Review of Twenty-First Century Portable Electronic Devices for Persons with Moderate Intellectual Disabilities and Autism Spectrum Disorders

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Abstract: Use of portable electronic devices by persons with moderate intellectual disabilities and autism spectrum disorders is gaining increased research attention. The purpose of this review was to synthesize twenty-first century literature (2000-2010) focusing on these technologies. Twenty-one studies were identified which evaluated use of: (a) media players with audio playback; (b) cellular/smartphones; (c) handheld computers and handheld video players across various skills and settings to assist persons with disabilities. Guidelines and recommendations for instruction and future research are provided.

Persons with moderate intellectual disabilities (ID) and those with a diagnosis of autism spectrum disorder (ASD) have been shown to have the ability to self-manage their own behaviors and to independently complete functional, daily tasks when provided with the proper tools and technologies (Mechling, 2007; Wehmeyer, Palmer, Smith, Davies, & Stock, 2008). With the use of assistive technologies or mainstream technologies, one of the goals is to increase independence while decreasing reliance on other persons for assistance. Today’s portable electronic technologies, including handheld computers, cellular (cell) phones, e-books or electronic readers, global positioning systems (GPS) and personal media or MP3 players, appear to hold potential for assisting persons with moderate ID and those with a diagnosis of ASD. These portable technologies may be adapted or specially designed for persons with disabilities (i.e., Community Integration Suite by Ablelink Technologies; Cyrano Communicator TM by Kiba Technologies, LLC) or generic, mainstream technologies such as cell phones and the iPod by Apple, Inc. that are mass produced (Carey, Friedman, & Bryen, 2005). Their portability and capacity for storing large amounts of data formulate a tool for providing multiple uses for persons with moderate ID and ASD including: (a) remembering and performing steps of a complex task (Riffel et al., 2005); (b) decision making (Davies, Stock, & Wehmeyer, 2003); (c) organization and time management (Gillette & DePompei, 2008); and (d) self-monitoring and self-management of behaviors (Cihak, Wright, & Ayres, 2010).

While these portable electronic devices are rapidly increasing in number and advancing in capabilities, research evaluating their applied use with persons with disabilities remains relatively minute. In their meta-analysis of single-subject design studies which evaluated use of technology by persons with intellectual disabilities, Wehmeyer et al. (2008) recommended more research with a wider range of technology devices and reported that only .9% of the 81 studies they evaluated used palmtop computers, 2.2% evaluated palmtop computers with audio vibrators, and 4.8% evaluated electronic and information technologies (i.e., cell phones).

The purpose of this review was to examine the most current research which has applied portable electronic devices to increase the independent functioning of persons with moderate ID and those with a diagnosis of ASD. By examining the present status of a relatively
new line of research, the review holds potential for laying the ground work for additional lines and directions for future research.

Method

The period of review was limited to those studies conducted in the twenty-first century. Although a review of this limited extent risks exclusion of some earlier findings, devices such as personal digital assistants, which have been in existence since the beginning of the eighties, have only become extensively popular in the last few years (Nashville, 2009). Likewise, cellular phones were a rarity fifteen years ago (Cell Phones.org, 2008), and the popular iPod and video iPod by Apple, Inc. were introduced in 2000 and 2005 respectively. Therefore, due to the relatively recent introduction of these portable electronic technologies into mainstream society, and the rapidly changing nature of technology, this review extended from the years 2000–2010. Journal articles published between those years were located using an electronic search through a university EBSCOhost database (Academic Search Premier, Eric, MasterFILE Premier, PsycARTICLES, and PsycINFO). Specific key words used in the search were a combination of the words disabilities, intellectual disabilities, autism, autism spectrum disorders, mental retardation and the words personal digital assistants, PDAs, handheld computers, palmtop computers, pocket PCs, cellular phones, cell phones, mobile phones, smartphones, mobile technologies, portable electronic devices, iPhone, iPod, video iPod, MP3 players, and portable media players. In addition to the electronic search, a cross-reference, manual search was made of previously identified articles.

In order to be included in the review, articles had to meet the following criteria:

1. Use of a quasi-experimental or single-subject research design.
3. Primary intervention was the evaluation of a form of portable electronic technology: handheld computer, cellular phone, MP3 player.
4. Participants were diagnosed with a moderate intellectual disability and/or autism spectrum disorder.

Results

Twenty-one studies (Table 1) were identified and included in this review. Although not within the scope of this literature review, readers may also wish to review the work being conducted with handheld devices and smartphones as memory and organization aids with persons with traumatic brain injury (i.e., DePompei et al., 2008; Gentry, Wallace, Kvarfordt, & Lynch, 2008; Gillette & DePompei, 2008; Hart, Buchhofer, & Vaccaro, 2004; Hart, O’Neil-Pirozzi, & Morita, 2003; Wade & Troy, 2001). The review is organized around three types of portable electronic technologies: handheld computers and handheld video players (17 studies), cellular phones (3 studies), and MP3 players (1 study). Skills addressed were: functional, multi-step skills (15 studies); time management and organization skills (4 studies), and independent transitions (2 studies). The majority of participants were 15 years of age and older (18 studies) while seven studies included students under the age of 15 years and two studies included elementary age students. The majority of the studies evaluated use of portable electronic devices with students with moderate ID (17 studies) and five of the studies included students with ASD.

