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ORIGINAL PAPER

Reducing the Need for Personal Supports Among Workers with Autism Using an iPod Touch as an Assistive Technology: Delayed Randomized Control Trial

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Abstract Personal digital assistants (PDAs) are versatile task organizers that hold promise as assistive technologies for people with cognitive-behavioral challenges. This delayed randomized controlled trial compared two groups of adult workers with autism spectrum disorder (ASD) to determine whether the use of an Apple iPod Touch PDA as a vocational support improves work performance and reduces personal support needs on the job. Baseline data were collected on 50 adults with ASD who were beginning a vocational placement supported by a job coach. Participants were randomized to receive training in the use of a PDA as a vocational aid upon starting their job or after working 12 weeks without PDA support. Workers who received PDA training at the beginning of their job placement required significantly less hours of job coaching support ($p = 0.013$) during their first 12 weeks on the job than those who had not yet received the intervention. Functional performance between the two groups was not significantly different. The significant difference in hours of job coaching support persisted during the subsequent 12 weeks, in which both groups used a PDA ($p = 0.017$).

Keywords Autism · Autism spectrum disorder · Assistive technology · Employment · Occupational therapy · Vocational rehabilitation

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Introduction

Adults with autism spectrum disorder (ASD) face daunting challenges in the American workplace. Recent studies have found competitive employment rates from 4.1 to 11.8 % among working age individuals with ASD (Taylor and Seltzer 2011; McDonough and Revell 2010) and rates of any sort of post-secondary employment at 55 % among this population, lower than the rates for people with intellectual or learning disabilities (Shattuck et al. 2012). In fact, even individuals with ASD who have completed college have reported significant challenges with under-employment and chronic unemployment (Hurlbutt and Chalmers 2004; Barnhill 2007; Hendricks and Wehman 2009; Henninger and Taylor 2013; Wehman et al. 2013). Across the ability spectrum, individuals with ASD have lower rates of participation in vocational or technical education, employment, and post-secondary education in 2 or 4-year programs than their peers with speech language impairments, learning disabilities or other intellectual disabilities for as long as 7 years post high school (Shattuck et al. 2012). These statistics are often attributed to functional difficulties related to cognition, behavior, communication and sensory-processing that can impact work performance (Matson and Rivet 2008).

At the same time, it is clear that adults with ASD often have valuable characteristics that are sought after in the workplace. Some individuals demonstrate remarkable logical and mathematical acuity, exceptional computer skills, or photographic memory. They may also possess important personal traits that foster productivity in the workplace, such as honesty, reliability and perseverance. The limited interest in interpersonal relationships that is characteristic of many people with ASD may sometimes be seen as a positive quality, because a worker with ASD may be less likely to engage in unnecessary social interactions with co-workers, allowing for increased work productivity (Capo 2001). Vocational support strategies that leverage these positive work attributes may help improve work attainment and retention for this population.

Literature on assistive technology interventions for people with ASD focuses primarily on children (e.g., Pierangelo and Giuliani 2008; Wehmeyer and Webb 2012), though, as noted below, a few researchers have explored assistive technologies for adults. Emerging research supports the use of personal digital assistants (PDAs) as assistive technology for cognition among people with brain injury (Gentry et al. 2008), multiple sclerosis (Gentry 2008), intellectual disability (Cihak et al. 2008; Furniss et al. 1999), Alzheimer's disease (Oriani et al. 2003) and mental illness (Simons and Gentry 2012). PDAs are pocket-sized, durable, easily accessible and designed to offer basic computing and task organization features that may assist in the management of everyday tasks at home, at school and in community settings. These devices may be especially appropriate for people with ASD, since research has shown that many of these people may prefer instruction and support provided by computers to that offered directly by another person (Bolte et al. 2010; Williams et al. 2002; Chen and Bernard-Optiz 1993).

Over the past few years, as PDAs, smartphones and tablet computers have developed into multi-functional appliances capable of incorporating advanced task management applications, communication and augmentative communication tools, way-finding supports, video cameras and video editors, accessibility settings and a rapidly growing library of educational media, opportunities to leverage these devices as assistive technology have outpaced the efforts of researchers to assess their efficacy with any disability population. Research on their use by workers with ASD is scarce, but a number of studies point to strategies used in school and transitional settings that have potential for successful implementation in the workplace. The following list describes some of these strategies along with references to studies that reported on their use among adolescents or adults with ASD:

Time Management

Reminder prompts may address memory impairment and transition difficulties by automatically cueing users to begin a task or switch from activity to activity (Mechling et al. 2009; Gentry et al. 2010). Timer applications may offer a visual analogue to the passage of time for those who cannot tell time (Gentry et al. 2012).

Task Management

To do lists, pictorial slide shows or task-sequencing videos may provide instruction and support for complex tasks. Myles et al. (2007) showed that a high school student with Asperger's Syndrome could improve homework adherence by recording his assignments on a PDA. Gentry et al. (2010) combined task reminders and typed to do lists on Palm Pilot PDAs in a 12-week trial that demonstrated improved functional independence by 20 adolescents and young adults with ASD. Pictorial prompts based on a Pocket PC PDA were shown to improve independent performance of a cooking task by three adolescents with ASD (Mechling et al. 2009).

Task-Training Using Video Modeling

Video modeling as an educational tool has been heavily researched over the past two decades, primarily using free-standing video cameras for recording, with playback on desktop computers. A 2007 meta-analysis of 23 studies (Bellini and Akullian 2007) found that the strategy promotes skill acquisition, with gains maintained over time and transferred across persons and settings among children and adolescents with ASD. The reviewers recommended video modeling as an evidence-based practice. Since then, a few studies have explored video modeling in pre-vocational or vocational settings for workers with ASD. Allen et al. (2010a) and Allen et al. (2010b) used desktop computer-based video models to successfully teach walk-around tasks to seven adolescents with ASD hired to wear air-inflated mascots. Cihak et al. (2010) used iPod-based videos to assist adolescents with ASD in school-day transitions. Bereznak et al. (2012) demonstrated that three high school students with ASD were able to learn cooking, cleaning and copying tasks video modeled on an iPhone. Burke et al. (2013) used a proprietary software named *VideoTote*, running on an Android tablet, to provide video-based task prompting for four adult workers with autism, finding the approach effective in helping them complete multi-step packaging and shipping tasks. Kellems and Morningstar (2012) used video-modeling delivered by Apple iPod to successfully train four young adults with autism multi-step job-related tasks.

