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# Evaluating Context-Aware Applications Accessed Through Wearable Devices as Assistive Technology for Students with Disabilities

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To the Graduate Council:

I am submitting herewith a dissertation written by Rachel Elizabeth Wright entitled "Evaluating Context-Aware Applications Accessed Through Wearable Devices as Assistive Technology for Students with Disabilities." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

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# Evaluating Context-Aware Applications Accessed Through Wearable Devices as Assistive Technology for Students with Disabilities

A Dissertation Presented for the

Doctor of Philosophy

Degree

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Rachel Elizabeth Wright

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## DEDICATION

To my remarkable parents

*Charlie and Ann Wright, the greatest teachers I will ever know.*

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## ABSTRACT

The purpose of these two single subject design studies was to evaluate the use of the wearable and context-aware technologies for college students with intellectual disability and autism as tools to increase independence and vocational skills. There is a compelling need for the development of tools and strategies that will facilitate independence, self-sufficiency, and address poor outcomes in adulthood for students with disabilities. Technology is considered to be a great equalizer for people with disabilities. The proliferation of new technologies allows access to real-time, contextually-based information as a means to compensate for limitations in cognitive functioning and decrease the complexity of prerequisite skills for successful use of previous technologies. Six students participated in two single-subject design studies; three students participate in Study I and three different students participated in Study II. The results of these studies are discussed in the context applying new technology applications to assist and improve individuals with intellectual disability and autism to self-manage technological supports to learn new skills, set reminders, and enhance independence.

During Study I, students were successfully taught to use a wearable smartglasses device, which delivered digital auditory and visual information to complete three novel vocational tasks. The results indicated that all students learned all vocational task using the wearable device. Students also continued to use the device beyond the initial training phase to self-direct their learning and self-manage prompts for task completion as needed.

During Study II, students were successfully taught to use a wearable smartwatch device to enter novel appointments for the coming week, as well as complete the tasks associated with each appointment. The results indicated that all students were able to self-operate the wearable device to enter appointments, attend all appointments on-time and complete all associated tasks.

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# CHAPTER I

## Understanding Context-Aware and Wearable Technology as Tools for Prompting Students with Disabilities to Initiate, Complete, and Acquire New Vocational Tasks

## Significance of the Problem

Since the passage of PL 94-142 guaranteed a free and appropriate public education in 1977, many advancements have been made in our knowledge and understanding about how to teach students with intellectual and developmental disabilities (I/DD) the skills needed to be successful in adulthood. Subsequently, several important amendments have occurred, enhancing the original wording and intentions of this law. For example, PL 105-17 added the Individual Transition Plan (ITP) component which mandates post-school transition be addressed for all students receiving special education services beginning no later than age 16. The purpose of the ITP is to prepare a student with disabilities for life after high school. Written by the student's Individual Educational Program (IEP) team, the ITP outlines the training and support that will be needed for the student to live, work, and participate in the community as an adult (The Individuals with Disabilities Education Act, 20 U.S.C. Chapter 33, Section 1401(a) (19)). For students with I/DD, independent living, vocational, and self-determination skills are critical areas of need included in ITP plans (Wehman, 2013).

In terms of real-world post school outcomes, however, transition efforts continue to fall short in producing meaningful progress. Upon exiting the public school system, the futures awaiting young adults with disabilities in the U.S. are shockingly harsh. These students enter adulthood faced with predicted experiences which include low rates of employment, low wages, limited benefits, inadequate community supports, and minimal probability of independent living (Grigal & Hart, 2010). This population is estimated to be three times more likely to experience poverty than their peers without disabilities (National Council on Disability [NCD], 2011). Individuals with I/DD show significantly lower rates of employment (Van Naarden et al., 2006). According to the 2011 National Report on Employment, only 20% of working-aged (i.e., 21 to

64) individuals with I/DD were reported to be either employed or actively seeking employment (Butterworth et al., 2011), and only 7.2 percent were employed full-time (NCD, 2011). Of those employed, most reported to work in entry level jobs receiving the lowest wages (Kohler & Field, 2003; Wehman, 2013), earning an average weekly salary of approximately $200 (Butterworth et al.). As such, they are typically the most vulnerable to job loss when the economy fluctuates (Halpern, Close, & Nelson, 1986). The skills necessary to maintain employment in these vulnerable positions expand beyond the scope of the technical or vocational skill requirements. In addition to hard skill deficits, people with I/DD experience difficulty with the soft skills, such as social competencies, which impact all aspects of life (Halpern, 1994; Van Naarden et al.; Wehman).

While many factors are likely contributing to the continuation of meager post-school outcomes for students with I/DD, the interconnectedness of three components stands out with particular importance: (a) the learning characteristics associated with I/DD, (b) the propagation of technology into adult and work life, and (c) the barriers to technology use presented through an interaction of associated learning characteristics and limitations of effective instructional practices. While technology is considered to be a great equalizer for people with disabilities; in actuality, a growing digital divide is further contributing to the isolation of people with I/DD. The proliferation of new technologies poses an additional problem that is compounded by the learning characteristics related to an intellectual disability, as well as the limitations in the application of current instructional practices to teach necessary digital skills.

Technology should provide greater access to information and improve the functional capabilities of users with disabilities. Students with I/DD must be taught skills that will lead to the independent use of technology in order to fully benefit from what the technological world has

to offer. Self-operation and self-management of digital supports are critical for maintaining independent use over time. There are two primary ways to address the growing digital divide (Burgstahler, 2002) for persons with I/DD: (a) provide an effective means for basic digital literacy skills to be acquired, maintained, and generalized, and/or (b) investigate emerging technologies capable of reducing the number of requisite digital literacy skills and cognitive demands as a means of bridging this harmful divide.

**Organization of This Dissertation**

This four chapter dissertation examines the use of context-aware wearable technology as assistive tools to facilitate self-directed instruction and self-management of prompts for students with intellectual and developmental disabilities. Chapter I establishes what context-awareness is, its relationship to assistive technology, the importance of mobile devices for learning in terms of augmented reality (AR) for students with disabilities, what research has been conducted on AR in education, and what needs exist in future AR research. Chapter II is the first study of a two study dissertation. It is designed to stand alone as a single subject design study examining a context-aware application delivered via Google Glass to teach three vocational tasks to postsecondary education students with I/DD. Chapter III is the second study of this dissertation and designed to stand alone as a single subject design study. It examines a context-aware self-management intervention for prompting students with I/DD to initiate and complete daily appointments and tasks. Chapter IV of this dissertation includes a general discussion of context-aware and wearable technologies, the findings from both studies, the importance of these technologies specifically for students with I/DD, and limitations and the implications for future research.

**Purpose**

The purpose of this dissertation is to empirically examine the use of context-aware and wearable technologies as self-management tools for prompting college students with intellectual and developmental disabilities (I/DD) to initiate, complete, and learn new vocational tasks.

**Study 1.** The purpose of this study was to examine the effects of using a context-aware application delivered through a wearable device to teach students with I/DD three different vocational tasks. Specific research questions include:

1. What are the effects of context-aware applications and wearable devices on the acquisition of three vocational tasks for college-aged students with I/DD?
2. What is the social validity of using wearable devices to learn new vocational skills?

**Study 2.** The purpose of this study was to examine the effects of a context-aware smartwatch application to teach college students with I/DD to self-manage appointments and tasks throughout a week. Specific research questions include:

1. What are the effects of using smartwatch devices and a context-aware checklist application on the independent completion of daily appointments and tasks for college students with I/DD?
2. What is the social validity of using smartwatch devices to self-manage prompts for task completion?

## Key Terms

**Augmented Reality (AR):** A field of technology that combines a live view of the physical world, overlaid with the display of associated digital content, which can include any combination

of text, pictures, audio, and video.

**Context:** Any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves, and by extension, the environment the user and applications are embedded in.

**Context-Aware Technology:** A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.

**Developmental Disability:** A disability that (a) is manifested before the age of 22, (b) is chronic and severe, (c) can be attributed to a mental or physical impairment or both, (d) results in substantial functional limitations in major life activities, and (e) requires a lifelong need for special services that are individually planned and coordinated (Handleman, 1986).

**Digital Literacy:** The ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers.

**Internet of Things (IoT):** A developing concept prevalent in technology-related fields that describes a world of objects interconnected as devices, including household appliances, medical devices, mobile devices, traditional computers and public infrastructure.

**Location-Based AR:** See Markerless AR.

**Machine Learning:** A subfield of computer science that evolved from the study of pattern recognition and computational learning theory in artificial intelligence. Machine learning explores the study and construction of algorithms that learn from and make predictions on data. Such algorithms operate by building a model from example inputs in order to make data-driven predictions or decisions, rather than following strictly static program instructions. Example applications include optical character recognition (OCR) and search engines.

**Marker-Based AR:** In the field of augmented reality (AR), a "marker" is a physical object or printed image used to activate the display of the associated digital content "aura" or overlay. *Also referred to as "trigger", "trigger image", or "tag".*

**Markerless or Markerless AR:** A type of AR that uses the device location or proximity to activate the display of the associated digital content "aura" or overlay, and generally requires access to the internet and/or GPS for accurate results. *Also referred to as location-based AR.*

**Mixed Reality:** A continuum describing the intersection of the physical world and digital information. This continuum includes both augmented reality (AR) and virtual reality (VR).

**Mobile Context-Awareness**: Context-awareness for systems or situations where the user and her devices are mobile. Mobility is particularly relevant for context-awareness as more frequent and rapid changes in the user's context occurs when mobile.

**Ubiquitous Computing:** First described by Mark Weiser (1991) as a phenomenon 'that takes into account the natural human environment and allows the computers themselves to vanish into the background' (p.1)

**Virtual Reality (VR):** A fully artificial digital environment in which a user navigates an avatar in order to complete tasks or gain experiences.

**Wearables:** See Wearable Devices.

**Wearable Technology:** See Wearable Devices.

**Wearable Devices:** The terms "wearable technology", "wearable devices", and "wearables" all refer to electronic technologies or computers that are incorporated into items of clothing and accessories worn comfortably on the body. These wearable devices can perform many of the same computing tasks as mobile phones and laptop computers. However, in some cases, wearable technology can outperform these hand-held devices entirely. Wearable technologies

tend to be more sophisticated than the hand-held technologies on the market today because they feature sensory and scanning capabilities not typically provided in mobile and laptop devices, such as biofeedback and tracking of physiological function.

## Theoretical Foundations of Context-Aware & Wearable Technology

Advancing new technologically-based interventions is critical for researchers and educators as they work to empower students with disabilities in educational, community, and workplace settings with the technologies already in their pockets. The introduction of context-aware and wearable technologies expands the existing research on mobile devices and augmented reality (AR) as tools to promote independence, self-management, and skill development. By further extending the immediacy, portability, and automaticity of device functions, the likelihood of independent use by individuals with intellectual and developmental disabilities (I/DD) is increased.

Context-aware applications and wearable devices have only just begun to emerge in the literature regarding individuals with disabilities, and therefore, a review is restricted to few empirical studies. However, the existing educational frameworks and learning theories support the use of context-aware and wearable technologies as promising tools for increasing the independence of individuals with disabilities across settings. To begin, a review of the literature defining context-aware and wearable technology, as well as connections to established practices and principles that support their use as assistive devices for individuals with disabilities is provided.

The idea of context-aware technology first emerged in 1991, under the term, *ubiquitous computing*. Ubiquitous computing was described as a phenomenon in which computers are equipped with the ability to simultaneously account for and interpret the natural human

environment while remaining imperceptible from conscious awareness (Weiser, 1991). This description was further elaborated upon to include the computers' abilities to capture and retrieve context-based information, offer seamless interaction to support the user's current tasks, and select appropriate actions according to the identified context. These descriptions provide the initial foundation for the conceptual framework of context-aware computing.

As its own term, *context-aware computing*, was defined as software that is able to recognize the location of use, relevant entities nearby (i.e., people, objects), and changes to those entities over time, in order to adapt intelligently and accordingly (Schilit & Theimer, 1994). Many nuances of this definition have since been applied to pertain to specific uses. However, for the purposes of the two studies included in this dissertation, *context* is defined as any information that can be used to characterize the situation of an entity. An *entity* is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves, and by extension, the environment surrounding the user and applications.

Various sources of information can be accessed by context-aware applications to determine the user's situation and identify potential actions accordingly. These informational sources typically are comprised of two types of sensors: software sensors and hardware sensors. Software sensors are used to identify information about the virtual or interconnected world of networks. Hardware sensors are used to detect information about the physical world; for example, hardware sensors would recognize various properties of the surrounding environment like illumination, temperature, noise level, and device movements (Gellersen, Schmidt & Beigl, 2002; Mäntyjärvi & Seppänen, 2002). Typically, these sensors are attached to, or embedded

within a device. The software application running on the device is used to perform the context-recognition and context-aware services.

The information most commonly used to determine context is location. Location can be detected using several different techniques, but the majority of context-awareness research involves the use of global positioning system (GPS) and/or mobile network identification. GPS is frequently used to determine outdoor locations, such as in automotive navigation systems. Mobile network identification is used to determine the device location with Internet-connected smartphones, tablets, and other devices using a data plan connection.  Other commonly used information to determine context include time, date, user identity, proximity to other devices and people, and user actions (Dey, Salber & Abowd, 2001; Osbakk & Rydgren, 2005).

Context-aware applications also depend on the collection of information from beyond the physical environment.  Sensors are useful in directly providing the raw physical data, but this data needs to be interpreted in order to aid in the understanding of the user's goals.  Information about a user's goals, user preferences, and social contexts are used to further increase the accuracy of the interpretive processes to determine the context and select the appropriate device behavior.  Knowledge about a user's goals helps prioritize the most relevant information sources to use in determining device actions.  A user's personal preferences offer useful information for profiling, personalizing services, and refining information retrieval.  Finally, social context forms an important type of context as mobile devices are commonly used to support communication between two people and used in the presence of other people.

**Assistive Technology: Context-Aware and Wearable Technologies**

Regarding the conceptual relatedness among technical terminology, researchers contend there is a distinction between the concepts of instructional technology and assistive technology.

As suggested by Ayers, Mechling, and Sansosti (2013), instructional technology (IT) refers to any tool designed to facilitate skill acquisition and only needed for a short, defined period of time (e.g., software to teach safety signs). Typically, IT is no longer required after the learner has adequately acquired the target behavior. In contrast, assistive technology (AT) describes any tools which are used to increase, maintain or improve the functional capabilities of the user (ATA P.L. 105-394) and that might be needed indefinitely (e.g., a calculator, text/screen reader). The rapid expansion of commercially-available technology has blurred the boundaries separating these two terms, as well as the need to maintain distinct definitions between these two categories of technological assistances for individuals with I/DD. However, the studies included in this dissertation focus more on AT as a means to support vocational skill development and increased independence in daily living. Further, the central focus of both studies involves the investigation of the applications of emerging technologies as metaphorical prosthesis, which is essentially an external support designed to compensate for something otherwise lacking. The idea of a "cognitive prosthesis" has long been discussed as a concept describing the use of technology as assistive devices to support the needs of persons with cognitive disabilities (e.g., Ayers, Shepley, Douglas, Shepley, & Lane, 2016; Cole, 1999; Linsley, 1964).

**Assistive technology.** The essential goals of assistive technology (AT) are aimed towards increasing the functionality and the creation of more equalized opportunities for people with disabilities (Patterson & Cavanaugh, 2012). AT is an established, evidence-based practice to facilitate transition, independence, and post-secondary educational outcomes (Mull & Sitlington, 2003). Initially introduced in 1988, The Assistive Technology Act provided the following definition of an AT device: " … any item, piece of equipment or product system,

whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (ATA P.L. 105-394).

Assistive technology devices range from low-technology (e.g. pencil grips and adapted utensils) to high-technology (e.g. voice-recognition software and handheld devices including iPads and iPods) (Martinez-Marrero & Estrada-Hernandez, 2008; Mull & Sitlington, 2003), and vary from no skill required from the user (e.g. eyeglasses) to complex skill levels (e.g. power wheelchair) (Cook & Hussey, 2007). AT devices also range in the levels of support provided from minimal (i.e., enhance the user's abilities) to significant assistance (i.e., supplant the user's abilities completely). Additionally, AT devices are categorized into two types of technologies: hard and soft (Cook & Hussey). Hard technologies refer to the actual devices, hardware and equipment, while soft technologies include processes such as training, decision-making, and concept formation.

While computer technology is defined as any electronic device which is designed to store, display, and process data (The American Heritage Dictionary, 2000), mobile technologies refer to any computerized device designed to be carried and used across daily activities and settings in the hand or pocket of the user. Wearable devices, or wearables, refer to mobile computer technologies that are actually worn on the body as clothing or as an accessory, such as a bracelet, a watch, or eyeglasses.

The ubiquity of wearable technology establishes it as a socially valid tool for providing AT supports to individuals with I/DD. First, regardless of form, technology is simply a tool. The usefulness of any tool is limited by the understanding of its use. Tools must be correctly applied to a situation in order to be helpful, and technology is no different. The proper use of technology must be taught in order to be beneficial to the user. However, the rapid evolution of

technology means the proper use is continuously changing too quickly for researchers and educators to keeps up. Technology is a primary source of education, communication, social interactions, and recreation for young adults of all ability levels (Cook & Hussey, 2007). Therefore, students with I/DD must be provided with instruction that will facilitate the application of technology for either learning or assistive purposes, and promote the generalizability across devices and platforms, rather than focus on a specific technology use or type. Educational programs for students with I/DD should empower them with the knowledge and digital literacy skills required for continued participation in the digital world over time (Cihak, Wright, Smith, McMahon, & Kraiss, 2015).

Second, modern technologies should be applied to reduce the complexity of digital skill demands and cognitive requirements necessary to provide access and increase the functional capabilities of the user. An emerging literature base is exploring the potential of mobile technology as assistive tools to supplement instruction of various types of skills for people with I/DD. Much of the existing research has examined the use of mobile technologies as alternate means to provide instructional prompts via the delivery of auditory, picture, video, or other visual cue (Mechling, 2011). Early investigations examined the use of portable DVD players to teach skills related to food preparation (e.g., Mechling, Gast, & Fields, 2008), MP3 players to teach daily living skills (Taber-Doughty, 2005), and handheld computers (e.g., the now obsolete PDA and Palm OS) to teach a variety of functional and vocational skills (Davies et al., 2002; Mechling & Savidge, 2011). For example, Mechling and Savidge employed a multiple probe design across three sets of tasks to evaluate the use of a Personal Digital Assistant (PDA) with multiple prompt levels to increase independent task completion and transitioning of students with

autism spectrum disorder (ASD). Students successfully acquired the skills needed to self-operate the PDA in order to complete the tasks and transitions independently.