Media Players with Audio Playback

In 2007, Millard reported that “every month a new portable MP3 player is on the market” with capabilities and functions extending beyond music players. She further sites the increased use of these players as a creative means for providing alternative methods for students with disabilities to learn. Simply applied, MP3 players can deliver auditory information to students in a step-by-step format for completing multiple step tasks or they can be used to prompt on-task behaviors. Media players such as the iPod provide auditory prompts and information in much the same way that earlier studies used portable cassette players (Post & Storey, 2003; Taber, Alberto, & Fredrick, 1998), but provide more sophisticated means for navigating through recorded
<table>
<thead>
<tr>
<th>Author(s)</th>
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<th>Target Skill (Dependent Variable)</th>
<th>Research Design</th>
<th>Setting</th>
<th>Results</th>
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<tbody>
<tr>
<td>Taber-Doughty, (2005)</td>
<td>n = 3 CA = 15-21yrs Moderate ID</td>
<td>Operate debit &amp; copy machine</td>
<td>Alternating treatment</td>
<td>Domestic living area of high school</td>
<td>Picture prompting system, SLP, &amp; MP 3 Player effective &amp; efficient procedures. Performance superior when students used their preferred system.</td>
</tr>
<tr>
<td>Stock, Davies, Wehmeyer, &amp; Palmer (2008)</td>
<td>n = 22 CA = 18-21yrs Full scale IQ range 47–69</td>
<td>Operate adapted phone functions &amp; mainstream phone functions</td>
<td>Within- Subjects paired samples</td>
<td>Center-based</td>
<td>Compared to a mainstream cell phone, participants required fewer prompts &amp; made fewer errors with the adapted phone.</td>
</tr>
<tr>
<td>Taber, Alberto, Hughes, &amp; Seltzer (2002)</td>
<td>n = 14 CA = 11-14yrs Moderate ID</td>
<td>Dial phone # from printed card when lost. Describe location</td>
<td>Multiple probe across groups</td>
<td>School-based. Generalization to community.</td>
<td>Participants effectively dialed phone numbers. Difficulty describing location.</td>
</tr>
<tr>
<td>Taber, Alberto, Seltzer, &amp; Hughes (2003)</td>
<td>n = 6 CA = 14-18yrs Moderate ID</td>
<td>Operate speed dial, answer phone when lost. Describe location</td>
<td>Multiple probe across students</td>
<td>School-based Generalization to community.</td>
<td>Participants effectively used speed dial function to place phone call &amp; to answer phone when lost in school or community. Difficulty describing location.</td>
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<tr>
<td><strong>PDA with Text, Sound, and Light Cues</strong>&lt;br&gt;Davies, Stock, Wehmeyer (2002a)</td>
<td>$n = 12$ CA = 19-46yrs Full scale IQ range 45–90</td>
<td>Compared performance of tasks on schedule using a written schedule or PDA</td>
<td>Two-group within-subjects design</td>
<td>Community vocational site</td>
<td>PDA with specially designed prompting software more effective than written schedule for prompting initiation of tasks.</td>
</tr>
<tr>
<td><strong>Gentry, Wallace, Kvarfordt, &amp; Lynch (2010)</strong></td>
<td>$n = 22$ CA = 14-18yrs Autism</td>
<td>Independent operation of PDA (enter appointments, schedules, assignments) &amp; frequency of use of PDA</td>
<td>Quasi-experimental pre- &amp; post-assessment</td>
<td>School setting</td>
<td>Students were able to use the PDA as a task management tool. Maintenance of skill up to 8 weeks.</td>
</tr>
<tr>
<td><strong>Gillette &amp; Depompei (2008)</strong></td>
<td>$n = 20$ CA = 6-20yrs Mild - moderate ID</td>
<td>On-time behavior using written time &amp; task list; paper planner, &amp; PDA</td>
<td>Comparison of incidence rate ratios across conditions &amp; periods using a Poisson regression</td>
<td>School-based settings</td>
<td>Highest rate of on-time behavior using the PDA.</td>
</tr>
<tr>
<td><strong>PDA with Picture Cues</strong>&lt;br&gt;Cihak, Kessler, &amp; Alberto (2008)</td>
<td>$n = 4$ CA = 16-17yrs Moderate to Severe ID</td>
<td>Transition between vocational tasks</td>
<td>Multiple probe across students</td>
<td>Community settings</td>
<td>Increased independent transitions between tasks. Maintenance up to 9 weeks.</td>
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### TABLE 1—(Continued)