Way-Finding and Person-Locating

PDA-based maps, videotaped routes inside workplaces, and person-finding applications may be useful to workers with ASD and their support personnel. We did not find any studies that researched these technologies for workers with ASD.

Social Interactions and Behavioral Management

Cognitive-behavioral therapy and behavioral reward applications, supportive audio or video segments from a caregiver, video-modeled social stories, relaxing games, and phone or video chat links to supervisors may help workers complete tasks, manage anxiety, socialize and/or reduce inappropriate behavior. Boyd et al. (2012) recommend these strategies, though they do not discuss PDA-based approaches. Ploog et al. (2013) review research using computer-based versions of some of these strategies on desktop platforms.

Work-related Supports

Money management applications, automated bus schedules, weather applications, etc., are a few of the many mobile tools that may be used as work-related supports. No studies were found that directly address the use of mobile applications for these purposes.

Accessibility Settings and Applications

Mobile devices offer a wealth of accessibility options that serve people with sensory and motor impairments, as well as non-readers and those with augmentative communication needs. Achmadi et al. (2012) demonstrated that two adolescents with ASD could learn to use a speech-generating application (Proloquo2go) on an iPhone for augmentative communication needs. Other access and communication strategies using PDAs as assistive technologies for adults with ASD have not been reported.

Each new generation of PDAs, tablets and smartphones offers additional features that may be adapted to support workers with ASD. In addition to built-in cameras and communication, task management, and accessibility tools, these devices may be customized with add-on applications appropriate to an individual's specific needs. At this writing, there are one million Apple mobile applications (apps) available for download and over one million apps that run on Google's Android platform. Choosing an appropriate suite of apps for any individual's vocational support needs may be compared to drinking from a fire hose. A training strategy based on vocational support and assistive technology theory, such as that used in the current study, may prove useful in applying these tools in the workplace.

All of the above-cited studies involved single-case or case series experiments, small *n* quasi-experimental methods, or were reviews of such research. Most were conducted in school or pre-vocational settings, examining single solutions to discrete problems. In actual practice, a worker with ASD may benefit from an appropriately chosen device with useful peripherals and an individualized suite of apps and strategies to address a range of workplace challenges. The current study is unique in examining this approach.

The Digital Divide

As PDAs, smartphones, tablets and other portable electronic devices evolve, their potential to serve as assistive technologies is growing rapidly, yet a yawning digital divide limits access to these tools among people with disabilities, who may have the most to gain from their use. For example, Jaeger (2012) has reported that people with disabilities use the Internet at rates that are half that of the general population. Macdonald and Clayton (2013) list the following obstacles to the use of computers and mobile technologies for people with disabilities: (1) lack of funds, (2) lack of state provision, (3) lack of training, and (4) lack of skills to use them. It is important for researchers, practitioners and policy makers to recognize this digital divide and find ways to bridge it. As Borg et al. (2011) have noted, in order for assistive technologies to be effective, access to affordable digital technologies must be seen as a basic human right, not as a commodity.

Vocational Rehabilitation Program Challenges

State-funded vocational rehabilitation (VR) programs are experiencing substantial difficulties in responding to the employment service needs of the growing population of adults with ASD. Cimera and Cowan (2009), in an analysis of VR agency reports nationally (RSA 911 data), found that the number of individuals with ASD served by these agencies doubled in 4 years (2002–2006), while the overall population served fell by 4.1 %. They also reported that VR agencies spent more in supporting workers with ASD than for most other disability groups. Cimera's (2012) follow-up analysis found continuing increases nationwide in VR agency clients with ASD but declining employment success rates for this group. Clearly, VR programs need new employment service options to offer people with ASD. Assistive technology may offer a cost-effective way to address these challenges.

Research Questions for this Study

The study reported here recruited adults with ASD who were about to begin job coach-supported competitive employment placements. The objective was to determine if the use of an Apple iPod Touch, as trained by an occupational therapist (OT), would significantly reduce the need for personal supports in performing job duties and building competence on the job. All participants in the study were trained to use the iPod Touch as an assistive technology at work, but the intervention was randomized to two time points. One group received the device and training in its use upon starting work; the other after working for 12 weeks. We hypothesized that the former group would require fewer hours of job coaching support than the latter group during that 12-week time period without detriment to their work performance. We collected data on hours worked, job coach hours worked, support needs and work performance across a full 24 weeks, in order to additionally compare outcomes after the latter group received their assistive technology training, and we interviewed the participants upon study completion to explore the social validity of the intervention.

Methods

The researchers implemented a delayed, randomized control trial to explore the efficacy of an assistive technology intervention in support of workers with ASD. The delayed RCT model allowed us to offer the intervention to both groups, while still allowing a 12-week comparison window. The delayed model also allowed us to compare the effectiveness of the intervention started at two different time periods (upon beginning work and after working 12 weeks).

Participants and Randomization

Participants in the study were enlisted from Virginia Department of Aging and Rehabilitative Services (DARS) clients with an ASD diagnosis confirmed by school record or medical report who were scheduled to begin a job coach-supported paid work placement in the Commonwealth of Virginia. All participants consented to participate prior to enrollment. Volunteers were randomized to one of two treatment groups; those randomized to the "Now" group received the intervention upon starting their job placement while participants in the "Delayed" group received the intervention 12 weeks after beginning their job placement.

Participants all worked in competitive employment settings at wages ranging from $7 to 11/h, paid by employers. Weekly hours ranged from 8 to 35. None had jobs that paid benefits or provided paid time off. Most jobs were service-oriented, including custodians, stockers, grocery baggers, car wash attendants, and food service workers; a few participants held clerical positions (see Table 1). As they would do with any other client, DARS-funded job coaches collaborated with their clients and prospective employers to find a promising employment match, then provided personal supports to facilitate success at work. These supports included environmental or task adaptations, transportation planning, employee training and/or direct supervision, as determined by their own clinical expertise and reasoning. Within the DARS system, job coaches have the responsibility of developing and assuring a successful employment placement for their clients. The intervention discussed herein was conducted as an experiment intended to supplement these efforts. Consented job coaches were apprised of the intervention and its aim to provide automated assistance to participants. They were asked to collaborate with the intervention OT in determining participant needs, but were not asked to program or manage the devices themselves.