Since the first introduction of the iPhone© in 2007, the proliferation of mobile technologies has resulted in exponentially more powerful smartphones and tablets. While a preference has begun to establish the use of these tools in current research, the function of the devices used has largely remained unchanged; the commonality includes the use of technology-delivered instructional prompts in place of teacher-delivered prompts to teach the acquisition of target skills. Kagohara, Sigafoos, Achmadi, O'Reilly, and Lancioni (2012) conducted a review 15 studies using mobile devices to teach people with I/DD and found that most studies involved the application of first generation iPods or iPads to either (a) deliver instructional prompts, or (b) teach the person to operate the mobile device to access preferred stimuli. The results of these 15 studies were largely positive, suggesting that mobile devices are viable technological aids for individuals with I/DD.

Taking a different perspective, Doughty (2011) described the potential uses of native, or standard built-in features of modern smartphones and tablets for assistive technological purposes to facilitate independence and quality of life for people with disabilities. These features included the camera, microphone, the accelerometer, the GPS receiver, and the touch-screen, as built-in capabilities of most available mobile devices. Through the use of downloaded applications, access to these features offer specific assistive properties, therefore, transforming readily available, inexpensive, "off-the-shelf" technologies into assistive systems comparable to those previously offered only through purchase of specialized, or customized equipment. For example, many personal electronics have a digital screen capable of displaying text or images, and the ability to play audio, either through headphones or a built-in speaker. Modern technologies also

are capable of video display, which provides users with any combination of text, video, image, and/or voice to deliver instructional prompting systems. Several studies evaluated the use of out-of-the-box electronics as assistive devices to increase independent task completion of persons with I/DD (e.g., Cihak, Kessler, & Alberto, 2008; Ferguson, Myles, Hagiwara, 2005; Gillette & Depompei, 2008;Van Laarhoven, Johnson, Van Laarhoven-Myers, Grider, & Grider, 2009). Instruction on the use of these features offers unlimited potential for future and continued use of these supports as assistive technologies. Once the native features and basic workings are understood, self-management of the instructional prompts is possible and more likely to occur in post-training situations. Further, self-management of the device allows for discreet use throughout vocational, independent living, social, and educational settings and activities, using the same devices as everyone else.

However, the limitations and challenges of using technology as assistive devices for people with disabilities often present significant barriers, which ultimately lead to abandonment (Phillips & Zhao, 1993). The major contributing factors of technology abandonment include (a) ease of use, (b) effectiveness in enhancing user performance, (c) flexibility to adapt to changes in the user's needs, (d) cost, (e) need for training, (f) maintenance, and (g) lack of understanding of the potential to benefit the person's daily life (e.g., Phillips & Zhao, 1993; Wehmeyer, Palmer, Smith, Davies, & Stock, 2008). Additionally, Woodward and Rieth's (1997) review of the literature regarding special education technical applications revealed that prototype devices and software programs were highly prevalent in published studies. Prototypes refer to tools not available to other educators or obtainable through the consumer market. The use of prototypes prevents the replication of studies and diminishes practicality (Woodward & Rieth). More recently, Tsui and Yanco (2010) analyzed devices that provided cognitive assistance for

prompting task sequencing and completion. A total of 13 devices were reviewed based on criteria relating to the types of prompting available (picture, text, audio, video, vibration), the ability to incorporate logic branching, contextual awareness, adaptation/customization, and commercial availability. Three devices were identified as having context-aware capabilities, and one device featured vibrational notifications. However, all four of these devices were identified as prototypes and unavailable for purchase through the consumer market.

Technology needs to provide access to information and improve daily functioning. In order for people with I/DD to take full advantage of all benefits of today's technologies, they must learn to self-operate and self-manage the technologies as support tools. There are two primary ways to address this need: (a) provide effective means for basic digital literacy skills to be acquired, maintained, and generalized by people with I/DD, and/or (b) investigate emerging technologies capable of by-passing requisite digital skills as a means of bridging the digital literacy gaps.

Combining the most advantageous features of available technologies with established evidence-based practices for teaching digital literacy skills can lessen the cognitive demands and the complexity of required skills for people with I/DD. Reducing these factors permits increased attention to the generalization of acquired skills across platforms and devices. Simplifying the skills required allows for high levels of success to be achieved more readily by people with I/DD. Moreover, delivering only the necessary information relevant to the context of task completion allows instruction to focus on one skill at a time without the impediment of the overwhelming overhead of other mainstream technology use to further increase access and the functional capabilities of the user. For example, the use of popular mainstream technologies, such as a smartphone, to search for and identify an instructional video on YouTube© requires

multiple complex skills beyond those required simply to access an instructional video. Context-aware technologies can remove much of the need for users to search for and request information by automatically recognizing the relevant results warranted by the user's context.

**Characteristics of Intellectual Disability**

The presence of an intellectual disability is characterized by significant limitations in intellectual functioning and adaptive skills which are manifested before the age of 18 (AAIDD, 2010). Intellectual, or cognitive functioning refers to the general ability to learn new skills, maintain these skills over time, and generalize learned skills logically to untrained situations or conditions. Adaptive behaviors are comprised of three skill types: conceptual, social, and practical skills. Individuals with I/DD often have difficulty with conceptual skills, such as understanding abstract concepts, generalizing from one setting to the next, and using language and communicating (AAIDD, 2010). Social and interpersonal skills often pose additional difficulties for young people with I/DD (Serna, 1996; Van Naarden Braun, Yeargin-Allsopp, & Lollar, 2006; Wehmeyer, 2007). Individuals with I/DD often fail to learn implicitly within social contexts; that is, they often are not able to observe the interactions of others around them as a means to acquire new knowledge or skills indirectly, as others without I/DD tend to do easily and automatically (Serna). Practical skills include activities of daily living, occupational skills, use of money and banking, safety, health and personal care, travel and transportation, schedules and routines. Individuals with I/DD experience difficulty with the acquisition of these skills, the ability to maintain learned skills over time, and generalizing skills across novel situations and settings.

Many of the functional activities once targeted for real-world instruction, such as skills related to business and banking, employment postings and application processes, educational pursuits, social engagement, and community interactions are now increasingly, and in some

cases, solely conducted online (Hoppestad, 2013; Shapiro & Rohde, 2000; D'Aubin, 2007). As more daily routine tasks are converted to online processes, physical Internet access (i.e., Wi-Fi connection), as well as functional Internet access (i.e., the skills to use the Internet and navigate through the completion of the task) are equally necessary. Carey, Friedman, and Bryen (2005) surveyed 83 adults with ID regarding their use of various technologies, and found that only 41% of these respondents used a computer, 25% used the Internet, and 11% used electronic organizers. These statistics were all significantly lower than the general population's use of such devices and technologies at that time (Carey et al., 2005). Functional use of the Internet to engage in any common activity, including communication, to obtain or provide information, recreational, and consumer activities require a level of functional literacy and a range of cognitive skills including decoding, comprehension, and written expression (Johnson, 2007).

In addition to limitations in intellectual functioning and adaptive behaviors, individuals with I/DD often demonstrate difficulties related to behavioral memory. Gentry, Wallace, Kvarfordt, and Lynch (2008) defined deficits in behavioral memory as limitations in the working and prospective memory processes, including attention and executive functioning limitations, such as memory, organization, planning, and goal setting. The skills and levels of functioning required for an individual to successfully remember to take medications on-time, create and manage a schedule, keep appointments, and independently complete multi-step tasks are related to behavior memory (Wehmeyer, 2007). Further, individuals with I/DD also experience deficits in reasoning and problem solving abilities, such as the ability to set expectations, identify strategies to resolve challenges, achieve goals, and adjust approaches to solve problems accordingly (Mithaug, 2006). Typically, individuals with I/DD generate fewer reasonable options as possible solutions to problems in general (Wehmeyer). Although research reports the

ability of individuals with I/DD to learn valuable skills such as problem solving, job specific task completion, or social competence (Bremer, Kachgal, & Schoeller, 2003; Dixon, 2008; Mithaug, 1996; Van Naarden et al., 2006; Wehmeyer), the distinctive cognitive characteristics of I/DD limit the number of complex skills required in adult social roles that are able to be taught (Davies, Stock, & Wehmeyer, 2003).

Although individuals with I/DD demonstrate differences and deficits when compared to their peers without disabilities, the expectations of adults in society remain the same (Gonzales, 2011). These expectations will continue to increasingly emphasize technological and digital literacy skills. In order to be contributing members within their communities, it is critical for students with I/DD to be digitally prepared for adult social roles upon exiting high school. Additionally, implications of using technology are particularly significant for employment because the effects of networking spread beyond the employer–employee nexus. Participation in social networks is considered to influence job satisfaction, job retention, and career advancement, as well as alternative routes for finding job availability. Because technologies are used for work on a daily basis, the application of technological-based interventions are socially acceptable (Cihak et al., 2007).

**Teaching Digital Literacy Skills**

The recent expansions in technology, including advancements in memory, power, portability, and connectedness of devices available continue to thrive in the consumer market. Coupled with decreased costs, electronics are more obtainable and available to people than ever before. Reported usage of mobile devices has skyrocketed, taking over as the primary and most preferred means of accessing many services previously only configured for desktop or laptop computers. Mobile devices have successfully and seamlessly permeated the way we work, learn,

interact and communicate with others, and often, seek pleasure and relaxation. The impact has been both extensive and almost instantaneous across many well-established educational and workplace institutions. For example, within 90 days of the initial launch, the first generation model of the Apple iPad was already in use by over 50% of Fortune 500 companies (Dignan, 2010), and more than 2.5 million iPads were purchased by schools in the U.S. by 2012 (Uhlig, 2012). Smartphone users spend over 4 hours a day using their devices (Barrabee, 2013), and teenagers send over 30 text messages each day (Lenhart, Ling, Campbell, & Purcell, 2010). Although Apple devices initially elicited the most attention, users now have their choice of iOS, Android, and Windows operating systems available across a surplus of device models, sizes, and styles. By the end of 2012, nearly three-quarters of the world's population had access to mobile technology, and over 30 billion mobile applications ("apps") were downloaded worldwide in 2011 (World Bank, 2012). In technology-related fields, this interconnectivity of networked smart devices is referred to as the *Internet of Things* (IoT) (Domingo, 2011; ITU Internet Reports, 2005).

The IoT revolution extends beyond the constraints of physical devices and users, to interact with everyday objects, places, and events. By incorporating emerging technologies like Radio-frequency Identification (RFID) (Amaral et al., 2011), real-time GPS location services and embedded sensors, everyday objects are transformed into "smart" objects that can sense, interpret, and react to the environment and context (Domingo, 2011). The progression of the IoT is represented in Figure 1.1. These types of capabilities will continue to progress and have a global impact on our way of life. As digital information continues to inundate our lives, it is clear that technology will continue to become an increasingly important and an integrated factor in the world, from the workplace to classrooms and from social communications, to daily living


**Figure 1.1.** Progression of the Internet of Things

tasks. Technology will most likely continue to outpace many institutions struggling to keep up, but participation is no longer a choice. Adoption of technology can no longer be ignored, in hopes that it will disappear or resolve itself. In order to best prepare students for the workplace demands awaiting all of them tomorrow, including students with I/DD, technology skills should be prioritized as educational goals (Collier, 2007).

In today's world, the ability to read and write also encompasses the skills needed to interpret and understand information presented through the realms of digital media. Gilster (1997) first introduced the concept of digital literacy as "the ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers" (Gilster, 1997 p.1). This definition has since been expanded upon and adapted to pertain to a myriad of purposes and technological actualities that exist in today's world, encompassing job-specific applications as well as the social, emotional, and cognitive aspects of operation in digital environments (Eshet, 2004). In education, the idea of digital literacy, often referred to as "21st century literacy", is defined as "the ability to read and interpret media (text, sound, images), to reproduce data and images through digital manipulation, and to evaluate and apply new knowledge gained from digital environments" (Jones-Kavalier & Flannigan, 2006, p. 9). Incorporating current technologies with the prerequisite skills potentially required for future technology, 21$^{st}$ century literacies focus on preparing students with the skills needed to participate successfully in tomorrow's workplace and classroom (Collier, 2007). The shift from a print-based to a screen-based society requires teachers to integrate digital literacy skills into instruction to prepare students for the expectations of potential employers. Because all students face the same technologically-oriented workplace of tomorrow, digital literacy skills are essential, and therefore, now considered to be functional life skills (Bawden, 2008).

**Increased Access**

The development of technological skills has been linked to positive post-secondary education outcomes for people with I/DD (Luftig & Muthert, 2005). When considering the rise in availability of new software and applications, teaching the fundamental operations of use is an obvious means to providing greater access to the environment, gainful employment, and independence in daily living for individuals with I/DD. McMahon and Smith (2012) described how digital literacy and technology use by students enrolled in a postsecondary education (PSE) program for young adults with I/DD supported inclusion in university activities and increased the accessibility of information related to their coursework. Technology use has the capability to assist students with I/DD in independent completion of assignments, participation in classroom activities, communication with peers and mentors, and self-determination in daily living (e.g., Burgstahler & Cronheim, 2001). In addition to portability, mobile devices offer a variety of built-in accessibility options for students with I/DD and ASD (McMahon & Smith).

**Improved Function**

Mobile devices can facilitate independent living skills infinitely. Wehmeyer, Palmer, Smith, Davies, and Stock (2008) conducted a meta-analysis of research on technologies used by people with disabilities, which identified several studies that support the effectiveness of mobile devices for teaching people with I/DD different types of skills across academic and functional domains. When systematically instructed, the basic operations of the device empower people with I/DD with the knowledge of how use the devices likely already in their pockets. Once basic operations of the device are gained, the user is empowered with the ability to use the device to support independent navigation, communication, and self-management and self-instruction across all pertinent settings and contexts (Brown, Shopland, Lewis, Dattani-Pitt, 2005; Liu et al,

2008). This is a shift from explicitly teaching students with I/DD how to respond to instructional prompts displayed on a device screen that were created, managed, and operated by someone else.

Students with I/DD must be provided with systematic instruction that will promote independence and increase opportunities in adulthood. Functional digital literacy skills have potential to empower, include, and improve the overall quality of life, and therefore, alleviate the digital divide for people with I/DD (Burgstahler, 2002). The majority of existing empirical I/DD and technology research relates to providing pre-loaded and configured devices as assistive technologies to support individuals with disabilities in various types of settings and activities by providing different types instructional prompting procedures. Despite the increased value of digital literacy skills, a limited number of studies have focused on teaching specific functional digital literacy skills to students with I/DD. Although sparse in quantity, these studies span across the past two decades.

Frank, Wacker, Berg, and McMahon (1985) taught five individuals with I/DD to complete two different tasks on a computer. The first task involved the use of a spelling program, and consisted of 32 task-analyzed steps from initiation to termination of the program. The second task involved the use of a clock program, and consisted of 23 steps from initiation to termination of the program. Using a combined multiple baseline across participants with an embedded ABAB withdrawal design, Frank et al. evaluated the effects of picture prompts as a means to increase the percentage of steps completed independently for each skill. All participants demonstrated immediate gains in the number of steps completed independently upon initial introduction of the picture prompt intervention. After only two sessions, the picture prompt intervention was withdrawn and baseline procedures were reestablished. Upon removal of the picture prompts, the percentage of steps completed independently showed a descending trend

that approached baseline levels. Re-introduction of the intervention replicated the improved gains. Results of this study established foundational support for extending the use of picture prompts and task analytic instruction to effectively teach digital skills to individuals with I/DD.

Jerome, Frantino, and Sturmey (2007) evaluated the use of backward-chaining and most-to-least prompting procedures to teach Internet skills to three adults with I/DD. A 13-step task analysis was developed in order to access specific websites for leisure use. Prior to instruction, a preference assessment was conducted to determine the online games or websites of highest interest to each participant. Backward-chaining procedures were implemented to teach the steps of the task so that access to the site was immediately obtained upon a single action from the user (i.e., clicking the link to the site). If the participant did not independently click the mouse button within 3 s, most-to-least prompting errorless learning procedures were implemented until the link was clicked independently. Introduction of the next step in the task analysis was contingent on independent completion of the previous step for two consecutive sessions. Instruction was concluded after independent completion of all 13-steps was observed for three consecutive sessions.

In a more recent study, Cihak, McMahon, Smith, Wright, and Gibbons (2015) studied the use of email by college students with I/DD across multiple platforms. A multiple probe across platforms design was used to examine the effects of digital literacy instruction on the students' abilities to access, respond to, and send email messages independently. Systematic and task analytic instruction of emailing skills were provided sequentially for each platform: desktop computer, laptop computer, and an iPad, which included pictorial cues, total-task chaining, and the system of least prompting procedures. All students acquired the skills to successfully email using each of the three platforms successfully and maintained the skills nine weeks after the

initial training. An average of seven sessions were required for the students to reach criteria for mastery using the first platform, the desktop computer, to email independently. The following platforms, the laptop and the iPad, required an average of five sessions each. Although participants required fewer sessions to reach criteria for using the laptop and the iPad to email, automatic generalization of how to email across platforms was not observed. All students required separate systematic instruction for each platform. In this case, systematic instruction was effective for the participants to acquire and maintain the skills needed to access, reply to, and send email using different platforms, but generalization of the same set of skills to a new device or platform did not spontaneously occur.

In another study, Cihak, Wright et al. (2015) expanded on the previous results to examine the effect of systematic instruction to teach three functional digital literacy skills to high school students with moderate I/DD. All three participants were able to acquire and maintain the skills required to send and receive email, utilize and manage a social bookmarking service, and access documents through a cloud storage service. The results of these studies further establish the use of systematic and task analytic instruction and prompting procedures as effective, evidence-based practices to promote the acquisition and maintenance of new skills for students with I/DD, including technology and functional digital literacy skills.

**Challenges of Teaching Digital Literacy Skills**

Systematic and task analytic instructional procedures are widely used evidence-based practices because, when implemented properly, they can be used to teach most any target skills effectively (Browder, Mims, Spooner, Ahlgrim-Delzell, & Lee, 2008; Courtade, Test, & Cook, 2015; Hudson, Browder, & Wood, 2013; Knight, Spooner, Browder, Smith, & Wood, 2013; Spooner, Knight, Browder, Jimenez, & DiBiase, 2011; Spooner, Knight, Browder, & Smith,

2011). However, in the world of continuously evolving technology, systematic instruction presents several considerable challenges. First, it is impossible to teach every skill systematically. Educators, researchers, practitioners, parents, and everyone else are, themselves, struggling to constantly learn new technological skills in order to stay abreast of these changes in their own lives and jobs. Subsequently, research efforts have focused on investigating effective means to ensure practitioners are up-to-date on the availability and application of digital tools (Ayres, Mechling, & Sansosti, 2013).