**Overview of Handheld Technology**

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<tr>
<td>Cihak, Kessler, &amp; Alberto (2007)</td>
<td>n = 4 CA = 18-19yrs Moderate ID</td>
<td>Independent task completion of progressively more difficult tasks</td>
<td>Multiple probe across tasks</td>
<td>Community settings</td>
<td>Independent task completion using the PDA. Maintenance up to 9 weeks.</td>
</tr>
<tr>
<td>Cihak, Wright, &amp; Ayres (2010)</td>
<td>n = 5 CA = 11-13yrs High functioning autism</td>
<td>Self-monitoring of task engagement</td>
<td>ABAB</td>
<td>Middle school general education classrooms</td>
<td>Self-model pictures on the PDA resulted in increased task engagement &amp; decreased teacher prompts.</td>
</tr>
<tr>
<td>Davis, Stock, &amp; Wehmeyer (2003)</td>
<td>n = 40 CA = 18-54yrs Full scale IQ range 24–76</td>
<td>Software &amp; Pocket PC assembly</td>
<td>Two-group within-subjects design</td>
<td>Community vocational setting</td>
<td>Use of PDA with specially designed software incorporating decision points resulted in increased independence &amp; accuracy assembling both tasks.</td>
</tr>
<tr>
<td>Davies, Stock, &amp; Wehneyer (2002b)</td>
<td>n = 10 CA = 18-70yrs Full scale IQ range 39–72</td>
<td>Assemble pizza boxes &amp; package software</td>
<td>Two-group within-subjects design</td>
<td>Community vocational setting</td>
<td>PDA with specially designed software produced improved task accuracy &amp; decreased reliance on adult prompts.</td>
</tr>
<tr>
<td>Lancioni, O’Reilly, Seethouse, Furniss, &amp; Cunha (2000)</td>
<td>n = 6 CA = 23-47yrs IQ unavailable Adaptive Behavior Scale, age equivalents 26.5 years for daily living</td>
<td>Cleaning, table setting, food preparation</td>
<td>Alternating treatment</td>
<td>Day activity center</td>
<td>Students completed more steps independently when using the PDA compared to a picture based system. Steps were also clustered into fewer pictures on the PDA.</td>
</tr>
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<tr>
<td>Riffel et al. (2005)</td>
<td>n = 4 CA = 16-21 yrs Mild to moderate ID, Autism</td>
<td>Table setting, rolling silverware, laundry</td>
<td>Multiple probe across participants</td>
<td>School, group home, retirement home, restaurant</td>
<td>Use of PDA with specially designed software increased number of steps performed without adult prompting. Decrease in duration time to complete tasks.</td>
</tr>
<tr>
<td>PDA with Video Cues &amp; Handheld Video Players</td>
<td>n = 4 CA = 6-8 yrs Autism</td>
<td>Transitions between school locations &amp; activities</td>
<td>ABAB</td>
<td>Elementary school</td>
<td>Increased independent transitioning with video models presented on video iPod. Performance decreased with withdrawal of video models.</td>
</tr>
<tr>
<td>Mechling, Gast, &amp; Seid (2010)</td>
<td>n = 3 CA = 15-17 yrs Moderate ID</td>
<td>Food preparation</td>
<td>Multiple probe across tasks</td>
<td>Home living area of high school</td>
<td>Use of PDA with multiple prompt levels (audio, picture, video) resulted in immediate increase in independent completion of cooking recipes. Students prompts used. Performance maintained over time.</td>
</tr>
<tr>
<td>Mechling, Gast, &amp; Seid (2009)</td>
<td>n = 3 CA = 16-17 yrs Autism</td>
<td>Food preparation</td>
<td>Multiple probe across tasks</td>
<td>Home living area of high school</td>
<td>Use of PDA with multiple prompt levels (audio, picture, video) replicated results of Mechling et al. (2010) although use &amp; self-adjustment of prompt levels differed from previous findings.</td>
</tr>
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<tr>
<td>Mechling &amp; Seid (2011)</td>
<td>n = 5 CA = 21-22yrs Moderate ID</td>
<td>Pedestrian travel (walking) locating landmarks &amp; destinations</td>
<td>Multiple probe across tasks</td>
<td>University campus</td>
<td>Use of PDA with multiple prompt levels (audio, picture, video) resulted in students independently locating three different destinations. Students self-adjusted prompt levels used. Maintenance of skills over time.</td>
</tr>
<tr>
<td>Van Laarhoven, Van Laarhoven-Myers, Grider, &amp; Grider (2009)</td>
<td>n = 1 CA = 17yrs Moderate ID</td>
<td>Emptying trash, mopping, cleaning bathroom, cleaning kennels</td>
<td>Multiple probe across tasks</td>
<td>No-kill animal shelter</td>
<td>Video prompting &amp; feedback, using a Video iPod, resulted in an increase in correct responding across tasks &amp; decrease in adult prompting for error correction &amp; use of the device.</td>
</tr>
<tr>
<td>Van Laarhoven, Van Laarhoven-Myers, &amp; Zurita (2007)</td>
<td>n = 2 CA = 18yrs Mild to moderate ID</td>
<td>Sorting &amp; sanitizing silverware, portioning recipes, cleaning &amp; sanitizing work area, clocking in &amp; out, rolling silverware</td>
<td>Multiple probe across tasks</td>
<td>Red Robin &amp; Applebee’s restaurants</td>
<td>Video modeling &amp; feedback back &amp; least to most prompting resulted in increased independent responding &amp; decrease in adult prompting</td>
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segments on the device. In addition, media players such as video iPods now feature video playback (see section titled Handheld Computers and Handheld Video Players).

In the only identified study evaluating use of a media player with audio playback, Taber-Doughty (2005) used a D’music MP3 Player (Pine Technology, Ltd) (Figure 1) to deliver auditory prompts while comparing the effects and efficiency of student choice and task performance between prompting methods (MP3 player, system of least prompts, and picture prompts). Data were collected for the percent of task steps completed independently and the duration of task completion for the tasks of operating a copying machine and making purchases using a debit card machine. Results demonstrated that each system was effective and efficient for five high school age students with moderate ID and that students’ performances were superior when using their system of choice.

Although the experimental design did not meet the criteria for inclusion in the current literature review, one additional study was identified which used a portable cassette player to prompt students with moderate intellectual and visual disabilities (Lancioni, O’Reilly & Oliva, 2001). The study demonstrated that although more sophisticated devices may be available, researchers and practitioners are still finding value in lighter tech systems. An interesting finding and focus of the study was that following task mastery using step-by-step auditory instructions, the participants were able to complete tasks when two auditory steps from the original instructions were clustered together.