Table 1 Types of jobs held by study participants in now and delayed intervention groups

Job title	Now	Delayed
Janitorial staff	4	4
Merchandise stock clerk	4	4
Grocery stock clerk/bagger	4	3
Office file clerk or mailroom clerk	3	3
Restaurant food preparation staff	3	1
Restaurant bus service staff	2	1
Pharmacy aide	1	2
After-school program teacher's aide	1	1
Machine shop service technician	1	1
Car wash detailer	1	1
Pet shop attendant	1	
Database entry clerk	1	
Rental car agency driver		1
Website designer		1
Library aide		1

Humans Subjects Research Review Boards of the affiliated university and DARS approved the project. Informed consent was obtained from participants and from their DARS job coaches. If a participant lived with a parent or legal guardian, consent was also obtained from that person. Upon consent, the PI used an automated random number generator to select participants for the two groups. Participants were randomized into a "Now" intervention group or a "Delayed" intervention group. Those in the "Now" Group received the intervention within 1 week of starting their job placement; those in the "Delayed" Group received the intervention 12 weeks after beginning their job placement. Thus, as our primary comparison, for the first 12 weeks the "Now" group can be considered an active treatment group and the "Delayed" group a control group. Follow-up information was collected from both groups for an additional 12 weeks so that the study spanned 24 weeks total.

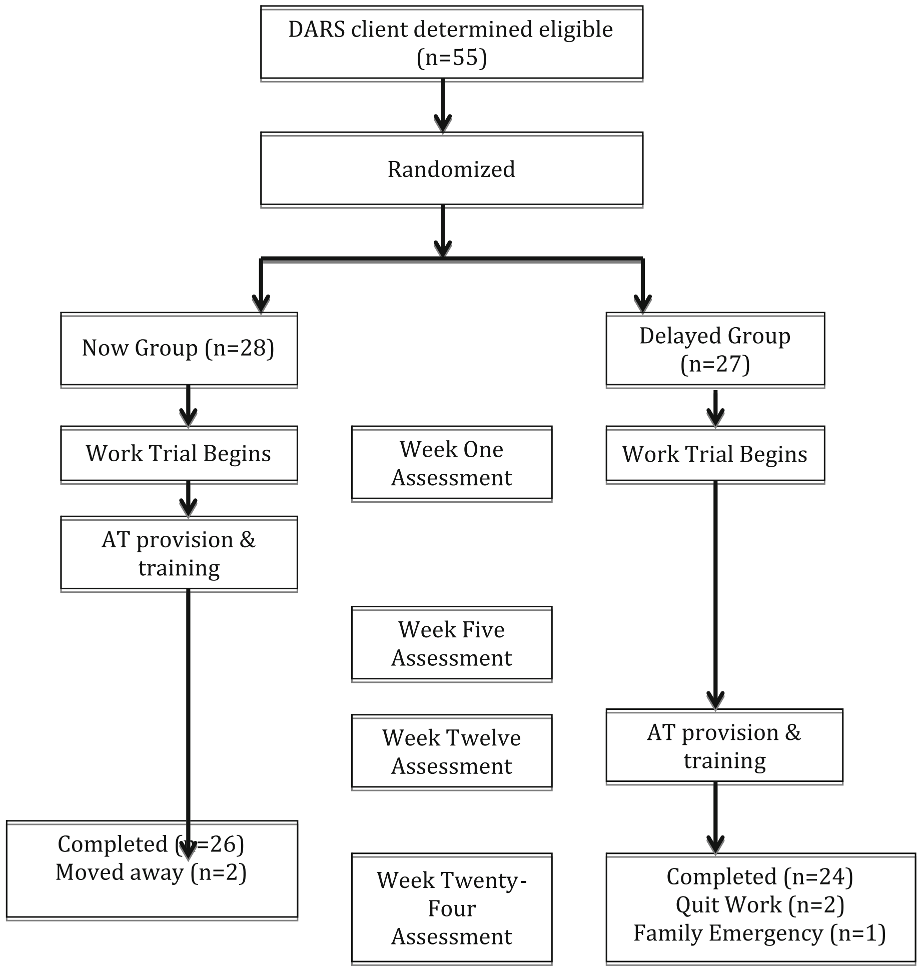

Fig. 1 Assessment and intervention flow diagram

Fifty-five participants enrolled in the study; 49 completed it and another completed fourteen weeks of the trial. Five participants voluntarily left the study (and their jobs) during their first 2 months at work—two because they moved away, two because they resigned, and the fifth because of a family emergency. One participant lost his job due to down-sizing in his fifth month at work. Data from the five participants who left work prior to the 12-week data collection time point were not included. However, data from the first 12 weeks for the participant who lost his job after that point was included. The randomization, assessment and treatment flow diagram for both groups is shown in Fig. 1.

Though participants in the study were randomized to one of the two treatment groups, the two groups were not significantly different in any demographic we recorded. These data were derived from DARS vocational aptitude assessments, which are conducted for all DARS clients.

The male: female ratio of 42:8 is similar to the ratio in the general population (50:9, Baio 2014), participant ages ranged from 18 to 60, though most were in their twenties (the average age for all participants was 24). Thirty participants were Caucasian, fifteen were African American, three were Hispanic and two were of Asian descent. Most participants (42) lived with parents, four lived with a roommate, two in a group home, and two alone. No participants had graduated college, 34 had attained regular high school diplomas, twelve had earned high school certificates and one had not completed high school. Most participants were designated "conversant" by DARS in an estimation of verbal skills. Fourteen were designated selectively non-verbal and two were non-speakers. DARS estimated that 46 participants could read at least at a second grade level; four could not. Demographic data for the participants is summarized in Table 2 below, including gender, age, living situation, highest level of schooling attained, verbal skill and ability to read.