Second, systematic instruction can be extremely time consuming. In an uninterruptedly changing technological environment, any given digital literacy skill is equally as likely to be outdated as it is useful immediately following acquisition. Additionally, isolation of each targeted skill from related skills is a fundamental feature of systematic instruction. The targeted skill is then further broken down into a series of discrete behaviors, potentially removing connections even more. This means successful mastery of one skill (or task analysis) may not be effective in producing immediate success in real-world application. If performance of the newly acquired skill fails to yield meaningful relevance, disappointment is likely experienced. Similarly, the very features that add to the effectiveness of systematic instruction may diminish the ability for students with I/DD to synthesize the isolated steps to relate to the overall end goal. For example, in the study by Jerome et al. (1997), participants took an average of 80-min of direct instruction to reach criteria for mastery, and the skill acquired only gained access to a single website. The authors note that although all three participants were eventually able to perform all 13 steps of the task analysis without any prompting, it remained unclear whether the participants learned to approach a computer, turn it on, and access the website independently, or if the procedures only targeted the specific response of clicking onto a website. Additionally,

when satiation on the once reinforcing website occurred, it is possible that interest in the computer overall could similarly decline. If performance of the newly acquired skill fails to yield meaningful results, students with I/DD are likely to experience frustration and disillusionment, ultimately resulting in abandonment of the technology.

## Technology to Reduce Skill Demands

Electronic media has been recognized as a means to greatly facilitate access to information (e.g., Adam & Tatnall, 2008; Florian, 2004). However, this material can remain inaccessible to those with limited physical or cognitive abilities or inadequate digital literacy skills. The availability of consumer technology with the potential to enable access to information is increasing rapidly (Baxter et al., 2012). The application of newer technologies to reduce cognitive skill demands, or circumvent the need to acquire all requisite digital skills is another way of addressing the digital divide and promoting achievement of immediate success in independent use. Recent technologies, such as QR codes and augmented reality, have been demonstrated as effective means to both increase access to information and improve the functional capabilities of users with I/DD (e.g., Gómez, Alamán, Montoro, Torrado, & Plaza, 2014; McMahon, Cihak, Gibbons, Fussell, & Mathison, 2013; McMahon, Cihak, & Wright, 2015). The emergence of even newer technologies, such as context-aware applications and wearable devices, brings promise for meeting the ultimate goal of closing the digital divide.

**Scan-able media.** In addition to the portability of devices, the rise of non-text interfaces offers opportunities to further overcome accessibility barriers (Doughty, 2011). QR codes are one example of providing a non-textual interface for interaction with electronic media. Similar to a traditional product barcode, a QR code is “scanned” through the use of a device to receive additional digital information. However, unlike product barcodes, QR codes are capable of

providing various types and larger amounts of information in a smaller physical area than product barcodes. Information contained in a QR code can include GPS location or physical addresses, contact card information, images, website URLs, and email addresses. Additionally, a QR code is accessible through the use of any device with a camera that is compatible with a QR reader application. When scanned, the corresponding application will launch automatically. For example, a smartphone used to scan a QR code containing an address will automatically open the map application to display the location. Additionally, QR codes are easily created, at no cost, through many different web-based or mobile applications. Created QR codes can be printed and posted on a flyer or business card, electronically sent, or scanned directly from another digital screen. The major accessibility advantage offered through QR codes includes the removal of the barriers presented by digital literacy skill deficits. Traditionally, these barriers often result in mistyping keywords, misunderstanding or selecting incorrect icons, or having to apply literacy skills to read text (Haworth & Williams, 2012).

Haworth and Williams (2012) investigated the accessibility issues associated with interactive QR code scanning in a museum and the visitors' ability to understand and use the QR system as provided. The QR codes were created for specific museum artifacts and exhibits, and then placed throughout the museum. When scanned, users were provided with additional information about museum artifacts and exhibits. The users accessed the additional information by scanning the QR code using their own smartphone or a borrowed iPad from the museum. When scanned, the user experience was that the QR codes were able to determine exact location within the museum because the digital information received matched the physical information provided in the exhibit, though the QR codes were not contextually intelligent. The results supported the use of QR codes as a viable means for providing improved accessibility to

information about the museum exhibits. Additionally, both the museum visitors and museum staff indicated positive and enthusiastic responses regarding use of the QR code system.

**Augmented reality.** Augmented reality (AR) describes a medium for using technology to combine live views of the physical world with overlays of digital information, which can include text, pictures, audio, and video (Craig, 2013). Stated another way, AR technology involves the blending of the actual, physical environment and digital markers or cues (Cobb & Sharkey, 2007). AR use relies on two main types of input to “trigger” an augmented response: location-based and marker-based cues.

Marker-based AR relies on a tangible, or physical marker, as a cue to activate the digital display of corresponding and preprogrammed information. When the marker is identified through the device camera, an overlay of digital information appears in tangent on the device screen view. Marker-based AR extends the QR code by providing views of both the physical world and the digital information simultaneously. As long as the marker remains to be recognized through the device camera, the associated digital content will be displayed. However, if view of the marker is lost, the digital display will be suspended until view of the connected marker is regained.

A recent study examined the use of marker-based AR to teach science vocabulary words to four college students with I/DD (McMahon, Cihak, & Wright, 2015). A multiple probe across sets of vocabulary words (i.e., plants, organs, and bones) was used to examine the effects of the AR instruction on the students’ abilities to correctly define and apply the targeted words to label a diagram. Pre-training sessions included instruction on how to operate the device to access the AR content. Upon mastery of pre-training sessions, students were given a printed booklet of vocabulary words, a tablet device, and asked to try and “beat” the video. When each AR marker-

based vocabulary word was scanned, the triggered digital content included a video clip of the definition and the application of the vocabulary word on a visual diagram. During the video clip, each definition was presented both visually, as text on the screen, and verbally, as computerized audio narration of the definition. A delay of approximately 2 to 5 s occurred prior to beginning the video for the AR application to recognize and process the content. This delay, therefore, simulated a time delay strategy, as well as provided a way to prime the students' attention. All four students readily acquired the definition and application of each vocabulary word and were able to label each word on the corresponding diagrams following the AR intervention. Additionally, the students reported high levels of enjoyment from the ability to control their own learning, access the information independently, and from use of the AR application overall.

In another study, McMahon, Cihak, Gibbons, Fussell, and Mathison (2013) evaluated the effects of using an AR application to identify potential food allergens for seven college students with I/DD. The participants were provided instruction on using the AR application to scan product bar codes of food items to identify which items contained specified ingredients, which a person might be allergic. Results demonstrated an immediate improvement in the students' abilities to identify foods with possible allergens when using the AR application. Further, the students mastered use of the AR application with minimal initial training maintained these skills six weeks following the study.

These two studies provide foundational evidence supporting the use of AR technology and mobile devices to both increase access to digital information, and improve the functional capabilities of individuals with I/DD. No text input was required in either study in order to access the instructional content. The application simply had to be opened and the marker had to be visible through the device camera in order to independently access the information needed to

learn science vocabulary or identify food items containing potential allergens. In both studies, the task analysis consisted of only two task analyzed steps (i.e., open app and scan marker).

In addition to providing access to information, AR can increase the functional capabilities of individuals with I/DD without the need of a AR marker. Location-based AR, or markerless AR, is activated by the specific location of the user. To provide the most accurate information, location-based AR relies on information provided though GPS and Internet access. Applications of location-based AR include the use of mobile devices to locate nearby points-of-interest, such as businesses with job postings, restaurants, and community social events (McMahon, 2014).

Several studies were identified as examples investigating location-based AR as a means to increase functional navigation skills for individuals with I/DD. Through systematic instruction, Smith (2013) taught three college students with I/DD how to use location-based AR to navigate a large college campus. Students were taught a two-step task analysis regarding how to open the AR application and how to position the smartphone in order to receive the information needed to independently travel to unknown locations. Using the camera feature, students viewed a visual prompt that appeared in the form of a hovering arrow that directed the students towards the specific destination. The AR interface functioned similarly to a compass in that the arrows continually oriented the students towards the final destination. The AR also include the name of the location and distance to the location in miles. The results indicated that all of the students were able to independently travel to novel locations using location-based AR.

McMahon, Smith, Cihak, Wright, and Gibbons (2015) replicated and extended Smith (2013) study by comparing the effects of a printed map, Google Maps on a mobile device, and a location-based AR navigation application for six college-students with I/DD to travel to unknown locations on a college campus. During the paper map condition, Google Maps was

used to produce a printed paper map of the campus as the navigational support. During the Google Maps mobile device condition, navigation information presented on the device map included the student's location, represented by a blue dot, the target location, represented by a red pin, and the best path to navigate was highlighted in blue. During the location-based AR condition, navigation information was presented similar to Smith (2013) study. The results indicated that location-based AR was functionally more effective than the paper and mobile device Google Maps conditions. All students were able to travel to unknown locations independently only using the location-based AR; all students required assistance using the other conditions when navigating the campus. McMahon, Cihak, and Wright, (2015) replicated and further extended the use of location-based AR to teach four college-students with I/DD to travel to unknown business location in a large city. Similarly, McMahon, Cihak et al. compared three navigation aids (i.e., paper map, Google Maps, and location-based AR) and found the results achieved to be analogous to McMahon, Smith et al. The location-based AR was more effective and it was the only condition which allowed students to travel independently to novel locations.

Augmented reality offers a promising means of providing access to digital information for people with I/DD by reducing the number of task analysis steps and lessening higher-order cognitive processes and literacy demands. AR systems have the capability to recognize and present information to people with I/DD that they might otherwise obtain independently. While the previous studies support the use of systematic and task analytic instruction to successfully teach digital literacy skills to people with I/DD, the reduction in the number of task analyzed steps involved through use of AR-based interventions (i.e., two steps) is dramatically significant.

AR functions as a "cognitive prosthesis" for people with I/DD. The idea of a "cognitive prosthesis" is a decades old idea of using technology devices to support the needs of people with

cognitive deficits (Cole, 1999). Individuals with I/DD often have difficulty recognizing environmental print, attending to relevant and multiple stimuli simultaneously. For example, when navigating the community, young adults with I/DD demonstrated difficulty in keeping track of the relative location of two nearby potential destinations (McMahon, Cihak, et al., 2015). AR navigation tools can simultaneously "attend" to both the locations of the target destination and the proximal progress of the person's position to provide the necessary prompts to support their independent navigation. Using live physical views through a mobile device camera combined with concurrent display of digital information obtained from online databases, AR applications produce the relevant and necessary information for people with I/DD to make decisions about their environment quickly and automatically. AR applications expand the concept of cognitive prosthesis through the ability to intuitively provide context relevant information to improve the functional capabilities of users with I/DD.

**Contextual Awareness**

In terms of the technological features of currently available technology, such as tablets and smartphones, signals and sensors are constantly streaming informational data. The process of context-aware technology is represented in Table 1. First, information obtained through sensors within the device, such as Bluetooth, Wi-Fi, and near field communication (NFC), are used to signal a specified event. For example, geolocation can be used to signal a proximity event and return a triggered response. The signal, event, and desired response are then defined within terms of a contingency statement, such as, "if my location (signal) crosses outside of a 200-foot radius of my workplace (proximity), send a text (response) to notify my mother I am "on my way home." Context-aware applications use the knowledge of a user's physical, social, preferential information as input to further determine the context, interpret the goals of the user,

and adapt the responses of one or more computational services appropriately. Combined with information accessed directly through applications such as email, calendar, contacts, notes, and Internet search history, the knowledge about the user is applied to build the user's context. The more information provided, the more accurate and specific the context will be. In fact, this information is not required to be stored in or on a specific device, the user's associated email address and login information allows this information to be stored remotely in the cloud, which provides the freedom to change devices as desired. Once the context has been built, context-aware applications are able to determine the information, or prompt, that would be the most relevant to the user within a given situation, therefore extending QR codes and AR in two important ways: removing the physical action of scanning to request information and determining the context relevant to users throughout the day.

**Table 1.1.** Processes of Context-Aware Technologies

| **Signal** | **Context Aware** | | **Response** |
|---|---|---|---|
| | **Event** | **Contingency Statement** | |
| Bluetooth | Time | If - then statement | Notification to user |
| NCF | Proximity | | Display a card |
| Geolocation | Value change | | Log event |
| Date/Time | | | Send text or email message |
| Email | | | Transmit signal |
| News alert | | | |
| Local weather | | | |

**Note:** NCF= Near Field Communication.

## Purpose of this Research

There is a compelling need for the development of tools and strategies that will help facilitate independence, self-sufficiency, and address poor employment outcomes in adulthood (Butterworth et al., 2011; Grigal & Hart, 2010; NCD, 2011). Assistive technologies have been established as evidence-based tools and strategies (Mull & Sitlington, 2003). However, individuals with I/DD experience slower rates of adoption of new technology, which results in restricted access to equal opportunities and future technology use when compared to their peers (National Council on Disability, 2011). Modern technologies can be leveraged to create an enhanced learning experience superior to current instructional approaches that will allow students with I/DD to independently operate and self-manage technological supports to acquire vocational and independent living skills needed for adulthood. By reducing the number of task analyzed steps required and eliminating the prerequisite skill demands of existing technologies, context-aware and wearable technologies offer considerable promise for bridging the digital divide. The potential use of emerging technologies and machine learning methods to deliver contextually-aware and highly accessible instructional supports for persons with I/DD is warranted. The ubiquity of such systems can alleviate fear of social stigma and anxiety in task performance. Empirical research is needed in order to broadly apply cutting edge technologies to the needs of people with disabilities. The two research studies included in this dissertation aim to advance the use of context-aware and wearable technologies as assistive devices to promote independence of people with intellectual and developmental disabilities.

## Research Questions

Both studies employed single-subject research design methods to investigate whether a functional relation exists between the use of a context-aware application accessed through a

wearable device and acquiring new vocational skills and self-management of prompts to initiate and complete daily tasks for college students with I/DD.

**Study I.** The purpose of this study was to examine the effects of using a context-aware application delivered through a wearable device to teach students with I/DD three different vocational tasks. Specific research questions include:

1. What are the effects of context-aware applications and wearable devices on the acquisition of vocational tasks for college-aged students with I/DD?
2. What is the social validity of using wearable devices to learn new vocational skills?

**Study II.** The purpose of this study is to examine the effects of a context-aware smartwatch application to teach college students with ID and ASD to self-manage and self-direct routine and novel prompts independently in a vocational setting. Specific research questions include:

1. What are the effects of using smartwatch devices and a context-aware checklist application on the independent completion of vocational tasks for college students with I/DD?
2. What is the social validity of using smartwatch devices to self-manage prompts for task completion?

# Chapter II

## Study I: Google Glass and a Context-Aware Application for Teaching Vocational Tasks to Postsecondary Education Students with ID and ASD

## Barriers to Employment

The Human Services Research Institute (2012) identified employment as a critical area of need for individuals with I/DD. Despite this recognition, high rates of unemployment for this population unfortunately continue to persist (Butterworth et al., 2012). Further exacerbating an already dismal outlook, people with I/DD were reported to experience some of the worst post-school outcomes of any group, with only 54% of people with ID and 47% of people with multiple disabilities reported to have worked for pay outside the home in the last two years (Newman, Wagner, Cameto, Knokey, & Shaver, 2010).

There is a compelling need for the development of supports and strategies for people with intellectual and developmental disabilities (I/DD) that will facilitate independence, self-sufficiency, and address poor employment outcomes in adulthood. Promising modern technologies can be leveraged to create a learning experience that might be superior to current instructional approaches to empower students with I/DD to live fuller, more independent lives. Combining the most desirable features of emerging technologies, such as augmented reality and wearables technologies with the capabilities of machine learning methods, will allow for a contextually-aware, highly accessible, scalable instructional service to support individuals with I/DD in the workplace and during adulthood.

## Technological Approaches to Vocational Supports

Technological approaches to vocational support for persons with I/DD have primarily involved the delivery of a combination of auditory and visual cues as supplementary instructional prompts in combination with other instructional methods to teach new behaviors or decrease unwanted behaviors (Mechling, 2011). Computer assisted instruction (CAI), video modeling (VM), and mobile devices have shown promising results in applications to teach vocational skills to people with I/DD (e.g, Ayres & Cihak, 2010; Bellini & Akullian, 2007;

Cihak, Kessler, & Alberto, 2008; 2007; Meching, 2005; Mechling, Gast, & Seid, 2009; Odom et al., 2014). CAI programs offer useful instructional opportunities, with an emphasis on repetition, individualization, and systematic presentation of materials. Wissick, Gardner, and Langone (1999) suggested that CAI is particularly beneficial when time, staffing, and budgetary constraints present significant barriers to in-vivo training. Although CAI programs have demonstrated success in teaching the acquisition of new skills, it often fails to demonstrate skill transfer to new settings because programming common natural stimuli or the lack of sufficient practice in the actual environment, is often difficult to accomplish. Cihak, Alberto, Kessler, and Taber (2004) suggested that skill generalization is more likely to occur for students with I/DD when CAI and *in*-vivo instruction occurred on the same day.

**Video Modeling.** Video modeling (VM) is an instructional strategy for teaching discrete and chained tasks in which the learner views a video clip of the correct performance of a targeted task, and then has the opportunity to practice the skill (Bellini & Akullian, 2007). Advances in technology have allowed researchers to use VM on mobile devices in order to more closely approximate in-vivo training, as opposed to televisions and computer screens (Cihak et al. 2012). However, VM systems require another person to develop the VM clips and upload the videos to a mobile device for the individual with I/DD. The individual is dependent upon another person to manage the device (i.e., set up the video as ready to play), prompt the viewing of video, as well as and create all video content for new skills and tasks. Due to the continuous involvement of another person, this contradicts true independence.  Therefore, VM tools are effective to facilitate the acquisition of new skills, but the technological skills required for self-operation and self-management limits the flexibility of interventions and continued use over time by individuals with I/DD.

**Self-Management.** Self-management can be a useful strategy to promote skill maintenance beyond the initial training period (Westling, Fox, & Carter, 2015). Self-management interventions are used to assist individuals with I/DD in learning how to self-direct, or manage, their own actions or regulate their behaviors across settings and situations appropriately and independently (Neitzel & Busick, 2009). As familiarity and understanding of the self-management routine is gained, the amount of the personal responsibility transferred from person-support assistances (e.g., teacher, job coach) to the learner themselves. The effectiveness of technological-based strategies used to promote self-management for individuals with ASD has been demonstrated to be highly effectively within vocational settings (Cihak et al., 2007; 2008; Copeland & Hughes, 2000; Davies et al., 2002).