Cellular/Smartphones

In addition to meeting basic communication needs, it is suggested that use of cell phones by persons with disabilities can address safety issues (i.e., being lost, being stranded if a wheelchair breaks down) or be used as a memory aid (alarms and reminder features) (Bryen, Carey, & Friedman, 2007). In their survey of cell phone use by 83 persons with intellectual disabilities, Bryen et al. found that in addition to day-to-day communication, cell phones were most often used for emergencies, storing phone numbers, and storing calendar information. In the current review, two of the three studies which evaluated use of cell phones by persons with moderate intellectual disabilities, used a cell phone as an intervention for the emergency situation of being lost in the community. In the first study, Taber, Alberto, Hughes, and Seltzer (2002) found that 14 middle school students were able to use a cell phone to dial a number by copying a phone number from a printed card and to describe their physical location. Sessions were first conducted at school and then generalized to a community setting. In a final phase, students also dialed a different phone number than the one used during training.

Because some students had difficulty dialing the phone number in the first study, speed dialing was used in a second study by Taber, Alberto, Seltzer, and Hughes (2003). In addition to the change in dialing, they also evaluated six secondary age students’ abilities to answer a cell phone and describe their location to the caller for those students who were not able to recognize that they were lost. Once again, training took place in the school setting and then generalization sessions occurred in two community settings. Results were again supportive of cell phone use by students with moderate intellectual disabilities when lost in the community. One interesting result of each of these studies was that in addition to some issues with operation of the cell phone itself, students had the greatest amount of difficulty describing their physical location.

In spite of their potential benefits, Bryen et
al. (2007) still found a gap between the use of cell phones by people with intellectual disabilities compared to persons without disabilities. In their report they found that non-use by persons with intellectual disabilities was primarily due to cost, perception of not needing a cell phone, and lack of accessibility. To address the issue of cognitive accessibility, Stock, Davies, Wehmeyer, and Palmer (2008) evaluated a specially designed multimedia software prototype, Pocket ACE (AbleLink Technologies), with 22 participants with intellectual disabilities (range IQ score 47–69). The program operated on the Pocket PC 2002 Phone edition of a mainstream PDA and incorporated a picture-based address book and simplified system for operating phone functions of the PDA. Adapted features allowed participants to place phone calls by tapping pictures on the PDA screen and to see a picture of the person calling them when they received a call. When compared to a mainstream Nokia cell phone, participants required fewer prompts and made fewer errors when placing and receiving calls.

With the widespread availability and relatively inexpensive cost of cell phones, it may be time for the field of special education to look in-depth into cell phone use beyond emergency applications. Other features and uses identified by Bryen et al. (2007) were: paging and text messaging, connecting to the internet, use of voice recognition capabilities, speed dialing, voice mail options, transmitting computer files, taking digital photographs, and video-calling. Incorporating these features into a cell phone is now recognized within the realm of smartphones. Smartphones are electronic handheld devices that integrate the functionality of a mobile phone, personal digital assistant (PDA), or other information appliances to offer features beyond making voice calls (www.en.wiktionary.org/wiki/smartphone). Smartphones include devices such as BlackBerry, Razr, iPhone and Palm Treo (www.sag.org/content/new-media-glossary).

Smartphones may also come equipped with built-in cameras and screens for visual, real-time communications. In the early 1990s AT&T introduced its VideoPhone, but the bandwidth limitation of dial-up phone lines, high cost of entry ($1,000 each), and requirements for both communication parties to own the videophones, prevented them from taking off (www.answers.com/topic/videophone-1). High-speed cable and DSL allowed video-phoning to eventually become popular by using a computer and specialized software. In 2006 Skype popularized the use of videophones by offering free worldwide calling (www.answers.com/topic/videophone-1).

In addition to computer-based systems, videophones are also available in desktop or land line models which provide video and audio transmissions for communication between people in real-time. These videophones are currently popular among deaf persons who use them with sign language and among persons with limited mobility (www.answers.com/topic/videophone) (Figure 2).

Video calling and downloading multimedia content on mobile smartphones are currently available with models such as the Sony-Ericsson K800 (www.en.wikipedia.org/wiki/Video-phone) (Figure 3) and the newly released iPhone 4 which allows video chats using a feature called FaceTime (www.apple.com/iphone/features/facetime.html) (Figure 4).

Renblad (1999) reported the positive results of using early picture telephones and video telephones (videotelephony) to increase communication and social interactions among persons with intellectual disabilities. In his review of the literature of studies con-
ducted in Europe, these technologies were reported as beneficial for assisting persons in making contacts outside of their work place and home which might otherwise be difficult to make. Yet, at the time of this review, presenting video in a portable cell phone format, had not been researched as a tool for independence by persons with moderate ID or ASD. Future research needs to investigate the application of portable electronic devices with video capability with persons with moderate ID and ASD. When re-examining the research of Taber et al. (2002, 2003) in which students had difficult verbally describing their location when lost, it appears that incorporating video on cell phones would allow students to video record and send visual images of their location (to the person trying to locate them) which would provide an important application for this technology.

Handheld Computers and Handheld Video Players

Handheld computers, often referred to today as PDAs (personal digital assistants), are also known as palmtop computers and Pocket PCs. These PDAs have been around since the beginning of the eighties, but have only become popular in the last few years due to innovative technologies such as 3G mobile telephony and wireless connectivity (Nashville, 2009). These features provide PDAs with the ability to do many of the things that a PC can do, such as connecting to the internet, running third party applications, and serving as a mobile phone (Nashville). In the field of special education, PDAs may provide digital content (i.e., pictures and video) in flexible formats that can be made meaningful to individual students with disabilities (Abell, Bauder, Simmons, & Sharon, 2003). In their meta-analysis of single-subject design studies, Wehmeyer et al. (2008) reported palmtop computers to be a simple and effective use of technology for prompting persons with intellectual disabilities. They suggested that these devices are highly effective in their use of cognitive access features such as touch screens as well as their audio and video output and input capabilities. Further, their portability, relative affordability, customization features, and ability to store large amounts of data, provide a means to address the needs of persons with intellectual disabilities (Stock, Davies, Davies, & Wehmeyer, 2006).