Intervention Activities—Assistive Technology

The intervention included four components:

1. A detailed workplace assistive technology assessment conducted by an OT in collaboration with the participant, job coach and employer;

Table 2 Characteristics of participants and primary outcomes

Data element	Level	Both groups (N = 50) N (%)	Range	'Now' group (N = 26) N (%)	'Delayed' group (N = 24) N (%)	p^a
Gender	Male	42 (84 %)		24 (92 %)	18 (75 %)	0.1319
	Female	8 (16 %)		2 (8 %)	6 (25 %)	
Age		24.0 (8.3)[b]	18–60	25.0 (9.9)[b]	22.9 (6.2)[b]	0.3884[c]
Home setting	Parents	42 (86 %)		20 (77 %)	22 (92 %)	0.5744
	Roommate	4 (8 %)		3 (12 %)	1 (4 %)	
	Alone	2 (4 %)		1 (4 %)	1 (4 %)	
	Group home	2 (4 %)		2 (8 %)	0 (0 %)	
Educational level	Less than HS	1 (2 %)		3 (12 %)	0 (0 %)	0.3220
	High school certificate	12 (24 %)		17 (65 %)	17 (71 %)	
	Regular HS diploma	34 (68 %)		6 (23 %)	6 (25 %)	
	Less than HS	3 (6 %)		0 (0 %)	1 (4 %)	
Verbal skills	Conversant	34 (68 %)		17 (65 %)	17 (71 %)	0.5501
	Selectively non-verbal	14 (28 %)		7 (27 %)	7 (29 %)	
	Non-verbal	2 (%)		2 (8 %)	0 (0 %)	
Ability to read	Yes	46 (92 %)		24 (92 %)	22 (92 %)	1.0000
	No	4 (8 %)		2 (8 %)	2 (8 %)	

Data element	Both groups		'Now' group	'Delayed' group	p^c
	Mean (SD)	Range	Mean (SD)	Mean (SD)	
SIS (baseline)	37.2 (10.6)	9–58	35.0 (10.7)	39.5 (10.2)	0.1281
SIS (12 weeks)	31.4 (11.2)	8–55	29.7 (10.9)	33.3 (11.4)	0.2607
SIS (24 weeks)	26.6 (11.6)	0–49	25.0 (11.6)	28.5 (11.6)	0.3144
EPS (baseline)	27.5 (6.8)	17–50	27.7 (5.7)	27.3 (7.9)	0.8370
EPS (12 weeks)	30.4 (5.8)	19–50	32.8 (6.1)	31.6 (5.8)	0.4702
EPS (24 weeks)	32.3 (5.9)	21–49	30.8 (4.8)	30.0 (6.8)	0.6129
CHART (baseline)	309.4 (64.0)	200–450	309.8 (70.3)	309.0 (58.0)	0.9685
Hrs worked (12 weeks)	244.1 (80.5)	29–479	250.1 (92.2)	237.4 (66.4)	0.5685
Hrs worked (24 weeks)	486.3 (173.0)	60–1044	494.8 (190.1)	476.3 (154.2)	0.7158
Job coach h (12 weeks)	62.6 (42.9)	11–184	47.6 (22.3)	79.4 (53.8)	0.0133[d]
Job coach h (24 weeks)	89.0 (65.9)	15–306	66.5 (28.9)	115.6 (85.8)	0.0168[d]

[a] *p* values calculated from an exact Pearson Chi square test, which tests that 'Now' group percentages are not equal to 'Delayed' group percentages

[b] Estimates are mean (SD)

[c] *p* value calculated from 2-sample t test of a difference in means between the two treatment groups

[d] *p* value calculated from unequal variance two-sample t test of a difference in means between the two treatment groups

2. Identification of an individualized suite of iPod Touch-based applications and strategies appropriate to support the participant in the workplace;
3. Training of the participant by the OT in the use of an Apple iPod Touch and the selected apps on the job; and
4. Follow-along and fading of occupational therapy supports as the worker incorporated the device into her/his workday.

In order to maintain delineation of support tasks, the OT in this study confined his efforts to the iPod-touch intervention, as outlined above. He did not consult or collaborate with the job coaches on other issues, such as adaptive devices, environmental modifications, employer relations or other areas that an OT might otherwise address in this setting. It is possible that staff OTs were called into help with these issues for some participants, as with any other DARS client, but the study OT did not do so.

The Apple iPod Touch was chosen for this project, because it was (and continues to be as of this writing) the only pocket-sized PDA on the market (see Fig. 2).

These devices can be carried in a pocket, on a belt clip or on a necklace lanyard, making them appropriate for

Fig. 2 Apple iPod Touch 4th Generation (4 g)

workers who must use their hands on the job. The iPod Touch, which costs under $200, includes task organization applications, such as an electronic calendar, address book, to do list, and a reminders program. The device also includes still and video cameras, wi-fi and Bluetooth interactivity, and a suite of accessibility features for users with sensory and motor impairment. At this writing, one million add-on apps are available for download from the Apple iTunes Store, allowing for a diverse range of customization approaches for individual users. The iPod Touch was chosen because no other available device seemed to match its combination of affordability, portability, and flexibility. During the 4-year course of the study, other devices appeared that may have been appropriate for the purposes of this study, including, for example, the Apple iPad and tablets using the Google Android operating system. For consistency, only the iPod Touch was used in this study.