**Augmented Reality.** Augmented reality (AR) allows the user to perceive and interact with the real world while simultaneously receiving additional information that is virtualized into their field of perception and has great potential in education (Bower et al., 2014). AR and wearables technologies eliminate the motor and cognitive demands needed to access information need to function more independently. AR limits the skills required need to operate mobile devices. Although empirical-based studies that included students with I/DD are limited , studies that exist have demonstrated positive results in teaching academics (Richard et al., 2007), independent living skills (McMahon et al., 2013), vocational skills (G´omez et al. 2014; Chang, Kang, & Huang, 2013), and independent navigation skills (McMahon, Cihak, & Wright, 2015).

**Context-Aware Augmented Reality**

Context awareness is the ability to provide information appropriate to a given situation ubiquitously. *Context* refers to the physical and social situation in which computational devices are embedded and human-computer interaction is occurring. The advantage of context-aware

computing is the delivery of information about the context that are appropriate to the person given their place, time, and/or event (Abowd, Dey, Brown, Davies, Smith, & Steggles, 1999). For example, a cell phone will always vibrate and never beep in a movie theatre, if the system knows the location of the cell phone and when the movie is schedule. Figure 1 illustrates the context aware computing system used in this study. For example, the person is attempting to use a copy machine to make a copy, but does not know how to operate the copy machine. The person is wearing Google Glass and interacts or triggers the system by voicing "what next?" The person takes a picture of the copy machine to interact with the context computing system which in turns perceives or recognizes the person's circumstance and computes or reasons an appropriate action regarding the situation. The system then delivers an augmented reality view of the image sent in the request instructing the actions required for step completion.

As in augmented reality and QR codes, contextual awareness often relies on physical markers, or tags, as means to provide the context. For example, Chang, Kang, and Huang (2013) created an interactive system for prompting using visual codes detected by an overhead cameras, and G´omez et al. (2014) used QR codes, in combination with user-entered context information to teach vocational skills with smartphones. For example, Chang and Wang (2010) investigated the application of contextual awareness provided via Bluetooth signals to teach navigational wayfinding skills using a PDA device.

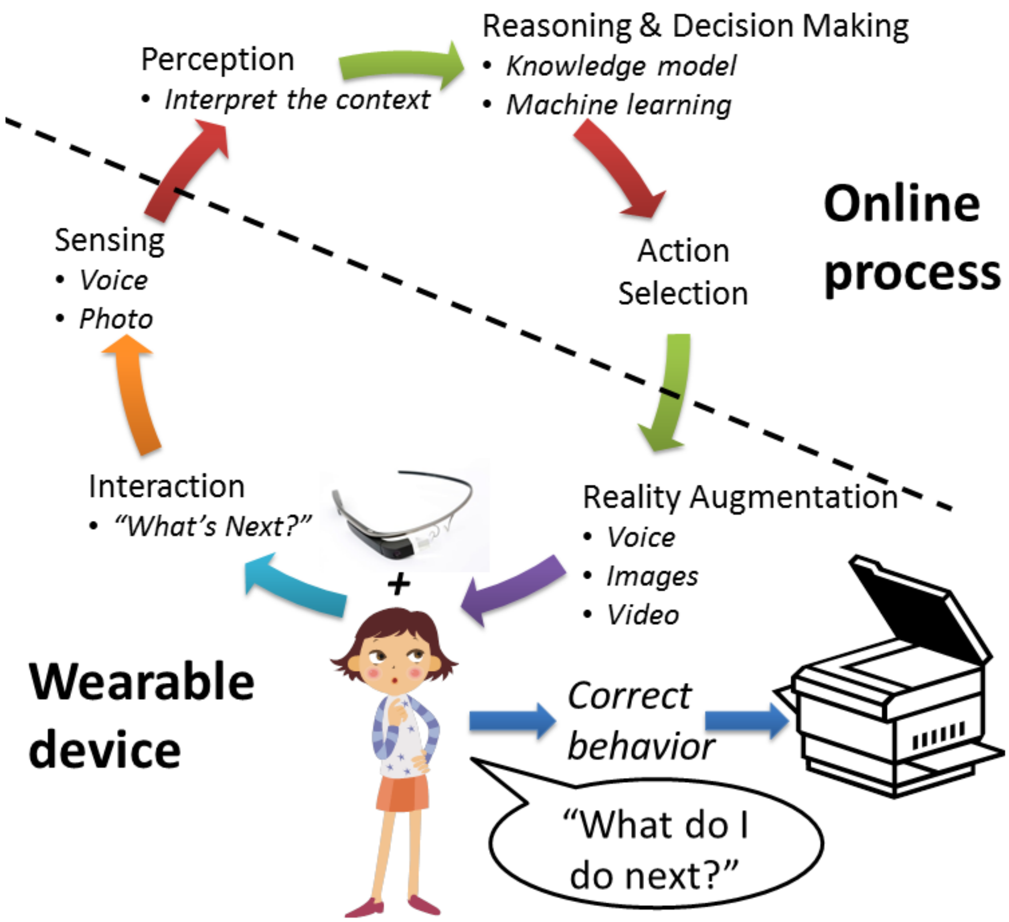


**Figure 2.1.** The What's Next? system overview

An overview of the What's Next? system is illustrated in Figure 2.1. Wearing the Google Glass device, the student is provided with the ability to ask for and receive assistance at any point in the task analysis when learning to perform the steps of a new task. Using an image taken from the user's point-of-view, the What's Next? system is able to determine the distinct step of the task analysis in which the student is requesting assistance, and select the appropriate instructional prompt to be returned to the wearable Glass device. A cloud-based server and machine learning methods are used to achieve the contextual awareness of the system. Using the voice command, "Ok Glass, what's next?" the initial image capture is triggered on the screen of

the device. The captured image is sent to the cloud-based machine learning server to be processed and analyzed. The image is then classified according to the task analysis to determine the instructional prompt needed in order to complete the step. The instructional prompt for all steps include text and audio directions, as well as an augmented view of the original image overlaid with digital highlighted objects, buttons, or points of interaction, correct models of the solution, and/or text as appropriate to the action(s) required for completion of each step.

Contextual awareness is achieved through perceiving the content of the image and deciding which instructional prompt to present. Our approach first parses the image for relevant information, then uses supervised learning to solve the problem of identifying the correct context of the image. Using the classifier output and the known ground truth, the proper visual and audio prompts for the next step in the task are selected from the knowledge model, which is specific to the task, for example in the form of a lookup table or decision tree. The prompt is then delivered seamlessly to the user through the wearable AR interface. The key differentiating feature of the context awareness is the ability to only provide prompts for the steps that the user cannot remember. This is especially significant when providing instructional support to students with I/DD in order to ensure skills are acquired quickly and independent performance is emphasized. Such self-directed learning gives the student complete control and propels them towards self-sufficiency.

By using modern computer vision and machine learning methods, the What's Next? system is able to extract the context from the scene without the use of QR codes or AR markers, thereby further liberating students with I/DD from dependency on others and reducing digital literacy demands. The purpose of this study is to examine the effects of a context-aware

application and a wearable device to teach students with ID and ASD three different vocational tasks. Specific research questions include:

1. What are the effects of context-aware applications and wearable devices on the acquisition of vocational tasks for college-aged students with ID and ASD?
2. Do college students with ID and ASD find wearable technology instruction to learn new vocational tasks socially acceptable?

## Methods

### Participants

Three college-aged students with an intellectual disability (ID) and autism spectrum disorder (ASD) participated in this study. All three participants attend a postsecondary education (PSE) program at a large southeastern university. The participants included two males and one female and ranged in age from 19-29 years old. All participants were selected based on the following criteria: (a) diagnosis of an ID or ASD, (b) participation in a postsecondary education program, (c) no physical disability that impeded the performance of the skill or ability to access the wearable device, and (d) consent to participate in the study. Participants' full-scale IQ standard scores ranged from 57 to 63 and adaptive scores ranged from 51 to 77. All students received special education services under the ID and/or ASD category during K-12 grades. In addition, all students met eligibility guidelines under ID for admission to the postsecondary education program. Diagnostic and educational information, including IQ and adaptive behavior standard scores is provided in Table 2.1.

**Table 2.1**. Demographic Characteristics of Participants

| Participant | Age | Disability[a] | Intelligence[b] (SS) | Adaptive Behavior[c] (SS) |
|---|---|---|---|---|
| Toby | 20 | ASD; ID | 62 | 77 |
| Steven | 18 | ASD; ID | 63 | 51 |
| Susan | 29 | ID | 57 | 61 |

**Note** [a]ASD = autism spectrum disorder; ID = intellectual disability. [b] Wechsler Intelligence Scale for Children-III (Schrank, Becker, & Decker, 2001); [c] Vineland Adaptive Behavior Scales, 2nd Ed. (Sparrow, Cicchetti, & Balla, 2005).

**Toby.** Toby was a 20 year-old student diagnosed with intellectual disability and autism spectrum disorder. Toby had a FSIQ of 62 on the Wechsler Adult Intelligence Scale, Third Edition (WISC-III). Results from the Vineland Adaptive Behavior Scales, Second Edition showed Toby to receive a standard score of 77. At the time of the study, Toby was enrolled in his third semester of the PSE program. He participated in an undergraduate level animal sciences academic class for audit credit and his internship placement was with the local zoo near campus.

**Steven.** Steven was an 18 year-old student diagnosed with intellectual disability and autism spectrum disorder. Steven had a FSIQ of 63 on the Wechsler Adult Intelligence Scale, Third Edition (WISC-III). Results from the Vineland Adaptive Behavior Scales, Second Edition showed Steven to receive a standard score of 51. At the time of the study, Steven was enrolled in his third semester of the PSE program. He participated in an undergraduate level religious studies academic class for audit credit and his internship placement was with a local charity organization.

**Susan.** Susan was a 29 year-old student diagnosed with intellectual disability. Susan had a FSIQ of 57 on the Wechsler Adult Intelligence Scale, Third Edition (WISC-III). Results from

the Vineland Adaptive Behavior Scales, Second Edition showed Susan to receive a standard score of 61. At the time of the study, Susan was enrolled in her third semester of the PSE program. She participated in an undergraduate level botany academic class for audit credit and her internship placement was with the campus agricultural program's community garden center.

**Setting**

Participants attended a postsecondary education program (PSE) specially designed for individuals with intellectual disability and autism. The PSE program was located and a part of a large university located in the Southeast United States. Each participant was enrolled in traditional university courses for audit credit, recreational classes, student work internship, and program-specific courses that included life skills, career development, and digital literacy skills. Each participant was included in traditional university courses and activities for a minimum of 80% of the week. The core courses were designed for college students with ID enrolled in the PSE program. All phases of this study occurred on campus within natural and inclusive areas regularly used by students with and without disabilities.

**Materials**

The materials used in this study included the Google Glass© device, Samsung Galaxy Avant© smartphone, and the What's Next? application on all tasks.

**Google Glass.** Google Glass is a wearable device worn on the face like a pair of eyeglasses. An optical prism extends over the right eye, slightly above the user's line of sight, to display digital information overlaid on the user's physical view. Users interact with the Glass device through combinations of natural language voice commands, gestures, and head movements. A touch pad is built in to the right temple of the device and recognizes a variety of swiping and tapping gestures. Alternatively, Glass can be controlled by using voice commands,

or “voice actions”, by speaking aloud recognized phrases. All voice command actions begin with “Ok glass” to activate or turn-on the device. Located on the right side of the device is an embedded high definition camera, capable of high-resolution photos and 720p HD video recording, from the user’s point-of-view. Audio features include a built-in speaker using a bone conduction transducer (BCT) technology to transmit sound through the occipital bone for increased privacy, which is found behind the right ear, as well as an external ear piece option, which is connected to the USB charging port on the device. Glass is connected to a companion smartphone via Bluetooth, which prompts the installation of the companion “MyGlass” application from the Google Play Store for further control of the Glass headset, Wi-Fi connectivity options, and accessing available third party applications from the Glass app library.

**Samsung Galaxy Avant Smartphone.** The Samsung Galaxy Avant served as the companion smartphone connected to the Glass device. Beyond initial configuration to the university WiFi network, MyGlass App, and Bluetooth pairing to the Glass device, the primary purpose of the smartphone was to screencast the Glass device. Screencasting is a process in which the screen of a connected device can be shared to the screen of another device in real time. Screencasting the Glass device was only done during the pre-training phase. By incorporating the screencast, the researcher was able to observe what each participant saw as they used the camera viewfinder. This allowed the researcher to provide specific feedback regarding the operation of the Glass device to the participant when needed.

**What’s Next? Glass Application.** The context-aware application used in this study, called What’s Next?, was created by the researcher for specific use on the Google Glass platform. The What’s Next? application was launched, or opened, by saying the command phrase, “Ok glass, what’s next?” aloud. For students with speech difficulties, the What’s Next?

application could alternatively be opened through the application of swiping and tapping gestures to the device track pad. Initial launch of the application provided audio instructions to "position the picture and tap" and simultaneously opened the device camera view through the prism display. The student positioned the camera view around the targeted area of the task and tapped the trackpad once to take a picture. The captured image was displayed on the device display and visual and audio directions were provided to "tap to accept, or swipe down to try again". Tapping to accept sent the picture to a cloud-based machine learning server to be processed and analyzed. Previously established criteria and the relevant features needed to determine the exact step of the task analysis were used by the server to decode the image and select the appropriate response by determining the corresponding image annotated with additional instructions to prompt completion of that step to be returned to the Glass device. Audio instructions also were provided using text-to-speech software (reading only the words displayed on each annotated image). The processes involved in the What's Next? application are outlined in Table 2.2.

**Tasks and task materials.** The first task involved making double-sided copies on a commercial copy machine. The copy machine used in this study was a Konica-Minolta Bizhub 363 model and was located in an office area on campus. The purpose of this task was teach a skill often associated with office or clerical work. The task consisted of 13 task-analyzed steps (see Table 2.3). The What's Next? application generated the appropriate instructional prompt for the next step through context-aware computation. The instructional prompts received by the students are illustrated in Figure 2.2.

The second task required students to check the amount of money available on their student ID card. Student ID cards are used like a debit card to make purchases on campus. All participates used their IDs daily to either buy lunch, purchase snacks from a vending machine, or

**Table 2.2.** What's Next? Application

| User Input | Glass | | Cloud |
|---|---|---|---|
| Action | Action | Audio | |
| 1. Either voice "ok Glass, What's next?" or swipes and taps to launch app | Opens camera view box | "position the picture and tap" | |
| 2. Moves head to position view; taps once to take the picture | Displays captured image | "Tap to accept" | |
| 3. Second tap to accept image/swipe down to retake | Sends image to cloud server | | Processes image; determines exact step; |
| | | | Corresponding annotated image sent to Glass device |
| | Displays annotated image sent back from cloud server | Audio instructions provided from annotated text | |
| 4. Completes step; Swipe down to dismiss image/take new image | | | |

**Table 2.3.** Making Copies Task Analysis

| Step | Skill |
|---|---|
| 1 | Take papers to be copied to machine |
| 2 | Place papers face up into the document feeder tray |
| 3 | Enter the 4-digit code using keypad |
| 4 | Tap "login" on touch screen |
| 5 | Enter number of copies to make using keypad |
| 6 | Tap "duplex/combine" button on touch screen |
| 7 | Press "1 side > 2 side" button on touch screen |
| 8 | Press green "start" button on key pad |
| 9 | Wait for copying to finish |
| 10 | Remove copies from the left side tray |
| 11 | Check to make sure new copies are double-sided |
| 12 | Remove original copies from top feeder tray |
| 13 | Log-off machine |


**Figure 2.2**. Example annotated images for steps 1 and 2 of Task 1, Making Copies.

buy items from the university center. The ability to access and retrieve electronic account information is a critical skill in both employment and independent living situations. Thirteen task-analyzed steps were required to check their ID financial statement (see Table 2.4). The materials needed to complete the task included the student's ID card and a desktop computer. The desktop computers used to complete this task were those provided in a student technology lab on campus and were Dell © models running Windows©7. The What's Next? application delivered the appropriate instructional prompt for the next step through context-aware computation. Two of the instructional prompts received by the students for completion of the ID account task are provided in Figure 2.3.


**Figure 2.3**. Example annotated images for steps 1 and 2 of Task 2, ID Account.

The third task was a geometric assembly task and it consisted of 20 steps (see Table 2.5). Students used tangram shapes to complete a random geometric assembly tasks. The materials included foam, colored shape block/tiles, 28 x 22 inch piece of white poster board with the center (starting position) marked in thick black lines, and 3 purple felt triangles affixed to mark the workspace area. The assembly task included four hierarchical categories: shape identification, spatial relationships, sub-composition, and rotations. The difficulty of the steps escalated from

**Table 2.4.** ID Account Task Analysis

| **Step** | **Skill** |
|---|---|
| 1. | Open Chrome Browser |
| 2. | Enter search term,“VolCard” |
| 3. | Click “VolCard Office/Division of Finance & Administration” link |
| 4. | Click “View Transaction History” link |
| 5. | Type NetID (username) & password |
| 6. | Click “Submit” button |
| 7. | Click “VolCard Account” link |
| 8. | Modify date range settings for current month |
| 9. | Click “View History” button |
| 10. | Right click (in white space) |
| 11. | Select “Save as..” |
| 12. | Click “Save” button |
| 13. | Click “Logout” link |

**Table 2.5.** Example Skills Included in Tangram Assembly (Task 3)

| Category | Skill | Example Instructional Cue | Example Feedback (correct) | Example Feedback (incorrect) | |
|---|---|---|---|---|---|
| Shape Identification | Square; Diamond; Rhombus; Hexagon; Triangle | "Place a square on the marker. When you're finished, ask "what's next?" | "Correct. A square has 4 equal sides." | "Try again" | (Level 1) |
| | | | | "The square has 4 equal sides" | (Level 2) |
| | | | | "This is the square (displays image of square)" | (Level 3) |
| Spatial Relationships | Adjacent Above; Adjacent Below; Right Adjacent; Left Adjacent | "place a triangle above the square so that the sides line up and it looks like an orange house with a green roof." | "Correct. This is called adjacent. The triangle is above the square. The triangle is adjacent to the top of the square" | | |
| Sub-composition | Combining shapes to make a new shape | Add another triangle right-adjacent to to make a diamond shape. | "Correct. Two adjacent triangles make a diamond." | | |
| Rotations | Clockwise: quarter turn, half turn; three quarter turn; full turn; Counterclockwise: Quarter turn, half turn, three quarter turn, full turn | | | | |

simple shape identification to relative placement and rotation, to assembling more complicated shapes. Within each category, specific skills were randomly assigned, so students assembled a novel tangram for each session. The ability to manipulate objects, understand relative object placement and orientation, and use the same set of parts, shapes, or items to follow novel assembly instructions is important in many job settings. Because this task involved fine motor manipulation of shapes, image inputs were contextual processed by first finding color contours, then classification was performed with a decision tree to determine the correct step and corresponding instructional prompt (see Appendix A). The What's Next? application was able to generate the correct prompt for the next step using that knowledge combined with rules for rotation and placement of the geometric shape.  Example instructional cue, error correction, and positive reinforcement images received by the students during the Tangram Assembly task are provided in Figure 2.4.