In the current review, identification of studies using handheld computers and handheld video players were categorized as those using: (a) text, sound, and light; (b) picture cuing with and without voice recording; and (c) video recordings. Within those categories, the identified purposes of the devices were to function as: (a) reminders and tools for time

Figure 3. Sony-Ericsson K800. Retrieved from http://www.sonyericsson.com/cws/products/mobilephones/overview/k800i

Figure 4. iPhone 4. Retrieved from http://www.apple.com/iphone/features/facetime.html
management; (b) transition aids; and (c) prompts and models for completing multi-step functional skills.

**PDA with text, sound, and light cues.** PDAs, which were originally designed to provide electronic task organization, can now be programmed to include complex activity schedules whereby each task can be linked to a reminder alarm to prompt students to check their schedule (Gentry, Wallace, Kvarfordt, & Lynch, 2010). The basic features of text, sound, and flashing lights have been used in this capacity to remind students to complete tasks. Gentry et al. used a quasi-experimental, pre- and post-assessment design to evaluate the ability of 22 high school students with ASD to enter appointments, schedules, and assignments onto a Palm Zire 31 PDA with a reminder alarm linked to each entry. Results showed that students were able to use the PDA as an electronic task management tool and to maintain their ability to use the cognitive aid over an eight-week period following a brief training period.

Davies, Stock, and Wehmeyer (2002a) used specially designed software, Schedule Assistant (AbleLink Technologies), as a time management tool that operated on a Windows CE palmtop computer platform. The program provided an auditory beep to cue 12 students with intellectual disabilities (IQ scores ranged from 45–90) to check their PDA schedule followed by a recorded auditory cue telling them what task to perform. When compared to a traditional written schedule, results demonstrated that the palmtop computer with schedule prompting software was more effective than the written schedule for prompting initiation of tasks.

Twenty students with intellectual disabilities were included in a comparison study which evaluated use of a written time and task list, paper planner, and PDA with students with mild to moderate ID (Gillette & DePompei, 2008). Students responded with the highest rate of on-time behavior using a 1-Dell Axim and a 2-Palm Zire 71 or 72 PDA with an alarm function compared to a list or planner. The alarm function served as an effective reminder to prompt students to read the written message on the PDA screen which indicated the task to be completed. The researchers attributed the positive results to the audible “beep” provided by the PDA since each system was comprised of a similar list of assigned tasks.

In light of these positive results using the more basic features of a PDA, future research may want to include evaluation of alarming or auditory signaling features as reminders for additional types of tasks from those which have been evaluated. These may include self-management of health and safety issues such as reminders to brush one’s teeth (O’Hara, Seafriff-Curtin, Levitz, Davies, & Stock, 2008), checking the lock on the front door of an apartment, or turning off the kitchen stove. Individuals with moderate ID or ASD may have the ability to complete these tasks, but may require a reminder to do so. For many, the inability to remember to complete such tasks may prohibit them from participating in less restrictive living and work situations or require external reminders to be delivered by other adults.

**PDA with picture cues.** Digital content, in the form of pictures, can also be incorporated onto handheld devices and have primarily been used to provide step-by-step instructions for performing multi-step functional skills that may be new or difficult for the learner (i.e., operating a washing machine) and tasks which are performed infrequently (i.e., baking a birthday cake). With these systems, information is presented on a single picture and the student performs the step based on the information provided in the picture before advancing the system to the next picture (step) in the task sequence.

Lancioni, O’Reily, Seedhouse, Furniss, and Cunha (2000) found that six students with intellectual disabilities correctly performed a greater number of cleaning, food preparation, and table setting steps when pictures were presented on an IBM 110 palm-top computer compared to a card-based picture system. The researchers further found that task steps could be clustered into fewer pictures as students’ task performances improved. One reason attributed to the differences in performance was the ease of navigation with the PDA (pushing one button to advance the program) compared to physical manipulation of the card system.

Cihak, Wright, and Ayres (2010) used self-modeling static picture prompts via an HP iPAQ Mobile Media Companion handheld devices.
computer with three middle school students diagnosed with high-functioning autism. Different photographs showing the individual student modeling task engagement (i.e., writing, reading) were downloaded onto PowerPoint slides so that one photograph was displayed every 30 seconds and the program advanced automatically during the class period. In addition to use of the PDA, students self-recorded their task engagement on a 3x5 inch index card as each new picture appeared. Results supported prompts delivered by the handheld computer and self-recording by students for increasing task engagement and decreasing teacher directed prompts. Students were further able to generalize use of the system across general education classrooms (i.e., math, science, language arts).

Picture-based PDA systems can also incorporate voice recordings to provide additional information to that provided by the visual pictures. Students typically touch the picture or a button on the PDA to hear a verbal description of how to perform the step. Davies, Stock, and Wehmeyer (2002b) provided information to students using picture + voice recording format. They evaluated the software program, Visual Assistant (AbleLink Technologies), which ran on a Windows CE platform of a handheld computer. Ten adults with intellectual disabilities (Mean IQ = 54.8) viewed step-by-step pictures along with verbal instructions as they completed steps for assembling pizza boxes and packaging software. Students demonstrated improved task accuracy and decreased reliance on adult prompts across both tasks within a vocational setting. Using the same Visual Assistant program and a Cassiopeia TFT palmtop computer, Riffel et al. (2005) demonstrated the ability of four transition-age students with mild to moderate ID and one student with ASD to increase the number of steps they completed without external adult prompting (i.e., doing laundry, rolling silverware, and setting tables) and to decrease duration time spent on each task.