The Assistive Technology Practitioner

The study's principal investigator, an OT experienced in the use of PDAs as cognitive aids, performed the study intervention with all participants. The intervention was based on the widely used Human-Activity-Assistive Technology (HAAT) theoretical model. This model allows for collaborative and ongoing problem-solving, a step-wise, individualized approach to the implementation of an assistive technology in the workplace, and straightforward assessment of outcomes (Cook and Polgar 2008). The

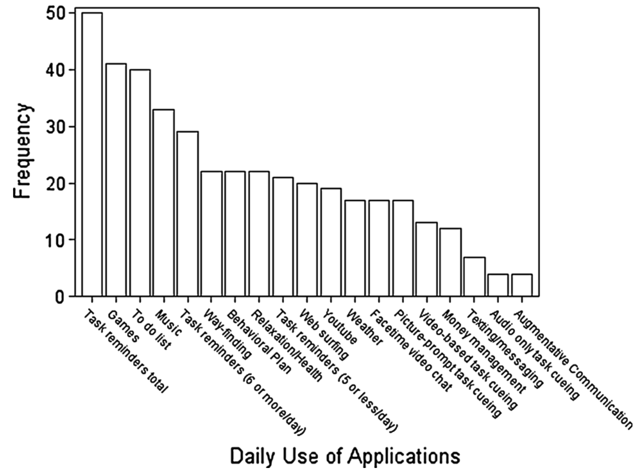

Fig. 3 iPod-based Apps Used by Study Participants

HAAT model describes the interaction of a human (H), an activity s(he) wishes to perform (A) and an assistive technology (AT) that facilitates this activity within a particular context. The model derives from the World Health Organization's (WHO) International Classification of Functioning, Disability, and Health (ICF) (WHO, 2001), which emphasizes the interrelated factors of a person and her/his goals, activity/participation, and the environment (assistive technology is considered an environmental factor under this classification).

A common fallacy in conducting research with assistive technologies is to consider the device itself as the only independent variable. This leaves out the key assessment, collaboration and training components necessary to successful adoption of an assistive device. The Assistive Technology Act of 1998 (as amended 2004) describes two components of assistive technology: (1) "any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities"; and (2) any *service that directly assists an individual with a disability in the selection, acquisition, or use of an assistive technology device*. Examples of such a service provided in the law include: (1) evaluating needs for assistive technology; (2) acquiring assistive technologies; (3) selecting, designing, repairing, and fabricating assistive technology systems; (4) coordinating services with other therapies; and (5) training both individuals with disabilities and those working with them to use the technologies effectively.

Following the HAAT model, the OT collaborated with the worker participant, the participant's DARS job coach and the employer to identify support needs that might be met by a PDA. The OT then configured an Apple iPod Touch provided by DARS, and trained the participant how to use the device as a vocational support aid, providing additional training on the use and maintenance of the device, troubleshooting assistance and follow-along oversight as needed. Participants were encouraged to use the PDA as trained at work, job coaches were encouraged to incorporate PDA-based vocational support strategies in their ongoing employment support efforts, and employers were asked to allow use of the PDA as an assistive technology on the job.

PDA-based applications and strategies employed in this way included: (1) task reminders, (2) task lists, (3) picture prompts, (4) video-based task-sequencing prompts, (4) behavioral self-management adaptations, (5) way-finding tools, (6) communication with the job coach via wi-fi, when available on the jobsite, and other supports. Figure 3 compares the daily use of these supports across all participants. The OT also selected an appropriate set of peripherals for the device, including a protective carrying case or belt clip, and in some cases an external speaker or keyboard. The OT then trained the participant and job coach in using the device as a vocational aid, and provided follow-along support, as needed, during a trial of device utilization on the job. Participants were asked to use the device as trained at work, but were invited to take it home after work, keep it charged, and use it as they wished at home. Upon completion of the study, participants were allowed to keep their devices.

Data Elements

A DARS researcher not involved with the assistive technology intervention conducted initial assessment for each participant. The initial assessment included a demographic survey and the Craig Handicap Assessment and Rating Technique (CHART), which provided baseline data on a participant's functional independence at home and in the community (Whiteneck et al. 1992). The CHART is a 32-item questionnaire that addresses six categories of functional disability, including: (1) physical independence, (2) cognitive independence, (3) mobility, (4) occupation, (5) social integration, and (6) economic self-sufficiency. Response scores can range from 0-100, with 100 denoting full functional independence in all categories. Four studies support the CHART as a reliable and valid instrument for measuring levels of functional independence (Dijkers 1991; Hall et al. 1998; Segal and Schall 1995; Whiteneck et al. 1992, b). The demographic items included a participant's age (years), gender (Male, Female), living situation (alone, parents, roommate, or group home), education level (less than a high school diploma or certificate, high school certificate, standard high school diploma or education beyond high school), verbal ability (conversant, selectively non-verbal or non-verbal) and reading ability (categorized by DARS as yes/no based on a person's demonstrated ability to read at a second grade level). This information was drawn from DARS intake records maintained for all DARS clients.

In addition to these measures, the job coach completed the Supports Intensity Scale (SIS)—Employment Subscale (Thompson et al. 2004) and the Employee Performance Evaluation Report (EPER) (Virginia Department of Aging and Rehabilitative Services 2009) at the following time points for each participant: (1) after 4 weeks, (2) 12 weeks and (3) 24 weeks on the job. The SIS is a multi-part questionnaire intended to identify the type, amount, and frequency of personal support required by individuals with intellectual disabilities, including persons with ASD, to perform 57 life activities. The SIS has been successfully tested for interrater reliability (Thompson et al. 2008), construct validity (Weiss et al. 2009), factorial validity (Kuppens et al. 2010), and efficacy (Wehmeyer et al. 2009) and found to be good to excellent as a measure of personal support needs for individuals with intellectual disability. For this study, the 8-item Employment Subscale Score was used. The SIS-EPS subscale rates eight work-related performance factors, each measured on a Likert scale: (1) accessing/receiving job/task accommodations, (2) learning and using specific job skills, (3) interacting with co-workers, (4) interacting with supervisors/coaches, (5) completing work-related tasks with acceptable speed, (6) completing work-related tasks with acceptable quality, (7) changing job assignments, and (8) seeking information and assistance from an employer. We used the SIS-EPS subscale as a dependent measure of personal support needs, generating an overall score ranging from 0 (independent on all items) to 85 (4 h or more of full physical assistance daily on at least an hourly basis for all items).

The EPER is a Likert-scaled questionnaire developed by DARS and used by DARS-affiliated job coaches to measure the everyday work performance of their clients. Job coaches rate ten performance factors on a 5-point Likert-scale (1 = needs significant improvement, 5 = exceptional performance): (1) knowledge and quality of work performed, (2) quantity of work performed, (3) work habits, (4) relationships with the public, (5) relationships with co-workers, (6) initiative, (7) dependability, (8) observance of working hours, (9) work attire and image, and (10) supervisory ability. We used the EPER as a dependent measure of job performance, generating an overall score ranging from 10 (needs significant improvement on all 10 items) to 50 (exceptional performance on all items).