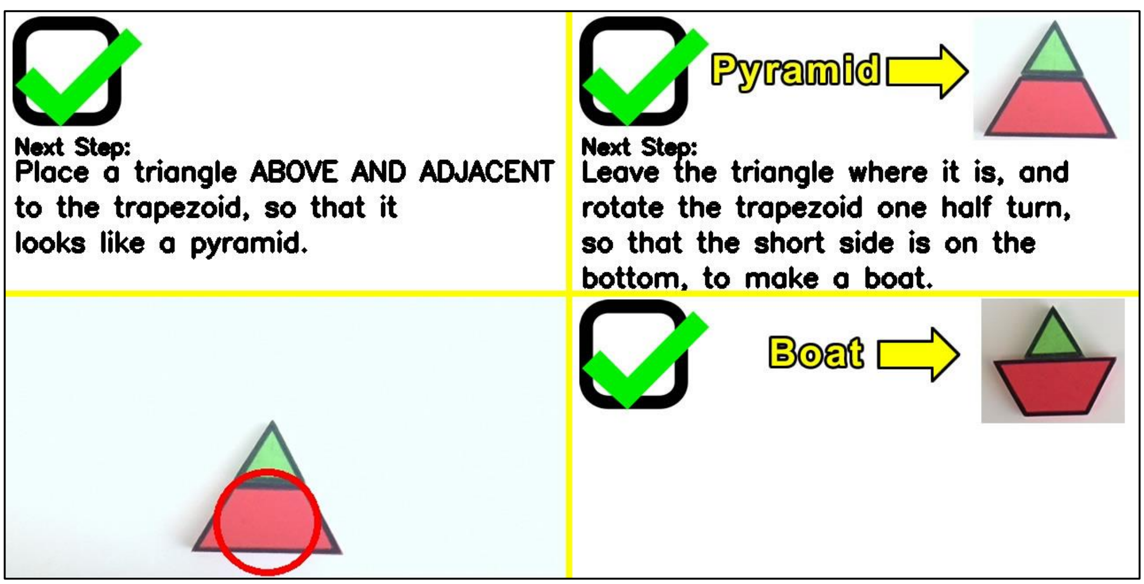


**Figure 2.4.** Example instructional cue, error correction, and positive reinforcement images sent to Glass device during Tangram Assembly task.

## Variables and Data Collection

The independent variable was the systematic implementation of the context-aware, What’s Next? Glass application on a wearable device to learn new vocational chained tasks. The dependent variables were the number of steps completed (a) independently without receiving context-aware instructional prompts or (b) correctly with independent use of the What’s Next? system to provide instructional prompts for each vocational task. Event recording procedures were used to record the number of task-analyzed steps completed independently or correctly through use of the What’s Next? system. Data were collected through use of a prepared data sheet designed to record the controlled presentation of tasks analyzed chains. An independent response was defined as initiating the first step in the task analysis within 10 s and completing each step within 10 s without asking the device for assistance. A correct response was defined as accessing the What’s Next? system independently to request assistance for how to complete the step and then performing the actions required to complete the step as instructed during the pre-training instructional phase.

The number of task-analyzed steps completed independently was divided by the total number of steps to calculate a percentage of task analyzed steps completed independently. The percentage of steps completed independently was graphed for visual analyses. Similarly, the number of task-analyzed steps completed correctly was also divided by the total number of steps to calculate a percentage of task analyzed steps completed correctly, and was graphed for visual analyses.

## Experimental Design

A multiple probe across skills design (Gast, 2010) was employed to evaluate the relation between the context-aware What’s Next? Glass system and the acquisition of the skills required

to complete the unfamiliar tasks for three college-aged students with ID and ASD. Each student was assigned three unfamiliar tasks. Each task consisted of three phases including baseline, pre-training, and the What's Next? system intervention. The intervention was first introduced to Task 1 when stability in baseline performance by each student was observed. For Tasks 2 and 3, introduction of the What's Next? system was contingent upon each student's acquisition of the preceding task. Task acquisition was defined as independent completion of all task-analyzed steps for three consecutive sessions.

### Procedures

**Baseline.** During baseline, each participant was asked to complete each of the three targeted tasks. For Task 1, Making Copies, each student was handed a stack of papers and given the verbal direction, "I need you to make three sets of double-sided copies". The four-digit copy code was written on a 3x5 inch post-it note and was stuck to the top of the stack of papers to be copied. For Task 2, Accessing ID Account, each student was asked to sit in front of a lab computer and then asked, "I need you to download a copy of your ID transaction history for this month". Students' login information (NetID and password) was provided if requested, but no additional assistance was provided. For Task 3, Tangram Assembly, each student was asked to sit at a large conference table across from the researcher. The student was asked to receptively identify different shapes by touching the shape requested out of a field of six to nine shapes presented in random arrangement on the table in front of them. Then, each student was asked to demonstrate spatial relationships, actions, and sub composition (e.g., adjacent, rotate clockwise 90º, make the same shape using only two pieces). Finally, each student was asked to use the set of foam blocks to complete three tangram puzzles. For the puzzles, a shape outline was shown on an index card and the student was asked to copy the shape using the tangram shapes provided.

The student was allowed to look at the card for as long as desired, but not allowed to place the foam blocks on top of the outlined shape on the index card. For all tasks, students were asked to "try your best" and no additional assistance was provided. Data were collected for a minimum of three sessions for each participant on baseline performance of each task until data were considered stable. The "80%-20%" stability envelope criteria, which states that the data are considered stable if 80% of the data points fall on or within 20% of the mean (Gast, 2010), was used to establish stability.

**Glass Training.** Two pre-training phases occurred regarding operation of the Glass device and the What's Next? application: (a) operation of the Glass device and the What's Next? application, and (b) using the Glass device and What's Next? application for Tasks 1 and 2. The first pre-training phase addressed navigation of the device interface. The second pre-training phase verified that the students were able to operate the What's Next? system *in-vivo*; that is, while completing the actual task. The researcher implemented the Model-Lead-Test procedures (Adams & Englemann, 1996) to instruct the participants on the basic operations of the Glass device and use of the What's Next? application. First, the researcher modeled launching the What's Next? application by using the voice command ("Ok glass, what's next?"), using head movements to position the device camera view around the targeted task image, and tapping the trackpad to take and accept the picture. Then, the researcher led the students as they practiced using voice commands to launch the application, using the device to take pictures, and tapping and swiping gestures on the device trackpad. When a student was observed incorrectly operating the device or taking photos that would not be sufficient to send to the machine learning server, the researcher implemented a system of least prompts to provide error correction procedures. A 4-s delay occurred between each prompt level. The least-to-most prompt hierarchy (Ault &

Giffen, 2013) consisted of the following levels (a) verbal prompt (e.g., “[Name] do you see the pink dot?”), (b) gesture plus verbal explanation (e.g., pointing to the pink dot and saying, “[Name], position the picture to include the pink dot), and (c) physical assistance plus verbal explanation (e.g., investigator guiding the participant’s head position to the correct angle, guiding the participant’s finger to access the device trackpad, and saying, “[Name], position the picture and tap”). Lastly, the researcher tested each participant on the ability to launch the What’s Next? application, correctly position the device camera to take a picture, and tap the trackpad to take and accept the photo independently for three consecutive sessions.

After students acquired the first training phase, the researcher implemented the second training phase. The purpose of this phase was to verify that students were able to operate the Glass device and the What’s Next? application *in-vivo* to complete Tasks 1 and 2. Additionally, the researcher wanted to verify that all students received the What’s Next? instructions for each step in order to complete the task independently. Although students may have been able to independently perform a specific step of the task prior to intervention, all students were directed to use the What’s Next? system to take a picture of each step and follow the instructional prompt received to complete each task two times. The second *in-vivo* pre-training occurred only for two sessions regardless of student performance. If student errors occurred, least prompt procedures were implemented similar to the first pre-training phase.

Students were instructed to wear the Glass device and launch the What’s Next? application using either the voice command or the touch/tap gestures on the device trackpad. For Task 1, the researcher handed the student a stack of papers to be copied and said, “I need three sets of double-sided copies”. The four-digit copy machine code was written on a 3x5 inch post-it note and adhered to the top of the stack of papers to be copied. Then, the students were asked to

face the copy machine and instructed to begin the task by using the verbal command, “Ok Glass, what’s first?” The device provided verbal and visual directions to “position the picture and tap” to take an image of the copy machine screen and the tap again to accept the captured image. The image was processed and the contextually-aware instructional prompt was returned. The student received the prompt and then was expected to complete that step of the task as directed. The image and text remained on the device display until the step was completed and the student was ready to repeat the process to receive instructions for the next step. When each step was completed, the student swiped down on the device trackpad to dismiss the image. This process repeated until the final step of the task, in which the student was directed to change the phrase to “Ok Glass, what’s last?” to receive the last instruction.

Similarly for Task 2, the researcher verified that students were able to operate the Google Glass device and the What’s Next? application to access their monthly transaction history for their student ID accounts. The researcher asked the students to begin the task by using the phrase, “I need you to download a copy of your ID transaction history for this month”. Students’ login information (NetID and password) was provided if requested, but no additional assistance was provided. Students were expected to ask, “Ok Glass, what’s first?”, tap to take and accept the picture, and complete the step according to the instructional prompt received. In summary, the purpose of the second pre-training phase was to verify that students were able to use the Google Glass device and the What’s Next? application to receive the instructional prompt to complete each step of Tasks 1 and 2.

**What’s Next? System Intervention.** After completing the two pre-training phases, students were simply asked to wear the Glass device and complete the task. Baseline and the second pre-training phase procedures were followed, except the students were allowed to

complete as much or all of the steps of the task independently. Students were reminded that if they did not know how to complete a specific step of a task that they could ask the Glass device for help by saying, “Okay Glass, what’s next?”. No additional researcher assistance was provided.

**Interobserver and Procedural Reliability**

Interobserver reliability (IOR) and procedural reliability data were collected by the lead investigator and a graduate student simultaneously and independently. Interobserver reliability data was collected during a minimum of 60% of baseline and intervention sessions for each participant. Observers recorded the number of steps performed independently for each vocational task for each student. Interobserver agreement was calculated by dividing the number of agreed upon participant responses by the total number of participant responses, multiplied by 100. IOR was defined as 90% or greater, if the IOR was lower than 90%, then the two observers met to review all data. The mean IOR agreement for each student across phases was 96% for Toby (range = 95 – 97 %); 94% for Steven (range = 93 – 95%); and 95% for Susan (range = 94 - 96%).

Procedural reliability data also were collected during a minimum of 60% of pre-training and intervention sessions for each participant. The researcher was required to provide participants with the necessary materials (i.e., Google Glass device, papers to be copied, copy machine code, tangram shapes, and tangram work area board), and provide a system of least prompts contingent on observation of incorrect device operation. Using the task analysis (see Appendix B) of the procedures provided, the observer was instructed to record whether the procedures were followed as intended. The procedural agreement level was calculated by dividing the number of observed investigator’s behaviors by the number of planned

investigator's behaviors and multiplying by 100. Procedural reliability was defined as 90% or greater. If procedural reliability was calculated to be below 90%, the investigator and observer met and reviewed all intervention procedures. The mean procedural reliability levels for each student across phases was 100% for Toby; 98 % for Steven (range = 94 – 100); and 100% for Susan.

### Social Validity

A 10-item Likert survey (see Appendix C) was created and administered to each student upon conclusion of the intervention phase to gather information regarding their opinions and acceptability of using the What's Next? system to learn new vocational skills. All survey items were read aloud to each student. The Likert scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree). Visual graphics were added to support comprehension of the response choices. Two open-ended questions were also included on the social validity measure and student responses were dictated and scribed by the investigator.

## Results

The results of each student are displayed in Figures 2.5, 2.6, and 2.7. Overall, the students completed a mean of 11% of the task analyzed steps independently to make copies, 10% to check their ID account, and 47% to assemble tangrams during baseline. During the context-aware intervention, students required a mean of 4.3 sessions with a mean of 98.6% of the task analyzed steps completed independently to make copies, mean of 5 sessions with a mean of 95.3% of the task analyzed steps completed independently to check their ID account, and mean of 6 sessions with a mean of 94.3% of the task analyzed steps completed independently to assemble tangrams. Toby, Steven, and Susan immediately acquired the tasks with a mean of 100% nonoverlapping data.

**Toby.** Figure 2.5 displays Toby's results. Toby completed a mean of 23% of the task analyzed steps independently to make copies, 10% to check his ID account, and 62% to assemble tangrams during baseline. During the context-aware intervention, Toby required three sessions with a mean of 100% of the task analyzed steps completed independently to make copies, six sessions with a mean of 93% of the task analyzed steps completed independently to check his ID account, and seven sessions with a mean of 92% of the task analyzed steps completed independently to assemble tangrams. Toby immediately acquired the tasks with a mean of 100% nonoverlapping data.

**Steven.** Figure 2.6 displays Steven's results. Steven completed a mean of 10% of the task analyzed steps independently to make copies, 10% to check his ID account, and 38% to assemble tangrams during baseline. During the context-aware intervention, Steven required three sessions with a mean of 100% of the task analyzed steps completed independently to make copies, three sessions with a mean of 100% of the task analyzed steps completed independently to check his ID account, four sessions with a mean of 99% of the task analyzed steps completed independently to assemble tangrams. Steven immediately acquired the tasks with a mean of 100% nonoverlapping data.

**Susan.** Figure 2.7 displays Susan's results. During baseline, Susan completed 0% of the task analyzed steps independently to make copies, a mean of 10% to check her ID account, and 42% to assemble tangrams. During the What's Next? intervention, Susan required seven sessions with a mean of 96% of the task analyzed steps completed independently to make copies, six sessions with a mean of 93% of the task analyzed steps completed independently to check her ID account, and seven sessions with a mean of 92% of the task analyzed steps completed

independently to assemble tangrams. Susan demonstrated immediate acquisition across all three tasks with 100% nonoverlapping data.

**Social Validity**

The results of the social validity questionnaire indicated that using the What's Next? system to learn new vocational tasks was reported to be socially acceptable by all students. Results also indicate all three students agreed or strongly agreed that they (a) liked the ability to see the visual and text directions at the same time as hearing the directions aloud, (b) the What's Next? system helped improve their vocational skills, (c) the What's Next? system was easy to use, (d) receiving help for only the steps needed helped them learn the task quickly and remember the steps independently, and (e) they would be interested in using Glass to learn more skills in the future. The open ended questions from the social validity survey also indicated that the participants enjoyed using the Glass experience to learn new vocational skills.

## Discussion

The purpose of this study was to examine the effects of using context-aware and wearable technologies to deliver instructional prompts for completing new vocational and independent living skills to college-students with ID and ASD. All students demonstrated the ability to independently use the context-aware intervention to acquire all of the skills required to complete each of the three tasks. All students demonstrated substantial increases in their performance tasks. A functional relation was established since experimental control occurred by demonstration of data variation patterns in at least three different series in time between improved task performance and the introduction of the What's Next? system intervention (Kratochwill et al., 2010). These findings support the previous lines of research demonstrating computer assisted instruction (CAI) is an effective method to teach students with ID to chained