Davies and colleagues (2003) evaluated an additional software prototype, Pocket Compass (AbleLink Technologies), which incorporated decision points into a picture + audio prompting system. The software application, which operated on a Pocket PC palmtop computer platform, provided multiple pictures on the screen and audio instructions which corresponded to different options available to the student (i.e., different colors of CDs to put into a box) (Figure 5). When the student touched one of the decision point pictures, the program advanced to the corresponding sequence of pictures and auditory cues. Forty transition-age students with intellectual disabilities (mean IQ = 55.53) participated in the beta test and increased their independence and accuracy in completing assembly tasks within a vocational setting as well as their ability to navigate decision points.

Cihak, Kessler, and Alberto (2007; 2008) conducted two similar studies to evaluate use of picture and auditory prompts via a PDA to prompt independent task completion and transitions by students with moderate intellectual disabilities. Each study presented the vi-
suval and auditory cues on an Axim X30 handheld computer by Dell. In the first study four students completed four separate community-based tasks (i.e., stocking milk, making sub-rolls) with each subsequent task increasing in the number of steps required for completion. The PDA, used in conjunction with a least-to-most prompting system delivered by the instructor, was an effective tool for delivering prompts to students and task performance was maintained up to 9 weeks. In the second study, four of the same tasks were used from the first study, along with six additional tasks, to evaluate independent transitions between tasks by four students with moderate to severe intellectual disabilities. Similar results indicated that the handheld prompting system was an effective tool for increasing independent task transitions and skills were once again maintained for up to 9 weeks.

In summary, although similar to picture-based booklets, the presentation of pictures on electronic PDAs, may provide a more efficient and effective means for delivering prompts whereby students may find the traditional form of presentation to be more cumbersome to manipulate and may lose their place in the sequence (Lancioni et al., 2000). Electronic picture-based systems with and without voice recordings were both found to be effective in this review. In light of research which indicates that students with ASD may be stronger visual than auditory learners (Quill, 1995; West, 2008), what remains unanswered is whether it is necessary to include voice recordings in conjunction with pictures. In addition to examining the need for voice recordings, future research should also continue the line of investigation initiated by Lancioni et al. concerning clustering multiple pictures into fewer pictures (2000) and clustering individual verbal prompts of steps into longer streams of auditory recordings (2001) as tasks are acquired. Research will need to examine not only students’ abilities to use these features, but the flexibility of systems for making these adjustments with regards to preparation time. The line of research initiated by Davies et al. (2003) into the capabilities of PDAs to function in a non-linear format also warrants more attention. With such programming, pictures on one screen can be linked to a different sequence of pictures depending on the choice or decision made by the user (i.e., which recipe to cook, laundry load size for a washing machine).

PDA with video cues and handheld video players. In a recent literature review of assistive technology devices (including PDAs) used as self-management tools for prompting students with ID, no studies were available (through 2005) evaluating the use of video presented on handhelds (Mechling, 2007). The current review identified eight studies between the years 2007 and 2010 addressing use of video modeling or prompting presented on portable handheld devices as intervention tools for students with moderate ID and ASD.

Video modeling, watching an entire video recording demonstrating how to perform a task prior to completing the task, was used in three of the eight identified studies utilizing video on handheld devices. Van Laarhoven, Van Laarhoven-Myers, and Zurita (2007) worked with two high school aged males with mild and moderate intellectual disabilities in two employment settings (Red Robin and Applebee’s) using video modeling presented on an HP iPAQ hg2700 series Pocket PC. Each student completed three different tasks (i.e., rolling silverware, portioning recipes) using video modeling and video feedback (re-watching the video after errors occurred) in conjunction with a least-to-most prompting system delivered by the instructor. Both students demonstrated an increase in independent responding and a decrease in external adult prompting while using the device.

Taber-Doughty, Patton, and Brennan (2008) used a 30GB Apple video iPod (Figure 6) to deliver simultaneous prompting in a library whereby students watched an entire video task chain, with audio instructions, while simultaneously completing each step. This format was used for locating books and DVDs and using a computer to obtain call numbers by three middle school students with moderate intellectual disabilities. This study compared simultaneous video modeling and delayed video modeling in which a student watched a video model at least one hour prior to traveling to the library and locating the items. The delayed video modeling was presented on a VCR/DVD player. Both systems were found to be effective and students were able to generalize the skills to a second library,
however, when using the video iPod with simultaneous prompting, acquisition and generalization of skills was slightly greater for two students for the computer task and for all three students when locating DVDs and books. Of further interest was the preference of two of the students for using the video iPod.

A video iPod, with video modeling was also used by Cihak, Fahrenkrog, Ayres, and Smith (2010) to increase independent transition behaviors of four elementary students diagnosed with ASD within a general education classroom. A combination of video self-modeling without audio (video clips of the student as the model lining up, walking in the hallway, and entering the next area of the school) and person first point-of-view (students’ vantage point as if they were walking to the next area) were used to create the video models of ten daily transitions. At the beginning of each transition the student watched the video model on the video iPod followed by a teacher prompt to “line up” and begin the transition. Students experienced an increase in independent transitions when using the handheld video device paired with a least-to-most prompting system delivered by the instructor and descending trends in performance when the device was removed.