The number of hours a participant worked each month, and the cumulative number of hours worked by a participant, were included as outcome measures, along with the number of job coaching support hours provided for each participant. This information, routinely reported by DARS-affiliated job coaches, was collected by DARS for each study participant and shared with the research team. For this study, job coaching hours recorded included only face-to-face or telephonic support for a participant; travel and documentation time were not included. The OT in the study recorded occupational therapy intervention data, including notes on assistive technology interventions for each participant, hours of assistive technology training and follow-along provided, and strategies, peripherals and applications used.

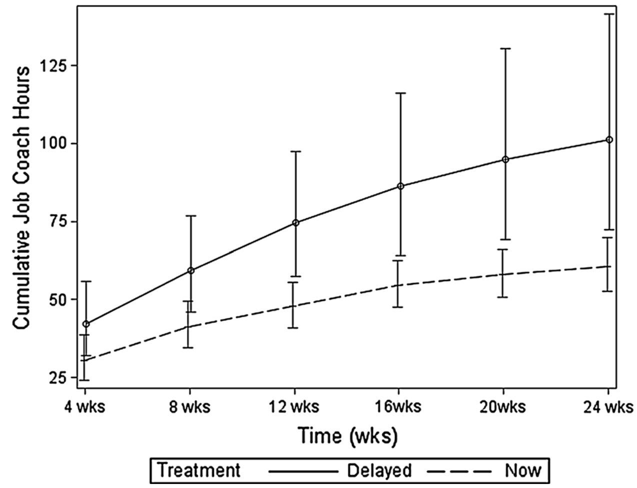

Fig. 4 Cumulative job coaching support hours over the 24 week study perioed, separately for the 'Now' (dashed line) and the 'Delayed' group (solid line)

Results

Statistical Analysis

The mean and standard deviations (SD) or frequency and percentage for each demographic variable were summarized as recorded at study enrollment. This was performed for the entire sample and separately for the two intervention groups. Two-sample *t* tests and Pearson Chi square tests were performed between the treatment groups to examine whether the two groups were demographically comparable at baseline. Unequal variance t tests were used to compare the number of job coach hours worked in the first 12 weeks and across the full 24 weeks of the study, since in these cases the equal variance assumption appeared to be violated.

A generalized linear mixed-effect model is suitable for the analysis with the aforementioned challenges, and it was used to adjust for each of the characteristics described previously. A gamma distribution was assumed for the error terms to adjust for the skewness of the outcomes. Separate error variances were estimated for the Now and Delayed group and for each of the time points. The observation time, treatment group, the interaction of these variables, age, gender, living situation, education level, and verbal ability were included as fixed-effects for all analyses. Due to the small number of participants observed in some of the variables, the levels of verbal ability, education, and living situation were combined in our analysis to the following bimodal variables: conversational/not conversational, high school certificate or less/high school certificate or more, and living with parents/other, respectively. The cumulative number of hours worked by the participant and both the initial SIS and EPS were included in the analysis of the cumulative job coach hours. The interpolated and observed value of the SIS and EPS were included in the analysis of the monthly job coach hours, as were the number of monthly hours worked by each participant.

The estimated mean outcome, either cumulative or monthly job coach hours, and 95 % confidence intervals (CIs) are reported for all observation points. However, due to space considerations, focus is directed toward the 12- and 24-week observation points; information on all other time points is displayed in the Online Supplementary Material. Rather than report differences in the mean outcomes between the treatment groups at each time point, the ratio of the estimated means were reported for the cumulative or monthly job coach hours outcomes. This is necessitated by our choice of the statistical model. Thus, mean ratios equal to 1 are representative of no difference between the levels of a data element. Mean ratios greater than or <1 are interpreted as one level having a higher or lower mean than a referent level, respectively. Since the SIS and EPS score are continuous, the results from the final analysis are presented as the comparison of mean ratios for a five point increase in the SIS or EPS scores. Similarly, the number of hours worked and age are presented as mean ratios for a 10 h difference in hours worked and a 5 year increase in age. For the continuous data elements, mean ratios >1 are indicative of an increase in the response being related to an increase in the respective continuous data element. All statistical analyses were performed using SAS v9.3 statistical software. Effects with $p < 0.05$ were deemed to be statistically significant.

Baseline Comparison and Outcome Efficacy

The summaries in Table 2 provide a description of the sampled participants and treatment outcomes. The information in the table demonstrates that there were no significant differences on the explanatory variables at baseline. Of particular note is the similarity in the CHART score upon study enrollment. Both groups have comparable scores, indicating that participants in both groups have very similar levels of functional independence upon starting work. DARS does not formally assess intellectual ability in

Table 3 Cumulative and monthly job-coaching support hours

Data element	Level[a]: Level[b] (referent)	Mean ratio	95 % CI	*p*
Cumulative job coach hours				
Treatment (0–12 weeks)	'Delayed': 'now'	1.56	(1.15, 2.13)	0.0056
Treatment (13–24 weeks)	'Delayed': 'now'	1.67	(1.18, 2.38)	0.0061
Gender	Female: male	1.08	(0.70, 1.67)	0.7281
Home setting	Other: parents	1.96	(1.35, 2.84)	0.0010
Education level	HS diploma or more: HS certificate or less	1.26	(0.87, 1.81)	0.2077
Verbal skills	Less than conversant: conversant	0.78	(0.56, 1.08)	0.1306
Age	(5 year increase)	0.93	(0.87, 1.02)	0.1321
SIS (baseline)	(5 point increase)	1.17	(1.08, 1.26)	0.0002
EPS (baseline)	(5 point increase)	0.90	(0.80, 1.03)	0.1136
Cum. h worked	(10 h increase)	1.00	(1.00, 1.01)	0.0696
Monthly job coach hours				
Treatment (0–12 weeks)	'Delayed': 'Now'	2.18	(1.37, 3.48)	0.0016
Treatment (13–24 weeks)	'Delayed': 'Now'	2.16	(1.16, 4.03)	0.0170
Gender	Female: Male	1.14	(0.72, 1.81)	0.5802
Home setting	Other: parents	1.62	(1.08, 2.44)	0.0217
Education level	HS diploma or more: h certificate or less	1.11	(0.74, 1.68)	0.5833
Verbal skills	Less than conversant: conversant	0.86	(0.60, 1.23)	0.3955
Age	(5 year increase)	0.98	(0.90, 1.07)	0.6913
SIS (baseline)	(5 point increase)	1.10	(1.01, 1.19)	0.0358
EPS (baseline)	(5 point increase)	0.96	(0.83, 1.10)	0.5421
Monthly h worked	(10 h increase)	1.05	(1.02, 1.08)	0.0032