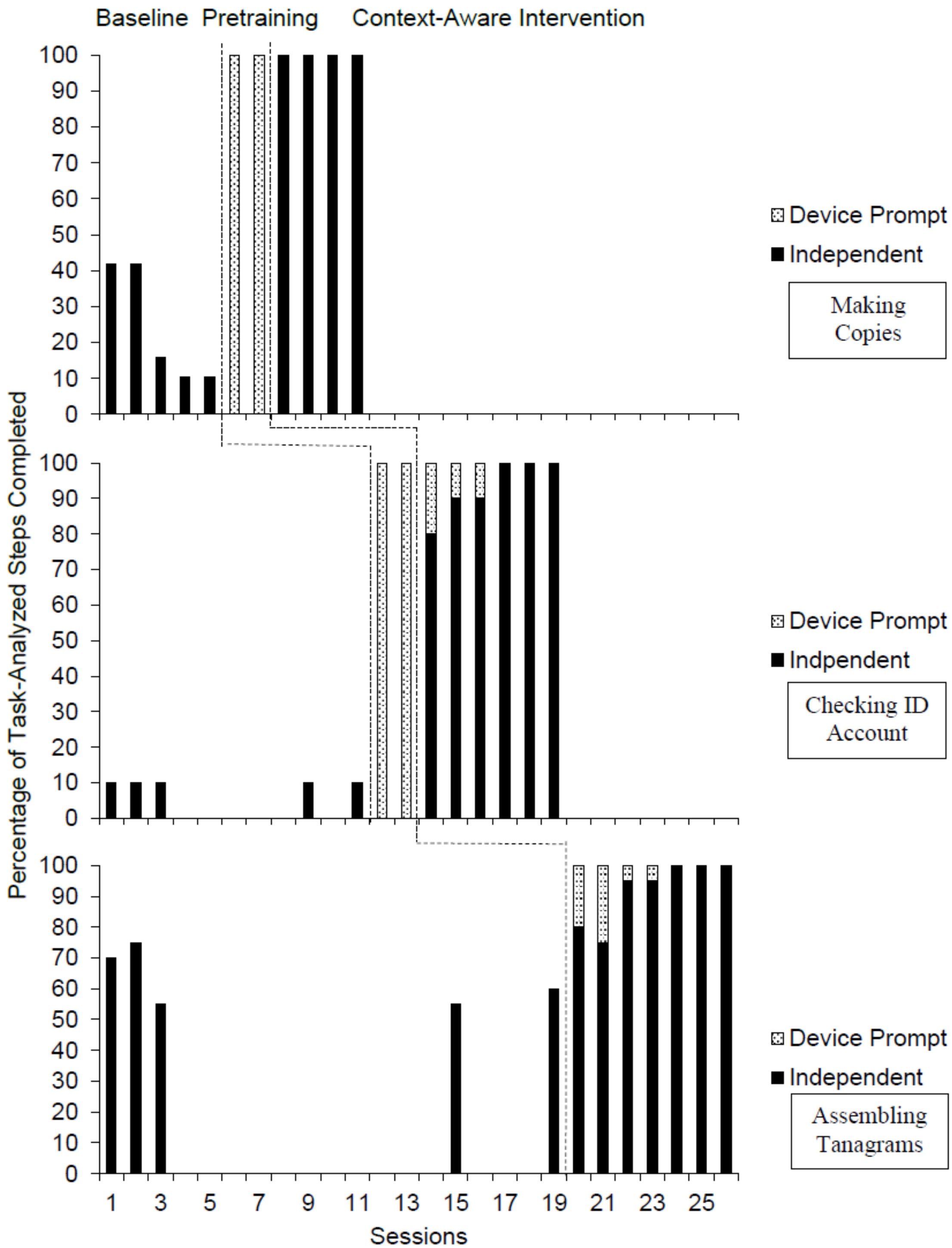


**Figure 2.5.** Toby's percentage of task analyzed steps completed independently

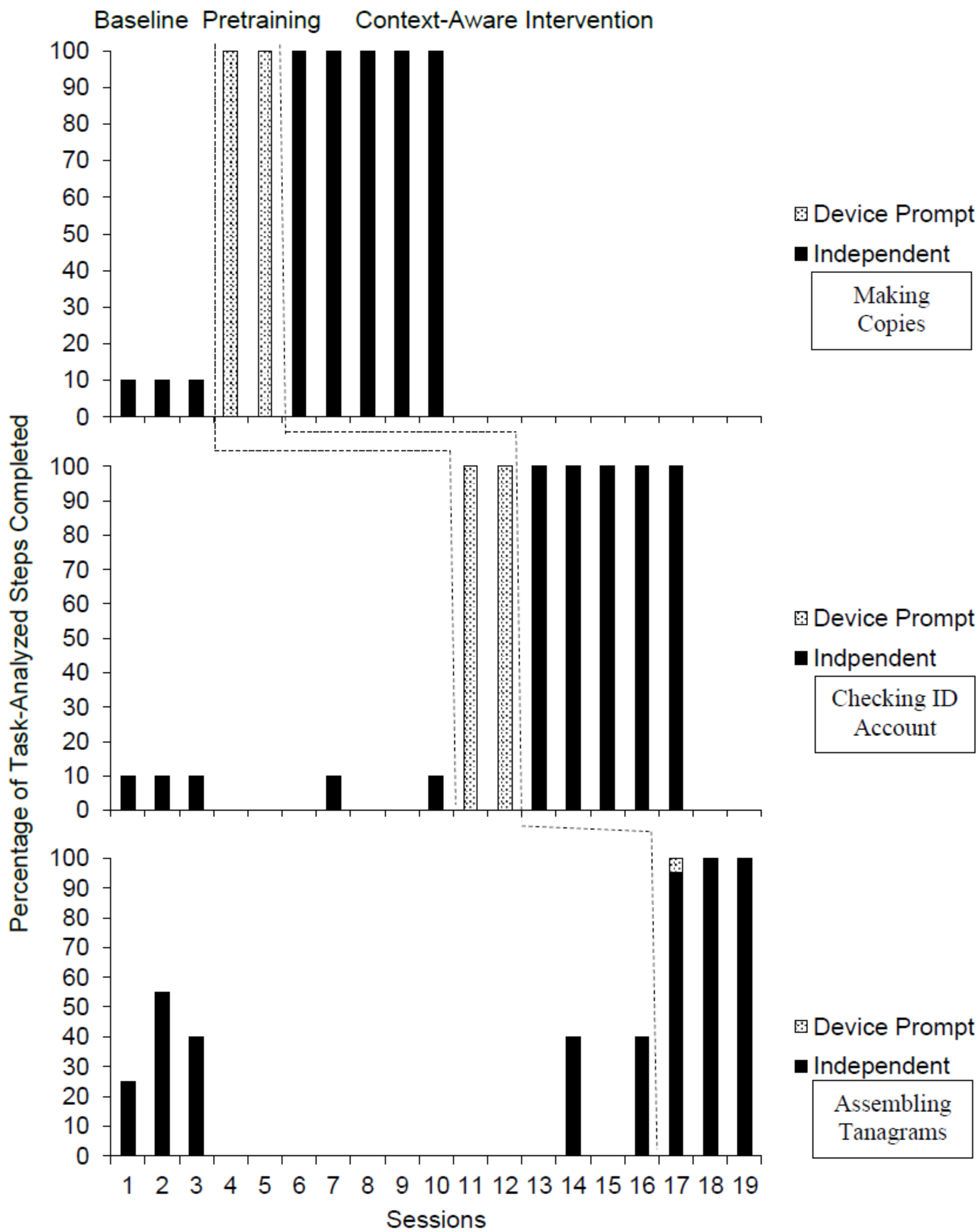


**Figure 2.6.** Steven's percentage of task analyzed steps completed independently

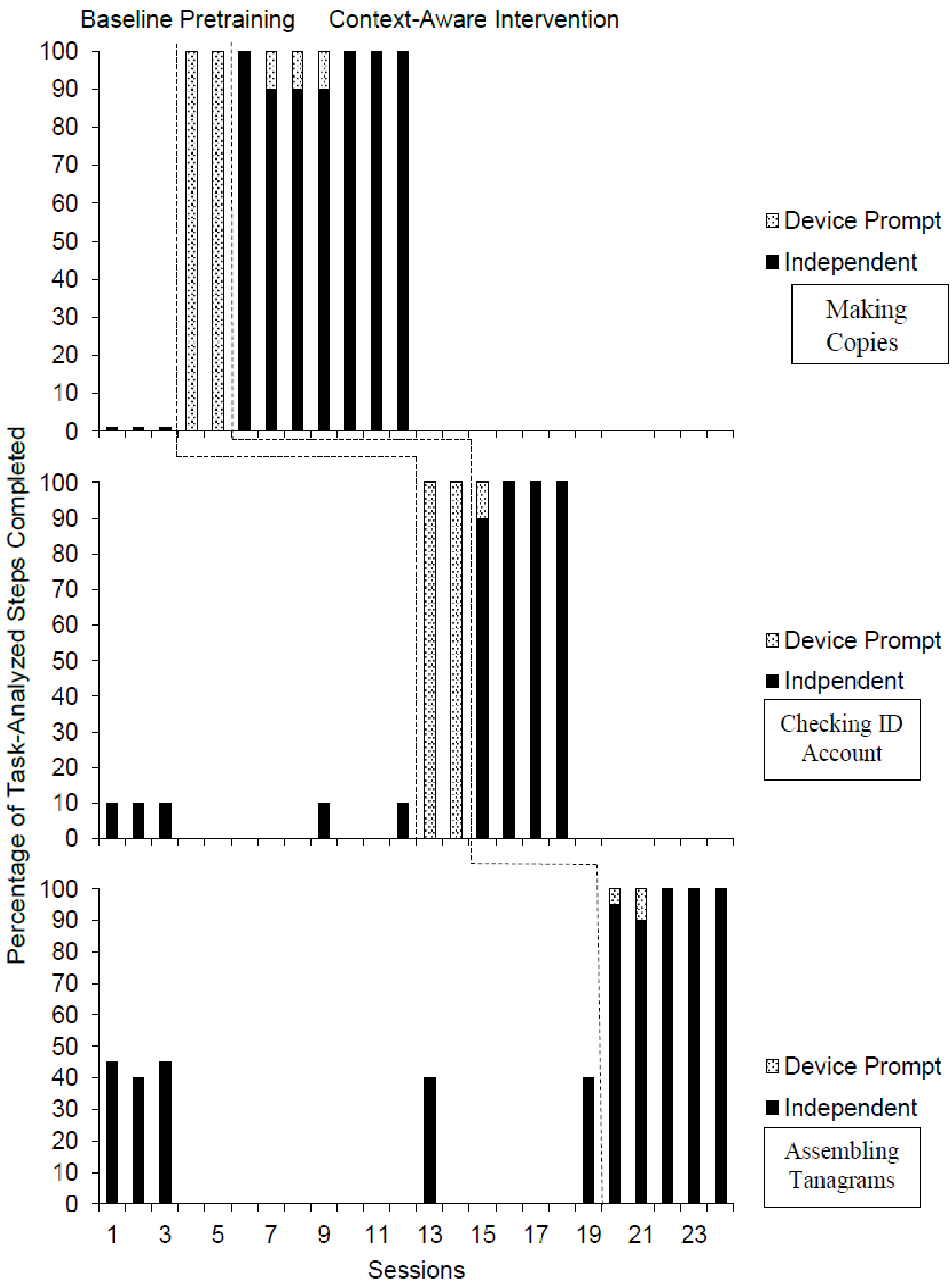


**Figure 2.7**. Susan's percentage of task analyzed steps completed independently

vocational tasks (Ayers & Cihak, 2010; Hutcherson, Langone, Ayers, & Clees, 2004; Riffel et al., 2005), and to demonstrate self-advocacy skills (Lancaster, Schumaker, & Deshler, 2002). Further, these findings support the use of mobile devices as effective tools for teaching vocational and independent living skills to students with ID (Ayres, Mechling, & Sansosti, 2013).

This study extends the research in several important ways. First, an intelligent, contextually-aware system using augmented reality views and wearable devices was demonstrated as an effective system to teach students with I/DD vocational tasks. Second, through the combination of machine learning and computer vision techniques, an in vivo learning experience was ubiquitously delivered through the use of a wearable Glass device display which allowed active engagement in and control over the learning environment and instructional prompts as needed. Third, all students successfully acquired the skills needed to independently operate the Glass device and access the application.

**Limitations**

Although this study indicated positive outcomes, conclusions must be interpreted within the context of this study and several limitations need to be considered. First, similar to other single-subject designs, only a small number of participants (*n* = 3) was included in this study. Small sample sizes makes generalization of the results to another population more difficult. Replication of this study across a larger number of participants.

Another significant limitation of this study is caused by the absence of measures for skill maintenance and generalization. Although students acquired the skills needed to complete the tasks quickly, the effects of the What's Next? system on skill maintenance over time are needed. The collection of maintenance probes in this study were prevented by time constraints. This

limitation also should be addressed in future research.  Further discussion of the potential for future research and implications is provided in Chapter IV.

# Chapter III

## Study II: Evaluating the Use of a Smartwatch Application as a Self-Management Tool for Prompting College Students with I/DD and ASD to Initiate and Complete Daily Tasks

## Authors Notes

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## Introduction

The primary goals of educational and vocational programming for individuals with disabilities are essentially one in the same, that is, 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 and autism, 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 (Hume, Loftin, & Lantz, 2009; Smith, Maenner, & Seltzer, 2012). Independent functioning in daily routines requires the ability to complete designated tasks from one activity to the next. Because self-management of appointments, schedules, and to-do lists is critical to independence in adulthood, it continues to be an area of interest and concern in the extant literature (Carnahan et al., 2009; Mechling, 2007).

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 (Ayers 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 (Hume, 2004). Prolonged prompt dependency results in limited future opportunities for students, including restrictions in possible career options (Hume et al., 2009). The use of prompting procedures often requires the use of additional supports or self-management strategies to increase the probability that an individual will learn to perform skills and tasks correctly and with 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, Sartini, & Spriggs, 2015). Picture or object cues, written words and checklists, environmental arrangements, maps, schedules, and scripts are all considered visual supports and are, in some way, used by everyone throughout daily life. Activity schedules are visual supports for completing daily routines and can be comprised of actual objects, photographs, icons, drawings, 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 (i.e., daily schedule) are referred to as between-activity schedules, and those providing directions for the actions to be completed during a given activity are called within-activity schedules (i.e, to-do list) (Banda et al. 2009; Lee 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. Self-operated prompting systems involve independent operation and are a type of antecedent self-management that involve 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, Alberto, & Fredrick, 2006; Taber, Seltzer, Heflin, & Alberto, 1999). Previous research has shown self-operated prompting 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 washing dishes and following the steps of a recipe (MacDuff, Krantz, & McClannahan, 1993).

Traditionally, self-operated prompting systems for completion of daily routines have relied on visual materials (Lancioni, O'Reilly, & Oliva, 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) student completes the step, (c) student marks the step as complete (i.e., cross off, flip page or card, remove card), and (d) proceeds to the next picture until all steps are completed. However, the recent advancements in and increased availability of 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 the steps of each task and transition between tasks independently.

**Purpose**

Context-aware and wearable technologies have the potential to compensate for some of the cognitive characteristics 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 at the right time and place the action is required. The major advantage of contextual awareness is that the user can be notified automatically without having to remember anything, such as keep 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, Baddeley, & Hewes, 2000; Jarrold & Towse, 2006). For example, information remembered on Monday may not be able to be recalled on Tuesday. With the use of context-aware the need to remember where a written checklist was stored or located, or remember to refer to it periodically throughout the day are no longer required 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.

A combination of a wearable smartwatch device and an installed application provided the context-aware technology used in this study. GuruWear is a free application that provides a mobile or web-based platform for creating visual, step-by-step routines. Within the GuruWear application, these visual routines are called formulas. Creation of a new formula offers many customizability features, including leveled text, the ability to add an image, audio clip, or short animation to a specific step, configure auto-start timers to count down or count up for a specified amount of time, and enter parameters based on reaching a specific step count for completion of a step in a fitness routine. Formulas created on the web-based platform can be sent to the user's wearable device through the accompanying application on the paired smartphone to be installed. Formulas are executed on the wearable device through a selection of companion applications

offered by the same application developers that only run on wearable platforms.  A smartwatch was the device used in this study.  MoveUp! Alarm was the application used to assign and execute formulas on the smartwatch device.  An example of this technology is illustrated in Figure 3.1.  The left image is an example screenshot of a formula step as displayed on the watch face.  The right image is an example screenshot of the final interactive checklist step of the formulas created for use in this study.  The progression of steps is performed by tapping done at the bottom of the step screen, and completion of the formula occurs when all checklist items are marked as complete.

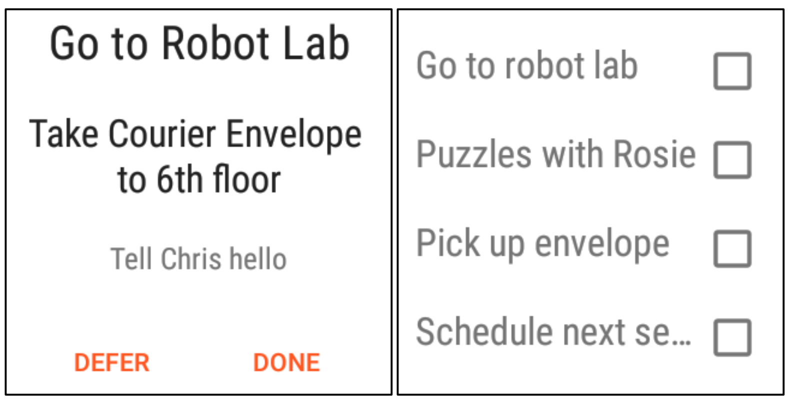


**Figure 3.1.** Example screenshots of initial and final formula steps as displayed on the smartwatch platform.

Due to the complexity of independent living skills, appropriate technology should be selected to assist individuals with disabilities in completing routine and novel tasks independently. The purpose of this study was to examine the effects of the use of a context-aware application and a wearable device as a self-management system to prompt independent task completion.  By teaching college students with I/DD 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:

1. What are the effects of using a wearable device as a self-operated prompting system on independent task completion by college students with ID and ASD?
2. Do college students with ID and ASD report their experience using the wearable device as a reminder 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 four to eight hours 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 three 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, pre-training, 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 inclusive campus and workplace environments, including common areas and a computer lab. Baseline data collection, pre-training 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 to 10 other university students with and without disabilities.

**Participants**

Three college-age students with intellectual disability and autism participated in this study. Participants attended a postsecondary education (PSE) program for students with I/DD located at a large southeastern university. 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 intellectual disability, (b) participation in a postsecondary education program, (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 in respect to the self-management of schedules was a consideration in selection for participation in this study. Each of the three participants included in this study exhibited unique challenges in regards to independently managing appointments. Descriptions of the participants are included.

Participants' full-scale IQ scores ranged from 61 to 67, all of which fall more than two standard deviations below the mean. 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, Schrank, McGrew, & Mather, 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 (IEP). Additionally, all students met the eligibility guidelines for admission to the PSE program (e.g. diagnosed with an intellectual disability or autism, had an IEP in K-12 education settings, and not able to enroll and/or not likely to be successful in a "regular" college or university program with accommodations). Diagnostic and educational information including IQ, adaptive behavior, and academic achievement measures for each participant is provided in Table 3.1.

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. The Digital Literacy Skills courses consisted of a four-semester sequence of classes focusing on the skills required to function in digital environments. As a part of these courses, students gained experience using desktop computers and mobile devices, specifically using the program-issued iPads assigned to each student for the duration of enrollment.

**Jackson.** Jackson was a 19 year-old student diagnosed with intellectual disability 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 indicates the probability of an autism spectrum disorder 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 as measured by the WJ-III Tests of Achievement.

**Table 3.1**. 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 |

**Note [a]**ASD = autism spectrum disorder, ID = intellectual disability, CCN = complex communication needs; [b] Wechsler Intelligence Scale for Children-III (Schrank, Becker, & Decker, 2001); [c] Vineland Adaptive Behavior Scales, 2nd Ed. (Sparrow, Cicchetti, & Balla, 2005); [d] Gilliam Autism Rating Scale, 2nd Ed. (Gilliam, 1995); [e]Woodcock-Johnson III Tests of Cognitive Abilities: Basic Reading Skills Subtest (McGrew & Mather, 2001); [f] Woodcock-Johnson III Tests of Cognitive Abilities: Understanding Directions Subtest (McGrew & Mather, 2001).

**Colby.** Colby was a 21 year-old student diagnosed with intellectual disability 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, Balla, Cicchetti, 1984). Academically, Colby's Basic Reading Skills subtest score was 17, which indicates negligible proficiency, and his Understanding Directions subtest score was 41, which indicates very limited proficiency as measured by the WJ-III Tests of Achievement.

**M.J.** M.J. was a 20 year-old student with intellectual disability 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 indicates the probability of an autism spectrum disorder to be "very likely". Results from the WJ-III showed a score of 77 on the Basic Reading Skills subtest, which

indicates very limited proficiency, and a score of 88 on the Understanding Directions subtest, which indicates limited to average proficiency.

## Materials

The materials used in this study included the smartwatch devices and paired smartphones, printed student checklists, and the GuruWear and MoveUp! applications. All materials were located in a cabinet in the classroom and were labeled with colored tape and stored in matching colored bins. In addition to participant pseudo names for confidentiality, each participant was assigned a color, which corresponded to the same colored bin where the smartwatch and paired smartphone, checklists, and data collection procedures and forms were located.

**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. Additionally, these smartwatches allow direct user input through either voice commands or swipe/tap gestures applied to the touchscreen of the watch face.

**Smartphones.** Each smartwatch was required to be paired with a smartphone for initial watch configuration and set up. Additionally, the smartphone was used to install GuruWear formulas to the paired smartwatch devices. The smartphones were used by the researcher for smartwatch settings configuration and to push the created and revised formulas to the paired smartwatches. The smartphone was also color-coded to match the paired smartwatch and stored in the same colored bin.