A third study also used a video iPod, but compared to the previously reviewed studies, the researchers used video prompting and feedback on the device rather than video modeling (Van Laarhoven, Johnson, Van Laarhoven-Myers, Grider & Grider, 2009). Video prompting requires the user to watch one video segment on the device, complete the corresponding step, return to the device, watch the next video segment in the task sequence and so forth. Van Laarhoven and others used video prompting and feedback to present steps to a 17-year-old young man for completing work-related tasks in a no-kill animal shelter. Compared to the Van Laarhoven et al. (2007) study, the participant referred back to individual video segments (rather than the entire video) when an error occurred on a particular step. The program also contained still photographs at the beginning of each video clip to present critical features of steps and a title screen at the end of each video clip to prompt the student to stop the device and complete the step. Voice over narration was also uploaded to the video iPod. Introduction of the video-based materials resulted in an increase in correct responding by the participant across three job-related tasks and a decrease in adult prompting for error correction and use of the device.

In the final three studies identified in this review, PDAs were used to present multiple media options to the users including: voice recordings, digital photographs, and digital video. Unlike the other studies reviewed which incorporated video onto handheld devices, each of these studies used a specialized assistive technology device rather than a mainstream, commercially available product. The studies used a Cyrano Communicator TM (Kiba Technologies, LLC.) which was originally designed as a portable augmentative communication device. The device operated using specially designed software on a commercially available PDA (Hewlett Packard iPAQ Pocket PC or Pidion BM-150R) with multimedia features that allowed the user to
access pictures, video, text, and audio all on one screen. In each of the three studies the PDA was used for prompting step-by-step completion of multi-step functional skills. Students could look at a picture to receive information, repeatedly touch a picture on the screen and hear a voice recording, touch a video icon and play a video recording, or advance the program to subsequent screens (task steps). Using these multiple prompting features students could choose and self-adjust the level of prompting delivered by the device for each step of the task. Unlike the studies previously reviewed in this section, no external adult prompting (i.e., least-to-most prompting system) was provided for task completion although the instructors did provide prompts for use of the device.

The first study evaluated the effects of multiple prompt levels on the independent preparation of recipes by three high school age students with moderate intellectual disabilities (Mechling, Gast, & Seid, 2010). Immediate and abrupt increases in the percentage of steps completed independently were demonstrated by each of the participants following introduction of the PDA system and performance was maintained over time. Results also indicated that participants initially used more intrusive levels of prompts and self-faded these levels of prompts (i.e., video to photos) and later reinstated use of more intrusive prompt levels, as needed, during maintenance sessions.

In response to the Mechling et al. (2010) study, a second study was implemented in order to evaluate the effects of the PDA procedure on the same food preparation tasks, but with three high school age students with ASD (Mechling, Gast, & Seid, 2009). Results replicated those of the previous study in support of a PDA with video, pictures, and auditory prompts as a self-prompting device to assist students with ASD to perform multi-step tasks. Differences did exist between the two studies in regards to the levels of prompts used by students with ASD. Although they also self-adjusted the use of prompt levels, overall their tendency was to continue to rely on prompts from the PDA within and across recipes even though they were able to complete the recipes independently when the PDA was removed.

In a third study Mechling and Seid (2011) evaluated the effectiveness of the PDA with multiple prompt levels to prompt independent pedestrian travel by three transition age students with moderate intellectual disabilities. Similar to a global positioning system (GPS), students who were unable to read maps or text used photographs and video recordings of landmarks along the routes to independently reach three different destinations on a college campus (Figure 7). Similar to the other studies using multiple prompt levels on one screen, the three students self-adjusted their use of prompt levels as they became more familiar with each route.

Results of this review on the use of handheld computers with students with moderate ID and ASD demonstrate that these small portable systems provide some definite advantages for individuals, including portability.
example, in contrast to previous studies examining video and transitions, students in the Cihak et al. (2010) study did not have to return to a “home base” in order to view the video on a television or computer screen. Instead, the portable device moved with the students across environments. Similarly, in the Mechling and Seid (2011) and Van Laarhoven et al. (2009) studies, students were able to walk with the PDA while locating destinations and completing job tasks within an animal shelter.

Although the results have all been positive when using PDAs with different presentation modes (i.e., picture, video), accessibility issues remain with these mainstream devices. Stock et al. (2006) identified and affectively addressed some of these barriers by developing and evaluating a simplified multimedia software system, Pocket Voyager (AbleLink Technologies) for use with a PDA. With their prototype, they created: (a) oversized icons to address the issue of physical access with small icons; (b) digital pictures for identification of contacts in the address book for persons who had difficulty reading text; (c) audio messages to assist understanding of what applications were represented by each icon; (d) recorded audio files for reading phone numbers in the address book; and (e) numbers in larger fonts for persons who had difficulty recognizing and dialing numbers. They further identified the problems persons have with complex PDA operating systems and provided greater consistency across steps for starting different applications in the system. When compared to use of a standard Windows CE operating system and Pocket PC, 32 participants with intellectual disabilities (mean IQ score 56.1) required fewer prompts and committed fewer errors when using the specially designed software program.