[a] Antecedent level

[b] Reference level

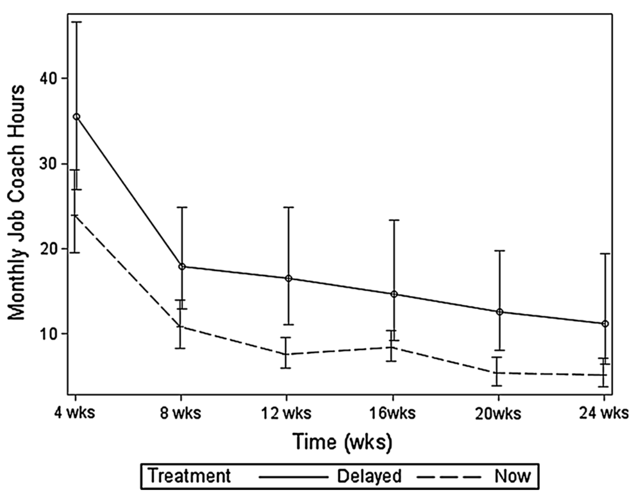

Fig. 5 Monthly job coaching support hours over the 24 week study perioed, separately for the 'Now' (*dashed line*) and the 'Delayed' group (*solid line*)

their clients. We included DARS estimations of verbal skill and reading ability, along with the other demographic variables, and no significant differences between groups were observed.

Cumulative Job Coach Hours Worked

The estimated mean cumulative job coach hours worked are displayed graphically in Fig. 4. Complete estimates and 95 % CIs can be found in the Online Resource. There is at least one difference in job coaching support hours between the treatment groups at any of the time points ($p = 0.0122$). Nominally, job coaches supporting the 'Now' group worked significantly fewer hours than those supporting the 'Delayed' group at all observation points. A significant difference in the cumulative hours worked by job coaches was found at the primary endpoint (12 weeks) and continued across the 24 weeks of the study. Although Fig. 4 suggests differing increases in the cumulative time for each treatment group, this interaction was not significant ($p = 0.0626$).

The estimated mean cumulative number of hours of support provided by the job coaches for the participants in the 'Now' group at 12-weeks (Mean 47.8, 95 % CI 41.1, 55.5) was 1.56 times less (95 % CI 1.15, 2.13; $p = 0.0056$) than the estimated mean for the 'Delayed group (Mean 74.7, 95 % CI 57.3, 97.4). This significant difference continued to 24 weeks ($p = 0.0061$), with the 'Now' group having an estimated mean of 60.6 (95 % CI 52.7, 69.7) while the 'Delayed' group had an estimated mean of 101.1 (95 % CI 72.4, 141.6). The 'Delayed' group had 1.67 (95 % CI 1.18, 2.38) times as many cumulative hours worked by the job coach at 24 weeks.

The estimated mean ratios for the cumulative hours worked by the job coach at 12 and 24 weeks as well as the other explanatory variables included in the model, can be seen in the upper portion of Table 3 (below). Participants who live with their parents tended to spend less time (Mean Ratio 1.96, 95 % CI 1.35, 2.84; $p = 0.0010$) with the job coach. As one might expect, participants with higher values of SIS (support needs) measured at baseline tended to require more hours of job coaching support ($p = 0.0002$); for every 5 unit increase in the initial SIS measurement, the number of hours worked tended to be 1.17 (95 % CI 1.08, 1.26) times higher.

Monthly Job Coach Hours Worked

Just as in the analysis of the cumulative job coach hours, the number of monthly job coach hours is nominally larger for the 'Delayed' group compared to the 'Now' group at all observation points. At least one difference between the treatment groups ($p = 0.0184$) was observed, however, no interaction between the treatment groups was observed ($p = 0.1362$). This means that the difference in job coach hours remained constant over the monthly observation points. The estimated profiles of the monthly hours worked by the job coach can be seen graphically in Fig. 5 and quantitatively in the Online Resource.

The mean monthly number of hours of assistance provided by the job coach for the participants in the 'Now' group at 12-weeks (Mean 7.6, 95 % CI 6.0, 9.6) was 2.18 times less (95 % CI 1.37, 3.48; $p = 0.0016$) than the estimated mean for the 'Delayed' group (Mean 16.6, 95 % CI 11.1, 24.8). A significant difference was observed at 24 weeks (Mean Ratio 2.16; 95 % CI 1.16, 4.03; $p = 0.0170$), with the 'Now' group having an estimated mean of 5.2 (95 % CI 3.8, 7.2) while the 'Delayed' group had an estimated mean of 11.2 (95 % CI 6.5, 19.4).

The mean ratios for the monthly job coach hours for 12 and 24 weeks, along with all of the other explanatory variables, can be seen in the lower portion of Table 3. Other variables that had a relationship with the monthly number of job coach hours are the number of hours worked in each month ($p = 0.0032$) by the participant, the monthly SIS score ($p = 0.0358$), and a participant's living situation ($p = 0.0217$). For a 5-point increase in the SIS score, the number of monthly hours spent by the job coach tended to increase by a factor of 1.10 (95 % CI 1.01, 1.19). A similar relationship was observed between monthly job coach hours and number of hours worked by a participant; a 10-h increase in the number of hours worked by the participant resulted in a 1.05 (95 % CI 1.02, 1.08) factor increase. The complete results of the tests for the monthly job coach hours can be seen in Table 3.

