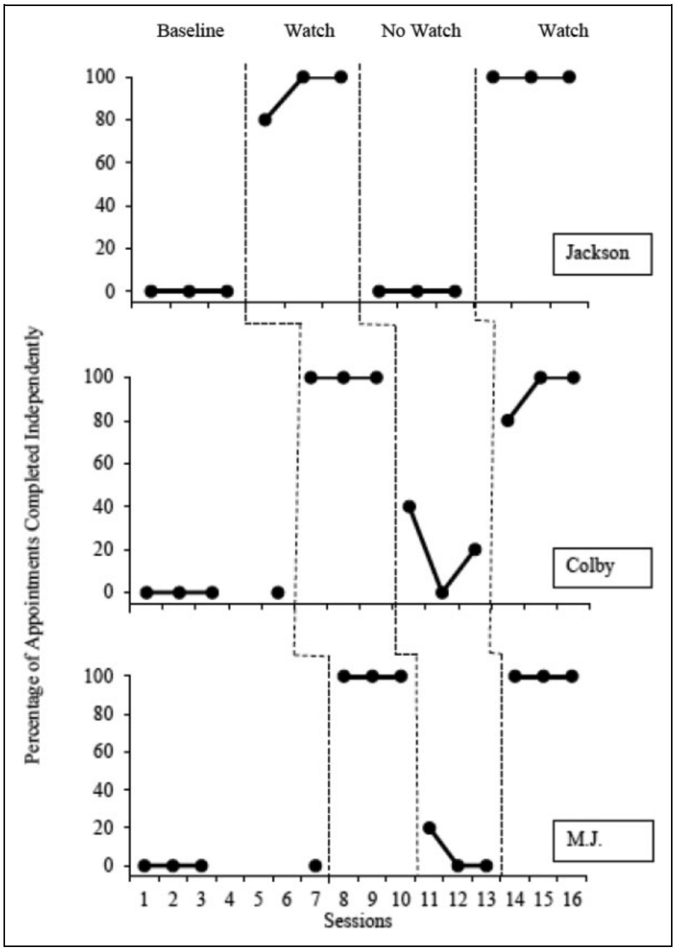

Figure 2. Percentage of appointment tasks completed independently across students with and without the smartwatch intervention.

Across all three students, visual analysis procedures clearly showed the smartwatch intervention to be a highly effective strategy for improving independent task initiation and task completion as the mean percentage of completed appointments increased to 97%. When the smartwatch intervention was withdrawn, descending trends were observed and the mean percentage of completed appointments decreased to 9%. However, the mean percentage of completed appointments increased to 97% and ascending trends were observed when the smartwatch intervention was reimplemented.

Jackson. Jackson was unable to complete any of the novel appointments independently during baseline. His baseline average was 0% of the appointments completed independently. During the smartwatch intervention phase, Jackson increased appointment completion to a mean of 93% (range = 80%–100%). He reached criteria after three sessions with 100% nonoverlapping data, demonstrating an immediate change. When the smartwatch intervention was withdrawn, Jackson's completed appointments decreased to 0%. When the smartwatch intervention was reimplemented, Jackson completed all appointments with 100% independence.

Colby. During baseline, Colby completed 0% of the novel appointments independently. During the smartwatch intervention, Colby's appointment completion increased to 100% independence for three consecutive sessions with 100% nonoverlapping data, demonstrating an immediate change. When the smartwatch intervention was withdrawn, Colby's completed appointments decreased to a mean of 20% (range = 0%–40%). During Session 10 of the withdrawal phase, Colby arrived at the appointment location at the correct time but could not remember the appointment's associated tasks or find the printed student checklist provided earlier in the day. During Session 12, Colby arrived at the location but was 2 hr past the scheduled appointment start time. When the smartwatch intervention was reimplemented, Colby's completed appointments increased to a mean of 93% (range = 80%–100%).

M.J. M.J. completed 0% of the novel appointments independently during baseline. During the smartwatch intervention, M.J.'s appointment completion increased to 100% independence for three consecutive sessions with 100% nonoverlapping data, demonstrating an immediate change. When the smartwatch intervention was withdrawn, M.J.'s completed appointments decreased to a mean of 6% (range = 0%–20%). During Session 11 of the withdrawal phase, M.J. demonstrated awareness of the scheduled appointment by texting the researcher to ask where he was supposed to be at the correct time the appointment was scheduled to occur but did not independently remember the appointment location or associated tasks to be completed nor independently locate the printed student checklist provided earlier in the day. When the smartwatch intervention was reimplemented, M.J.'s completed appointments increased to 100% independence for three consecutive sessions.