In addition to access when using handheld computers, further research and development should continue to investigate the following:

- use of video prompting compared to video modeling on portable handheld devices.
- comparative effects of different systems (i.e., picture-based and video-based systems; self-operated auditory prompting and video prompting) (Taber-Doughty et al., 2008).
- importance of verbal/voice over recordings when using picture-based and video-based systems (Rayner, Denholm, & Sigafoos, 2009).
- effects of handheld devices on different types of task (i.e., fine motor compared to gross motor) (Furniss et al., 1999).
- provision of high-tech handheld systems during acquisition of skills followed by use of light-tech (picture or auditory) systems during review or continuous performance of skills.
- provision of multiple prompt levels (text, audio, picture, and video) on one device or one screen of a device.
- ability of users to self-adjust the prompt levels used on devices and development of systems that permit this adjustment (Van Laarhoven & Van Laarhoven-Myers, 2006).
- effects of clustering multiple pictures of steps into fewer pictures (Lancioni et al., 2000), lengthening or shortening verbal recordings (Lancioni et al., 2001), and adjusting the length of video recordings (Cannella-Malone et al., 2006) as tasks are learned and repeated.
- use of wide screen or zoom shots with photographs and videos when presenting different components of tasks (Van Laarhoven et al., 2007).
- comparative effects of screen size and images for delivering information through pictures and video (Stock et al., 2008).

Discussion and Recommendations for Future Research

Research into the potential benefits of portable electronic technologies for persons with a diagnosis of moderate intellectual disabilities and autism spectrum disorders is in its initial stages. Studies to date support the use of these technologies across environments including work, school, and community settings and across skills including functional multi-step skills, transitioning between tasks and environments, and time and task management.

In spite of the positive results reported in the studies reviewed, persons with intellectual disabilities have traditionally accessed cutting edge technologies far less often than those without disabilities (Carey et al., 2005). In their survey of 83 adults with intellectual disabilities, Carey and colleagues found that only
41% used a computer, 25.3% used the Internet, 27.7 used cell phones, and 10.8% used electronic organizers on a regular basis. They reported that primary barriers to use included lack of access, lack of training and support, and expense. They further found that age, employment status, and self-perceived ability to perform fine motor tasks, significantly affected use of these technologies. More specifically, younger persons used more technology; those employed in competitive employment and those unemployed used more technology than those in sheltered workshops; and persons who were manually able to copy information (i.e., write/copy an address from a business card) used more technology.

To address the issues of availability and expense, some researchers support the use of mainstream, generic devices that are designed for the general population in mass quantities (Cihak et al., 2008). In developing these generic devices, commercial producers are increasingly following the principles of universal design which allow accessibility to all users (as much as possible) without incorporation of special designs or customization (Cihak et al.). Wehmeyer et al. (2008) recommend future research and development across a wide range of technologies, including newer electronic and information systems which employ aspects of universal design to determine their applicability to persons with intellectual disabilities. In addition to being readily available and less expensive, mainstream handheld devices and phones are reported to be non-stigmatizing means for providing assistance to persons with intellectual disabilities because they are predominantly used by the general public (Davies et al., 2002b; Gentry et al., 2010; Gillette & DePompe, 2008; Myles, Ferguson, & Hagiwara, 2007). Results of the reviewed studies further indicate that students like handheld devices and are motivated to use them (Cihak et al., 2010; Mechling & Seid, 2011; Taber et al., 2003; Taber-Doughty et al., 2008; Van Laarhoven et al., 2007). However, the old saying, “one size does not fit all” may also apply to the use of portable electronic devices. For many users, cognitive and physical accessibility are concerns and there continues to be a need to modify mainstream software which operates portable electronic devices in order to increase their accessibility and use by persons with intellectual disabilities (Stock et al., 2006; 2008). Researchers may wish to evaluate commercial mainstream products such as the video iPod to determine if they are as effective as those made specifically for persons with disabilities (i.e., Ablelink Technologies, Kiba Technologies, LLC.) in delivering information and providing access.

Other directions for future research center around the need to explore the application of currently available features offered by PDAs and smartphones (Gentry et al., 2010). These include:

- text to speech features on portable devices so that information (i.e., emails, contact information) can be read to the user. Fonix VoiceCentral 3.1 (Fonix Speech, 2008) has built-in text-to-speech software that allows a Pocket PC to read information and VoiceCentral Black Swan, available for iPhones (Riverturn, Inc., 2009–2010), has this capability.
- voice recognition for operating applications, making phone calls etc. Features are now being offered through products such as Dragon Pdsay (Nuance Communications, Inc., 2010) which provides voice input as well as text to speech features.
- video telephoning to increase skills and opportunities such as social, communication (Renblad, 1999), and safety skills.
- video playback on smartphones to prompt task completion.

In addition to these directions, it appears that special education and related fields should also explore development of applications that will afford the following:

- use of electronic readers on a PDA or smartphone which would allow instant photographs to be taken of text which could be converted to speech to allow ready access to print materials. This feature, which is available on the Intel Reader (Intel Corporation) would allow persons with moderate ID or ASD to take a photograph in a community setting (i.e., street sign, grocery aisle) and have the information read to them.
- simple to use GPS systems which provide pictorial, auditory, and video information to users with moderate intellectual disabilities who are walking (Mechling & Seid, 2011) or
using public transportation. Devices such as the Trekker Breeze (HumanWare, 2005–2009) are currently used by persons who are blind to provide auditory information about locations, directions, routes, and landmarks.

While considering these listed features, it appears relevant to individually evaluate them as independent variables as well as to evaluate them in conjunction with each other such as using a single device for prompting step-by-step task completion, providing reminders to complete a task, and serving as a travel aid. It is important to recognize that future technologies that merge functions into one device, mainstream or customized, will be made available so that students will have access to multiple features on one device.

Finally, while it is important to realize these portable electronic devices may not be appropriate for everyone, and that persons in more restrictive settings with fewer task demands may have less need for PDAs and smartphones (DePompei et al., 2008), it is also possible that these innovations will create opportunities for access and engagement in living, work, and recreational environments that are currently not available to persons with more significant disabilities.

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