**Student checklists.** The student checklists were created by the researcher using Microsoft Word. Each checklist included three sets of appointments and four associated tasks to be completed by the student during the coming week. The appointments (locations) were selected by the researcher 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 upon arrival to digital literacy class each Monday morning for the duration of the study. An example of the student printed checklist is provided in Table 3.2.

**Table 3.2.** Example Printed Student Checklist

| Computer Lab[a] | Bookstore | Library | Robot Lab |
|---|---|---|---|
| 9:00 am on Mon. | Wed. @ 1:45 pm. | 3:00 pm. 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 |

**Note.** [a]Pre-Training 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, which are described by the application developers as step-by-step plans, 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. Formulas are associated with the user's Gmail address and can be synced across all linked devices, computers, and tablets through the installed application and an Internet connection. Creation of a new formula can be done through the GuruWear website or through the mobile application. Execution of formulas on a wearable device requires one of the companion applications offered by GuruWear and w9 software, 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 download through the Google Play store at no cost.

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 appointment information had been entered as a new alarm and saved, students were notified to begin the practice appointment by initiating the first task. 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.

**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 appointment information as a new alarm. An example screenshot view of the MoveUp! Alarm application alarm creation screen is provided in Figure 3.2. 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 GuruWear formula is selected.

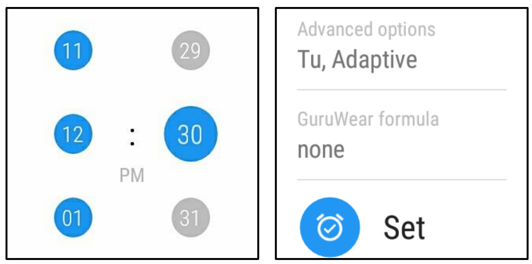


**Figure 3.2**. Example screenshots of the MoveUp! Alarm application alarm configuration view on the smartwatch.

### 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 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., Wednesday 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 level of assistance required. Data were collected through use of a prepared data sheet designed to record the controlled presentation of tasks 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 3.3.

**Table 3.3.** 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 |

## 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 percent 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 participant in the baseline phase. Baseline ($A_1$) 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 ($B_1$), the criterion for changing the phase was defined as 100% independent task completion for three consecutive days. For the withdrawal phase ($A_2$), 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 ($B_2$). When the first participant started the intervention reintroduction phase ($B_2$), the next student was introduced to the smartwatch intervention phase ($B_1$), followed by the withdrawal phase ($A_2$), and, finally, the reintroduction of the smartwatch intervention ($B_2$). This process continued until all students participated in all phases of the study.

## Experimental Procedures

**Baseline**. Baseline data were collected for a minimum of three sessions or until stability was achieved. A session was defined as 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 were 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 following tasks by Friday. The list included a specific day, time, location, and four discrete tasks that needed to be completed. No additional feedback was provided.

**Pre-training**. Prior to implementing the intervention, the researcher provided three 20-minute training sessions to each student individually. The pre-training 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.

First, the relevant pieces of information in an appointment were defined and each student was then asked to identify the appointment name, location, time, day, and associated tasks of sample scenarios given by the researcher. 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 & Englemann, 1996) were implemented 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 GuruWear formula on the smartwatch is provided in Table 3.4, and a screenshot view of the alarm creation screen on the smartwatch is provided in Figure 3.2.

The researcher modeled how to enter an appointment and assign a formula to create a new alarm using the MoveUp! Alarm application on the smartwatch. Then, the researcher 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 (Adams & Englemann, 1996) were used to teach basic operation of the smartwatch device to access the installed GuruWear formula, swipe left to view the next step, and mark the tasks as complete on the final checklist card. Then, the researcher led each student through the process of accessing the formula, swiping left to view the next step, and marking the tasks as complete on the final 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 prompts procedures (Ault & Giffen, 2013). A four-second 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 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 GuruWear 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 was 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% independency for three consecutive sessions.

**Table 3.4.** 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. |

**Context-aware smartwatch intervention.** The intervention was implemented after the student reached pre-training 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 GuruWear formula into the smartwatch in the same fashion as during

the pre-training sessions. Figure 3.1 illustrates the GuruWear display. 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 printed and 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.

**Re-implementation of the smartwatch intervention.** Similar to 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 students participating in the study. The students completed a 10-item Likert survey questionnaire related to the opinions and acceptability of using the smartwatch as a self-operated prompting system (see Appendix E). All questions and response choices were read aloud to the students. Each survey item used a Likert

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 response 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 change in the dependent variable, and data across all phases were used to document a functional relation (Gast, 2012).

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. The percentage of non-overlapping data (PND) was calculated between the baseline and intervention phases for each participant (Scruggs, Mastropieri & Casto, 1987). The 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 a highly effective intervention, PND greater than 50% and less than 70% as questionably effective, and PND less than 50% to be considered an unreliably effective intervention.

**Interobserver 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. Interobserver agreement 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 pre-training 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 pre-training and intervention procedures by the researcher. The observer was provided with a task analysis of instructional procedures for the treatment conditions (see Appendix D) and recorded if specific instructional procedures were observed. The procedural agreement level was calculated by dividing the number of observed researcher's 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 of the study. If procedural reliability fell below 90%, then the researcher and observer reviewed the instructional procedures. The 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 3.3. Baseline measures indicated the students could not complete any of the novel appointments prior to intervention. No correct responses occurred during baseline. 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. When students used the smartwatch device during intervention, ascending trends were observed and 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% to 100%). He reached criteria after three sessions with 100% nonoverlapping data, demonstrating an immediate change. When the smartwatch intervention

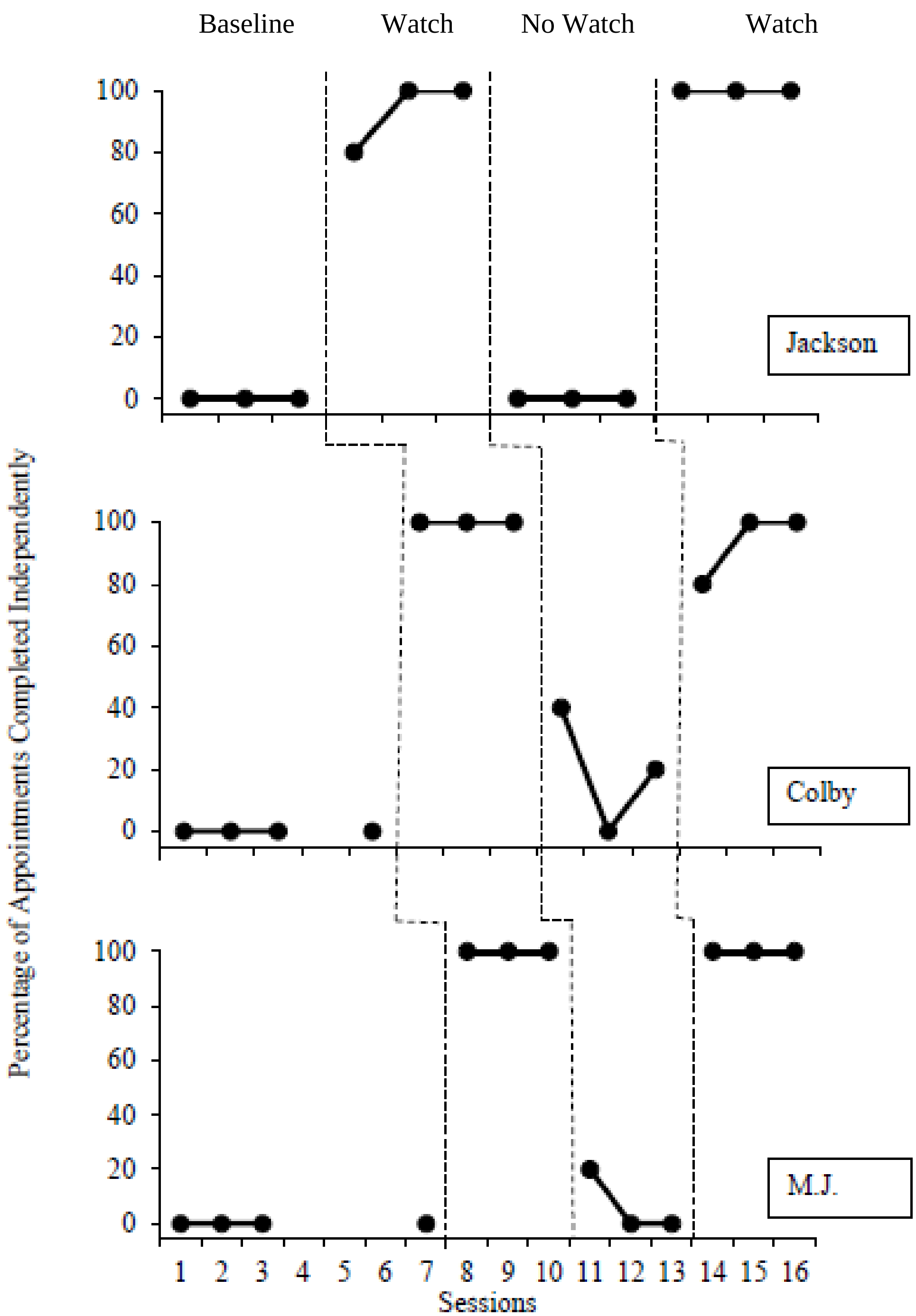


**Figure 3.3.** Percentage of appointment tasks completed independently across students with and without the smartwatch intervention.

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% to 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 appointment location but was two hours past the scheduled appointment start time. When the smartwatch intervention was reimplemented, Colby's completed appointments increased to a mean of 93% (range = 80% to 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% to 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 MoveUp! Alarm and GuruWear formulas were easy to use, and (c) that 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 a tool 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).

These findings extend previous literature in several ways. 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. Students were able to complete novel appointments and tasks independently without person-provided prompts or time intensive visual supports. 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 for students to improve self-management and task completion skills.

**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 only allowed 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 teaching students with ID and ASD to self-manage prompts for completion of appointments and associated tasks. 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 should also include examination of instruction to teach independent formula, or checklist, creation for real-world tasks.  The social acceptability of this tool offers users the opportunity to improve independent task completion in a socially valid and acceptable way.

# CHAPTER IV

## Discussion

This dissertation examined the potential for wearable devices to provide contextually-aware supports to individuals with intellectual and developmental disabilities. Chapter I defines wearable technology and context-aware applications, as well as provides a preliminary exploration of the currently available research. These technologies have yet to be featured in investigations involving increasing independence of students with intellectual disabilities. While the available research is limited in special education applications of these technologies, Chapter I provides a theoretical foundation supporting their use in special education by establishing connections to evidence-based practices.

The two companion studies included in this dissertation shared the common purpose of improving the autonomy of college-aged students with I/DD through the use of wearable devices and context-aware applications. The results of these two studies replicate and extend previous research evaluating the effectiveness of technology-based interventions for teaching new skills, task initiation and completion by students with I/DD. Previous findings suggest that mobile technology is an effective tool for students with intellectual disability to learn vocational and independent living skills (e.g., Cihak et al., 2010; McMahon, et al., 2015), and self-management of prompts (Mechling, 2007). These two studies extend this research by including wearable devices and focusing on the development of self-determination skills.

**Study I**. The results from Study I demonstrated that the skills required to complete new vocational tasks independently were quickly acquired by three college-aged students with intellectual disability. These results support the findings from previous research, illustrating students with I/DD can learn chained vocational tasks through the use of mobile devices (Ayers & Cihak, 2010; Hutcherson, Langone, Ayers, & Clees, 2004; Riffel et al., 2005).

However, Study I also extends the previous line of research to include self-operation of a hands-free, smartglasses wearable device to learn new vocational tasks. Through implementation of the Model-Lead-Test procedures (Adams & Englemann, 1996), students learned the skills to operate the smartglasses device independently in order to complete the functional tasks. Study I also extends the line of augmented reality (AR) research involving students with disabilities. Much of the previous AR research conducted with individuals with I/DD involved the use of hand-held mobile devices, such as smartphones and tablets. This study demonstrates that wearable, head-mounted displays, like Google Glass and other smartglasses automatically provide AR and, therefore, can further build on the AR foundational work to support functional skill development and self-management by students with I/DD.

**Study II.** Study II illustrates that students with ID and ASD can learn to self-manage schedules and enter novel appointments into a wearable smartwatch device. Using the smartwatch intervention, students' abilities to remember new appointments and complete associated tasks during appointments was dramatically and immediately increased. Withdrawal of the smartwatch intervention returned to approaching baseline levels, and reimplementation replicated initial intervention effects. This data pattern suggests that the wearable smartwatch intervention used in this study is likely to be a viable means of providing permanent antecedent prompts to people with intellectual disability and autism to mitigate cognitive limitations. By teaching students to self-operate the smartwatch device and enter new appointments, the students were able to achieve high levels of success in self-managing their weekly schedules and in performance of associated tasks during appointments.

The characteristics associated with an intellectual disability include difficulty with memory, prolonged attention, maintaining task speed, and accuracy in task performance (Brewer

& Smith, 1982). These central learning traits produce a negative impact on the productivity levels of individuals with intellectual and developmental disabilities. For example, people with I/DD frequently require extended amounts of time and repeated opportunities for practice in order to acquire, maintain, and generalize learning of new skills (Turnbull, Turnbull, & Wehmeyer, 2012). Additionally, when compared to their peers, people with I/DD demonstrate delays in physical movement overall (Rarick, 1973). These have been shown to be major contributing factors to experiences of hesitation from potential employers (Johnson, Greenwood, & Schriner, 1988).

**Self-Determination Skills**

Improved self-determination skills have been identified as one of the key benefits of postsecondary education programs for students with I/DD (Weinkauf, 2002). These two studies incorporated opportunities for self-operation, self-instruction and self-management to further enrich self-determination skill development. Higher levels of self-determination are correlated with greater positive outcomes as adults, including increased opportunities for employment and financial freedom (Wehmeyer & Palmer, 2003; Wehmeyer et al., 2007). The results of these two studies support these findings as participants demonstrated the ability to independently operate the technology to self-instruct new skills and self-manage daily reminders. Lachapelle et al. (2005) established that self-determination was significantly correlated with higher quality of life. As students gained the ability to self-operate the wearable devices, they were able to self-direct their learning of new vocational skills and self-manage prompts for daily and weekly reminders. Both of these outcomes promoted the development of self-determination skills and autonomy.

**Technology for Self-Instruction and Self-Management**

Independent living requires a variety of complex skills be acquired. Transportation, employment, personal care, and cooking are all critical components to gaining autonomy in adulthood. All of these components, however, are dependent on the underlying abilities to employ executive functioning skills in order to manage time and maintain and manage a daily schedule. The development of time-management skills has been shown to be correlated with successful school performance, higher scores of achievement, and stronger sense of responsibility (Britton & Tesser, 1991; Trueman & Hartley, 1996). Limitations in memory and difficulty with conceptual understanding of abstract processes, such as time and the passage of time, are often included as defining characteristics associated with the presence of an intellectual disability. These limitations often prevent activities requiring time-management and personal scheduling abilities from being successful. Most jobs require tasks be completed on time and in a specified sequence (Colorado Dept. of Education, 1983), as well as the ability to divide amounts of time and attention appropriately between and within multiple tasks (Martin, Elias-Burger, & Mithaug, 1987). With appropriate supports, previous findings suggest that students with I/DD can learn to self-manage and follow time-based schedules and task sequences, regardless of time-telling abilities (Martin et al., 1987; Bambera & Ager, 1992; Lovett & Haring, 1989).

While the majority of early investigations into self-management incorporated the use of pictures and other visual supports as antecedent prompts to increase students' abilities to follow different types of schedules and routines. The widespread growth and use of technology introduces a potential solution to mitigate the negative impact of cognitive limitations on time-management and task completion for people with I/DD. Further, the development of context-

aware applications and systems lessens the responsibility of the user to remember multiple things at any given time. Task automation allows the technology to remember for the user, and provides only the relevant reminders to the user's current activity or environment.

For example, in Study I, the What's Next? system provided an accessible technological tool for students to self-instruct new vocational tasks. However, once the students received the instructional prompts for every step of each task, they were encouraged to try to complete the task independently. If a student was unsure how to complete a specific step, they simply accessed the What's Next? system to receive just the information needed to complete that step and then allowed to continue completion of the task independently. In this way, the What's Next? system served as a self-management device. In Study II, the smartwatch intervention incorporated an interactive checklist of the tasks presented in the formula. The interactive checklist screen provided a means for the students to self-evaluate their task performance. Self-evaluation is also an important component to gaining successful self-determination and self-management skills.

**Limitations**

Although the results of these two studies indicated positive outcomes, conclusions must be interpreted within the context of this study and several limitations need to be considered. First, as is the case with all single-subject design research, both studies included a small number of participants ($n$ = 3 in both Study I and II). The small sample size makes it difficult to generalize the results to a broader population. These studies require replication across a larger number of participants.

A second limiting factor that should be considered involves the levels of fine motor, visual, and speech abilities required in order to access the applications and information presented

on the displays of the wearable devices. Although both the Google Glass and the Samsung Gear Live Smartwatch include options for user customization and accessibility, these options are restricted to few and minor changes. Also, these options are further constricted when using a device that is shared across users. The small size of the display screen is not conducive to increasing magnification levels, although options for doing this are provided in the settings of both devices used. The gesture-recognition areas (watch display and trackpad) are highly sensitive and therefore require a fairly high level of precision in use. These limitations should be heavily weighed by users with limited fine motor, vision, and/or speaking abilities. Future research should investigate other options and devices which may offer a greater variety of user-input options and accessibility settings.

Finally, it is important to consider the limitations of the technology itself. While application used in Study II was available for download through the Google Play Store at no cost, the What's Next? application used in Study I was custom-built by the researcher for the purpose of this dissertation. Smartwatches, such as the model used in Study II, are steadily becoming more prevalent and affordable in the consumer market. However, increased availability of device types can lead to ambiguity in identifying the best model to meet individual needs. Each brand and model of smartwatch currently on the market offers a different combination of features, which can create difficulty making informed comparisons. Additionally, although the Android Wear application development is thriving and new applications are released to the community daily, the platform is still relatively new. Therefore, an application may not be available to suit all needs of an individual with intellectual and developmental disabilities. Open-source application development allows and encourages sharing of application builds, but a high-level of technical expertise is required to do so successfully.