Social Validity Results

Results of the social validity questionnaire indicated that all students responded positively to the smartwatch intervention. Students indicated they enjoyed using the smartwatch and application to remember novel appointments and what they needed to complete when they arrived at appointments. Additionally, results indicated that the students agreed or strongly agreed that (a) the target skill of remembering to complete appointments and tasks was important, (b) the smartwatch formulas were easy to use, and (c) they would be interested in using the smartwatch again in the future.

Discussion

The purpose of this study was to examine the effectiveness of a smartwatch device as an UDL support for executive functioning to teach three students with ID and ASD to self-manage prompts to complete novel appointments and tasks. All students successfully entered the appointment information, selected the corresponding formula of tasks associated with the appointment, and followed the prompts to complete the appointments. Prior to the study, all of the students demonstrated basic technological skills (e.g., iPad usage) and relied on and followed an electronic daily schedule created and managed by the PSE program staff. However, none of the students were able to successfully create their own calendar appointments or reminders nor remember to complete appointments that were not included on their program-provided electronic schedules. A functional relation was established since data variation patterns were observed in at least three different series at three different points in time between independent appointment completion and introduction of the smartwatch intervention (Horner et al., 2005).

This study extends the research base on the UDL guideline supports for executive functions (UDL 6) and its checkpoints. Additionally, this study presents findings in accordance with the UDL reporting criteria by clearly addressing learner variability and environment, using a proactive and intentional design for UDL, and documenting implementation and outcomes (Rao et al., 2018). Through the use of commercially available devices and applications, students were able to self-operate a wearable device to create novel appointment and task reminders (Checkpoint 6.1 Guide appropriate goal setting, Checkpoint 6.2 Support Planning and Strategy Development). Students were able to complete novel appointments and tasks independently without person-provided prompts or time-intensive visual supports to manage information (Checkpoint 6.3 Facilitate managing information and resources). Students were able to use the smartwatch to self-monitor their progress (Checkpoint 6.4 Enhance compacity for monitoring progress). Students were able to receive various types and levels of prompts discreetly and access the prompts while completing the tasks hands-free. Finally, the smartwatch intervention offered a socially valid tool to improve executive functioning skills of self-management and task completion skills. The ability to provide options, such as the options for executive functioning in this study, makes these wearable devices a promising new platform to provide UDL based interventions for diverse learners. While this study examined a specific guideline, these tools may also be effective tools to support other specific UDL guidelines and learner needs.

Limitations

Full interpretation of the results of this study includes consideration of several limitations. As in all single-subject case designs, a small number of students participated in this study ($n = 3$). Future research should consider the use of a larger sample size to increase external validity and generalizability. Also, the specific smartwatch application did not allow students the option to select the date for the appointment, only the day of the week. Therefore, this application allowed only new alarms to be created for the coming week. Additionally, all of the students attended a PSE program for highly motivated adults with disabilities. Therefore, results cannot be generalized to all young adults with disabilities or other age groups. Also, due to time constraints involving the university calendar, no maintenance probes were collected in this study. This limiting factor should be addressed in future research.

Future Research

The results of this study suggest that a contextually aware wearable application and device can be effective tools for supporting the executive functioning needs for students with ID and ASD. It is necessary to evaluate these tools with additional groups of participants. The smartwatch intervention should also be investigated as a means to support actual appointment and task completion rather than arranged appointments and tasks for the purpose of the study. Future research could explore academic prompting task such as completing homework projects for K–12 students with ASD. Future research should also include an examination of instruction to teach independent formula, or checklist, and creation for real-world tasks.

Conclusion

This context-aware smartwatch system provided a viable option to support the executive functioning needs of students with ID and ASD. This smartwatch intervention extends the UDL research support for providing options for executive functioning. The findings of the study support further examination of wearable devices such as smartwatches to support the needs of students with ID and ASD. The social acceptability of this tool offers users the opportunity to improve independent task completion in a socially valid and acceptable way. Smartwatches and other wearables are socially valid and customizable mobile learning tools that can support individuals with ID and ASD in a wide range of settings.

Author's Note

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