The smartglasses used in Study I were the original release of the Google Glass device and operating system. Not only were these devices more expensive, they are already no longer available for direct purchase through Google. Instead, it seems that different industries have adopted and adapted the original Glass device for specific uses within each field. While this model is no longer available for public purchase, it is evident that the concept of wearable computer devices, especially those worn directly on the face as glasses will continue to be improved upon and more options for purchase will soon be introduced. Regardless of the brand or operating systems of future smartglasses, the user-interaction experience and methods for user input (i.e., gestures and voice commands) will continue to be primary features. Typing to input information into technological devices as we know it will soon be replaced with alternative and more ergonomic means. The text-free adaptations of wearables on the mobile technology market align with meeting the needs of more people, especially people with limited reading and writing abilities.

For both Study I and Study II, internet access, preferably a high-speed connection, was required. Additionally, it was mandatory for all the devices and applications used to be connected to the same Wi-Fi network for the duration of the studies. The Wi-Fi network used in both studies was the one provided by the university to all students and staff campus-wide. Due to the nature of accessing such a large network, fluctuations in the speed and quality of the connections occurred frequently and were not able to be controlled by the researcher.

**Future Research**

This dissertation provides evidence of the effectiveness and capabilities of two types of wearable devices (smartwatches and smartglasses) to support the needs of individuals with intellectual and developmental disabilities. The participants in these studies were all students in

a university based post-secondary education program. Future research could explore these tools in K-12 educational settings and with older adults with disabilities. Future studies could also include other types of mobile and wearable technologies to determine which features and technologies lead to be the best outcomes. For example an alternating treatment design could be used to compare smartwatch based decision making supports versus the same or similar support on a smartphone or tablet. The headmounted display used in Study I could be compared to similar tools such as the Microsoft Hololens (Microsoft, 2016) across a range of academic and functional skills for individuals with I/DD. These comparison studies should include a strong social validity component to ensure the interventions being developed are meaningful, helpful, and preferred by this community. Wearable devices are projected, within the next five years, to exceed the impact of mobile devices as a $150-billion dollar industry (Merel, 2015). All aspects of life are likely to be immersed in these technologies, just as smartphones and tablets are today but it will likely happen even faster. Future research is needed to determine the best uses of wearable devices as assistive technologies. Continued investigation of wearable devices should help contribute to an active applied research agenda of development, testing, training, and implementation in order to fully realize the potential benefits of wearable technologies for individuals with I/DD.

## Conclusion

This dissertation extends research in special education and computer science while examining the capabilities of wearable devices to provide context aware prompts for individuals with disabilities. In the next several years new wearable devices will continue to expand the capabilities of this field and provide new resources to support individuals with disabilities. This dissertation provides a research foundation for future studies examining wearable devices,

augmented reality, real-time learning, and context-aware supports for individuals with disabilities.

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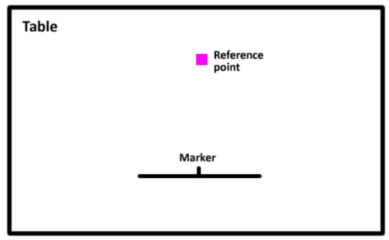
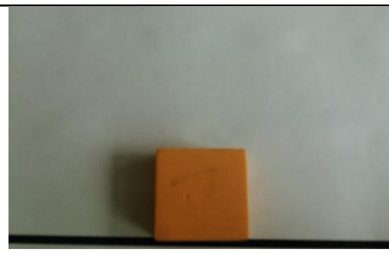
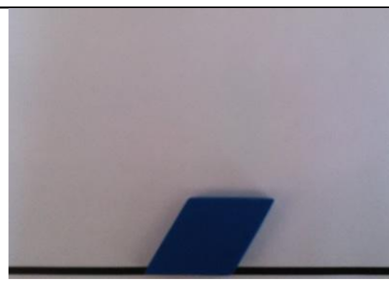
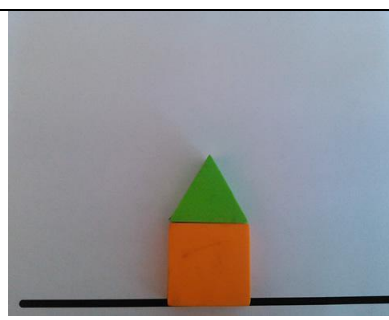
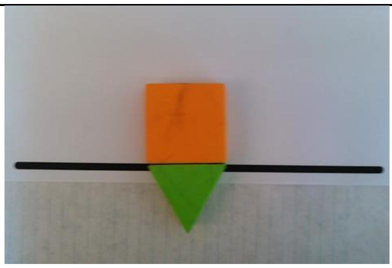
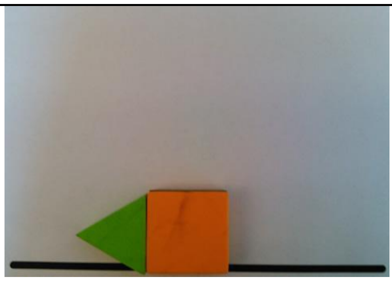
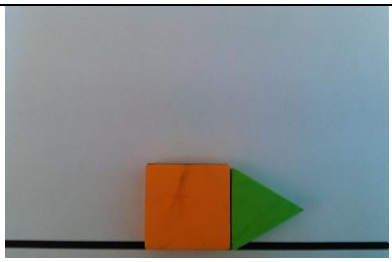
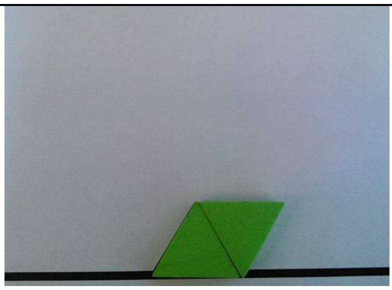
# APPENDICES

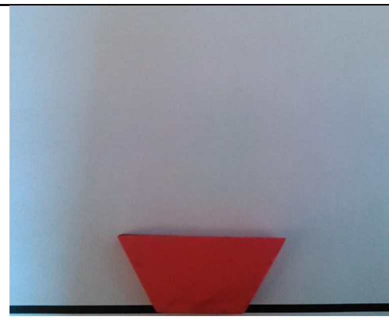
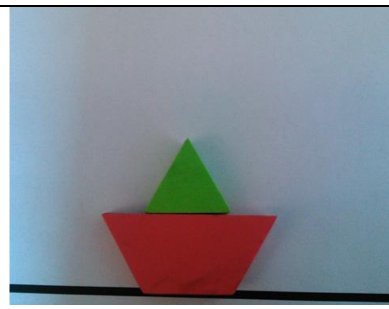
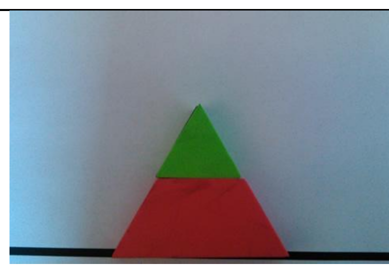
# Appendix A

Tangram Assembly Task Decision Tree

Study I

| **Step** | **Goal** | **Prompt** | **Desired Result** | **Feedback** |
|---|---|---|---|---|
| 0 | Setup | NA |  | NA |
| 1 | Teach placement on marker | Place a shape on the marker, covering the center line |  | Correct |
| 2 | Teach shape identification<br><br>(square, triangle, diamond, trapezoid, hexagon) | Place a square on the marker. |  | This yellow hexagon has six sides.<br><br>…<br><br>This red trapezoid has four sides: a small top , a long bottom, and two slanted sides |
| 3 | Teach adjacent / above | Place a square on the marker, then place a triangle above it so that the sides line up and it looks like an orange house with a green |  | This is called adjacent. The triangle is above the square.<br><br>(when two shapes touch together and their sides are lined up evenly, they are adjacent. Here, the triangle is above the square, so the bottom of the triangle is adjacent to the top of the square.) |

| | | | | |
|---|---|---|---|---|
| | | roof. | | |
| | Teach adjacent / below | Place a square on the marker, then place a triangle below it so that the sides line up. |  | This is called adjacent. The triangle is below the square. |
| | Teach adjacent / left | Place a square on the marker, then place a triangle to the left of the square so that the sides line up. |  | This is called adjacent. The triangle is to the left of the square. |
| | Teach adjacent / right | Place a square on the marker, then place a triangle to the right of the square so that the sides line up. |  | This is called adjacent. The triangle is to the right of the square. |
| 4 | Teach sub-composition | Place one triangle on the marker, point up, then place another triangle right-adjacent to |  | Two adjacent triangles make a diamond. |

| | | | | |
|---|---|---|---|---|
| | | it to make a diamond shape. | | |
| 5a | Teach rotate | Place a trapezoid on the marker with the long side up |  | Do you want to simply teach rotate in isolation first? Like this position, then rotate quarter turn to the right (clockwise ); another quarter turn to the right (upside-down ); another quarter turn to the right x etc. - before adding another shape like below? |
| 5b | Teach rotate | Place a triangle above and adjacent to the trapezoid, in the middle, so that it looks like a boat. |  | |
| 5c | Teach rotate | Now, rotate the trapezoid one half-turn, so that the long side is on the bottom, to make a pyramid. |  | |
| | Embedded baseline | ? | | |

Decision Tree

Start

1. Teach placing on marker

a. Prompt: “Place a shape on the marker, covering the center line.”

b. “When you’re ready, tap to take a picture and check your answer.” -> Take picture

i.Correct:

1. “Correct. That is the marker.”

2. Advance to next prompt (Go To “III.”)

ii.Incorrect:

1. Show image of solution

2. Repeat prompt (Go To “a.”)

2. Teach shapes

. Prompt: “Place a [square, diamond, trapezoid, triangle, hexagon] on the marker”

a. Take picture

.Correct:

1. “Correct. That is a [shape]. This [color] [shape] has [number] sides. (The trapezoid has a short top and along bottom.)”

2. Advance to next prompt.

i.Incorrect:

1. Show image of solution

2. Repeat prompt

3. Teach relative direction and adjacent

. Prompt: “Place a square on the marker”

a. Take picture

.Correct:

1. “Correct.”
2. Advance to next prompt.

i.Incorrect:

1. Show image of solution
2. Repeat prompt

b. Prompt:

.“Now place a triangle above it so that the sides line up and it looks like an orange house with a green roof.” OR

i.“Place a square on the marker, then place a triangle [below/to the left of/to the right of] it so that the sides line up.”

ii.Take picture

1. Correct:

a. “Correct. This is called adjacent. The triangle is [above/below/left of/right of] the square.”

b. Advance to next prompt.

2. Incorrect:

. Show image of solution

a. Repeat prompt

4. Teach sub-composition

. Prompt: “Place one triangle on the marker, point up”

.(standard correct/incorrect)

a. Prompt: “Now place another triangle right-adjacent to it to make a diamond shape.”

.(standard)

5. Teach rotate

. Prompt: “Place a trapezoid on the marker with the long side down”

a. Take picture

.Correct:

1. “Correct.  You have placed the trapezoid with the long side down”
2. Advance to next prompt

i.Incorrect:

1. Show image of solution
2. Repeat prompt

b. Prompt: “Now, rotate the trapezoid one quarter turn to the right”

.Take picture

i.Correct:

1. “Correct.  That is one quarter turn to the right”
2. Advance to next prompt

ii.Incorrect once:

1. Show image of previous step with turn arrow
2. Repeat prompt

iii.Incorrect twice:

1. Show image of solution
2. Repeat prompt

c. Prompt: “Now, rotate the trapezoid one half turn”

.Take picture

i.Correct:

1. “Correct.  That is one half turn”
2. Advance to next prompt

ii.Incorrect once:

1. Show image of previous step with turn arrow
2. Repeat prompt

iii.Incorrect twice:

1. Show image of solution
2. Repeat prompt

d. Prompt: "Now, rotate the trapezoid one quarter turn to the left"

.Take picture

i.Correct:

1. "Correct. That is one quarter turn to the left"
2. Advance to next prompt

ii.Incorrect once:

1. Show image of previous step with turn arrow
2. Repeat prompt

iii.Incorrect twice:

1. Show image of solution
2. Repeat prompt

e. Prompt: "Place a triangle above and adjacent to the trapezoid, in the middle, so that it looks like a boat."

.Take picture

i.Correct:

1. "Correct. You have made a boat."
2. Advance to next prompt

ii.Incorrect:

1. Show image of solution
2. Repeat prompt

f. Prompt: "Now, rotate the trapezoid one half turn, so that the long side is on the bottom, to make a pyramid"

.Take picture

i. Correct:

1. "Correct.  That is one half turn.  You have made a pyramid"
2. Advance to next prompt

ii. Incorrect once:

1. Show image of previous step with turn arrow
2. Repeat prompt

iii. Incorrect twice:

1. Show image of solution
2. Repeat prompt

6. Stop

. Reset Step # for next trial.

## Appendix B

Procedural Integrity Data Sheet
Study I

Data Collector: ______________________ Date: ______________________________
Coder Name: ________________________

| | **Observed** |
|---|---|
| 1. Checked Google Glass battery charge prior to session? | YES NO |
| 2. Checked Samsung phone battery charge prior to session? | YES NO |
| 3. Powered on Google Glass device prior to session? | YES NO |
| 4. Verified Glass Wi-Fi connectivity prior to session? | YES NO |
| 5. Verified Glass Bluetooth connectivity to Samsung phone prior to session? | YES NO |
| 6. Provided Glass device to student? | YES NO |
| 7. Instructed student to put the glasses on and follow the "Student Procedures"? | YES NO |
| 8. Observed student follow Glass device procedures (for adjusting prism/eyepiece)? | YES NO |
| 9. Observed the student launch the "What's Next" Glass application? | YES NO |
| 10. Allowed 10 seconds of wait time throughout session? | YES NO or N/A |
| 11. Provided prompt using system of least prompts if student indicated an incorrect response | YES NO or N/A |
| 12. Provided praise for correct response? | YES NO |
| 13. Recorded student responses throughout session on data collection sheet? | YES NO |
| 14. Collected mobile device at the end of the session? | YES NO |

TOTAL: _________/__________ = __________

“What’s Next?” Glass Intervention Procedures: Researcher

1. Ensure that the Glass is charged
2. Turn on Glass device by pressing the small circle button on the inside of the right earpiece
3. Wait for Glass to boot up (may take up to 60 seconds)
4. From the home screen, swipe forward until you see the Settings Card
5. Tap once to select
6. Tap once again to select “glass settings”
7. Ensure that the Glass is on the “Samsung Galaxy Avant 8646” network
8. Swipe forward once to move to the Bluetooth settings card
9. Ensure that the Glass is connected to the Phone

   Should say: SM-G386 Headset<br>Data from Wi-Fi<br>MyGlass
10. Move the Glass timeline back to the Home Screen
11. Open the MyGlass App on the Samsung cell phone
12. Select “screencast”
13. Instruct the student to put the glasses on, and follow the “Student Procedures”
14. Check to make sure the student is on the correct card by looking at the screencast on the phone

“What’s Next?” Glass Intervention Procedures: Participant

http://youtu.be/4EvNxWhskf8

1. Put on Google Glass
2. Tap once on the right temple to wake up the display

3. Adjust the prism to the position where you see the display best
    a. Use index finger and thumb to grasp the plastic, NOT the prism itself

4. This is the “home screen”


5. Practice swiping forward and backward from the home screen
6. Practice swiping down to exit
7. Practice tapping once on the touchpad to wake it up

## Appendix C

Social Validity Questionnaire
Study I

Student: ___________________________ Date: ____________

"I have some questions to ask you about the "What's Next?" Glass study. There are no right or wrong answers to these questions, I am simply interested in your opinion. Do you have any questions before we begin?"

| | Questions | Responses | | | | |
|---|---|---|---|---|---|---|
| 1. | I like using the "What's Next?" Glass app to learn new jobs skills. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 2. | Learning how to use the "What's Next?" app to learn new job skills helped me to improve my technical skills. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 3. | The audio directions helped me learn how to complete the task. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 4. | The screen showing how to complete the next step helped me learn how to complete the task. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 5. | I would use Google Glass again to help me learn new skills. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 6. | I would recommend using Google Glass to a friend. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 7. | I like using the "What's Next?" Glass app better than having someone teach me. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 8. | I learned all of the steps for the tasks using Google Glass. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

9. What did you like best about using Google Glass?
10. What did you not like about using Google Glass?

## Appendix D

Procedural Integrity Data Sheet
Study II

Data Collector: ______________________ Date: ______________________________
Coder Name: ________________________

| | Observed |
|---|---|
| 1. Checked smartwatch device battery charge prior to session? | YES NO |
| 2. Provided the student with a printed appointments and tasks list? | YES NO |
| 3. Provided smartwatch device to student? | YES NO |
| 4. Observed the student open the GuruWear application? | YES NO |
| 5. Observed the student enter the correct date for the appointment? | YES NO |
| 6. Observed the student enter the correct time for the appointment? | YES NO |
| 7. Observed the student assign the corresponding formula correctly? | YES NO |
| 8. Allowed 10 seconds of wait time throughout session? | YES NO or N/A |
| 9. Provided prompt using system of least prompts if student indicated an incorrect or no response | YES NO or N/A |
| 10. Provided praise for correct response? | YES NO |
| 11. Observed student view notifications on watch? | YES NO |
| 12. Recorded student responses throughout session on data collection sheet? | YES NO |
| 13. Collected the smartwatch at the end of the session? | YES NO |
| 14. Tallied the correct responses at the end of the session? | YES NO |

TOTAL: _________/__________ = __________

## Appendix E

Social Validity Questionnaire

Study II

Student: _________________________ Date: ___________

"I have some questions to ask you about the smartwatch. I am interested in your opinion, so there are no right or wrong answers. Do you have any questions before we begin?"

| Questions | Responses  |  | | |  |
|---|---|---|---|---|---|
| 1. I like using the smartwatch to remember to do the tasks on my daily task list. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 2. Learning how to use the checklist app helped me to remember to do things on my daily task list. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 3. The smartwatch notifications helped me remember to do more things on my list. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 4. The smartwatch was easy to use for reminding me to do the things on my daily task list. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 5. I would use this system again to help me remember to do daily tasks. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 6. I would recommend using this system to a friend. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 7. I like using the smartwatch system better than the written list. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 8. I always remembered to do the things on my daily task list using the smartwatch. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 9. I always remembered to do the things on my daily task list without the smartwatch. | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

10. What did you like best about the smartwatch system tool?

11. Was there anything that you didn't like about using the smartwatch?

12. Is there anything you would like to change about using the smartwatch to remember to complete daily tasks?

# VITA

Rachel Wright is originally from Knoxville, Tennessee and a graduate of Knoxville Catholic High School. After high school, Rachel attended the University of Tennessee where she graduated with a B.S. in Special Education in 2007. Upon earning her M.Ed. in 2008, Rachel moved to Oregon to work as an Autism Spectrum Disorders Specialist for four years before she began the doctoral Special Education program at the University of Tennessee in the fall of 2012. Rachel will receive her Ph.D. in May of 2016.