Table 4 FATCAT findings—social validity

	Item	Mean[a]	SD
1.	Using a PDA has helped me improve performance in at least one area of my work	5.00	0.00
2.	I received enough training to use the PDA effectively for my purposes	5.00	0.00
3	I find the PDA simple to use	4.83	0.52
4.	I am able to use the PDA without any help from another person	4.50	0.41
5.	I primarily use the PDA as a reminder system for things I need to do	4.00	0.60
6.	I found that I was able to respond to reminder alarms almost every time one rang	4.32	0.22
7.	I would like to continue using the PDA	5.00	0.00
8.	Using the PDA is just a waste of time	1.00	0.00
9.	I misplaced the PDA at least once	2.45	0.84
10.	The PDA broke down at least once	1.45	0.45

[a] Items are scored on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree)

Cost Effectiveness Estimate

Because these findings demonstrate a significant reduction in job coaching hours for participants who were trained to use an iPod Touch immediately upon starting work, it is possible to estimate the cost-effectiveness of the intervention. For this estimate, we followed hourly pay estimates of DARS for an OT and job coach of \$80 and \$50/h, respectively. The average cost of the iPod Touch, downloaded apps and peripherals was \$230. The OT averaged 9.2 h per participant in conducting the intervention. As noted from Fig. 4 and the Online Resource, the job coach spent 47.8 h over the first 12 weeks with a participant in the 'Now' group and 60.6 h over the full 24 weeks. Based on these figures, the average overall cost of job coaching support and the AT intervention for a participant in the 'Now' Group was \$3356 over 12 weeks and \$3996 over 24 weeks. In comparison, the average cost of job coaching and the AT intervention for a participant in the 'Delayed' group (estimated cumulative job coach hours of 74.7 and 101.1 h for the first 12 and 24 weeks, respectively) amounted to \$3735 for the first 12 weeks and \$6021 over 24 weeks. This results in savings of \$379 over the first 12 weeks and \$2025 over a full 24 weeks. These estimates suggest that training in the use of an iPod Touch as a work-related assistive technology may save money for the state vocational rehabilitation agency.

Device Usage and Social Validity

The OT tracked device usage during the study for all participants and interviewed them upon study completion using a Likert-scaled instrument, the Functional Assessment Tool for Cognitive Assistive Technology (FATCAT), which is intended to examine the social validity of the intervention. Upon study enrollment, only six of 56 enrollees had owned or used a PDA, computer tablet or smartphone. Thirty-four did not have a cell phone of any kind. Participants were trained to navigate and maintain an iPod Touch and to use an individualized suite of iPod Touch-based applications. No worker appeared to need more than five applications for job support, though many learned to use other applications for recreational purposes. As Fig. 3 shows, every participant used a reminder application to assist with time management and task transitions. (Many used the onboard *Clock* app, though some required add-on apps that provided spoken word reminders or that automatically linked to picture-prompts or video-based task sequences.) Text, picture-based or video-based to do lists, way-finding directions and/or behavioral adaptation cues were frequently used. Many participants also learned to play games, listen to music and use the wi-fi interactivity of an iPod Touch to access the Internet. Those who worked in wi-fi enabled worksites were trained to communicate with their job coaches via video chat using Facetime or Skype apps, as needed (telephonic and video-based communication with clients are routinely recorded in contact hours reported by DARS job coaches and were included in our calculations of job coach support hours). The FATCAT asks those interviewed to demonstrate interaction with the device as trained. At study completion, all participants were able to demonstrate how to navigate the device interface and manage reminder alarms and other apps they had been trained to use, providing evidence of retention of learning and suggesting that they regularly used the device as trained.

As summarized in Table 4, study participants found the intervention to be successful and said they would recommend it to others. After training, they answered that they were able to use the iPod Touch independently and said they planned to continue using it after study completion, providing qualitative evidence of the intervention's social validity.

Discussion

This study explored training in the use of an Apple iPod Touch as an assistive technology for workers with ASD. It is the first randomized clinical trial investigating assistive technologies as vocational support tools for this population. The results show that training in the use of a PDA as an assistive technology significantly reduces the need for job coaching support by workers with ASD, without reducing functional performance on the job. In this study, job coaching support hours fell among participants using a PDA as a vocational aid, whether the device was provided immediately upon starting work or 12 weeks later, but those trained to use the device upon starting work required significantly less job coaching support across the 24 weeks of the study as compared to those who received the device later. So while training in the use of a PDA reduced job coaching needs at either time point, starting sooner was more effective. The reduction in job coaching hours shown in this study was large enough to offset the cost of the AT intervention, representing a cost-saving for the state vocational rehabilitation agency.

As one might expect, statistical analysis revealed that in both groups participants who worked more hours required more hours of job coaching and those who scored higher on the SIS (showing increased support needs) required more hours of job coaching. Interestingly, participants who lived with parents required fewer hours of job coaching than those who lived on their own. The role of living situation in job preparation and support for this population may be of interest to future researchers.

Job Coach Hours versus Support Needs Scores

Though job coach hours were significantly fewer for the 'Now' group across all weeks of the study than for the 'Delayed' group, work performance as measured by the EPER and support needs as measured by the SIS were not significantly different. This result seems to support the use of PDAs as vocational aids in that using the device did not increase support needs or decrease vocational performance, despite fewer hours of job coaching supervision. But how is it possible that support needs and occupational performance for both groups were not significantly different even as job coaches reported significantly fewer support hours in one group? The SIS vocational scale used to measure support needs has a scoring floor that may have impacted this result. The employment subscale does not appear to have sufficient granularity to reflect some differences that may have occurred (for example, the same score on the SIS question for "hours of support provided" might designate a range of 0.5–16 h weekly). Future researchers are advised to take account of this finding and utilize a tool that may be more sensitive to this parameter. Similarly, competent performance on all job performance questions of the EPER would result in an overall score of 30. That ceiling was reached for the average participant in both groups by the 12th week on the job, before the participants in the 'Delayed' group had begun training in the use of the PDA.

Though statistically significant, the average weekly hours of face-to-face job coaching provided at Week 12 (1.2 for the 'Now' group and 3.6 for the 'Delayed' group) suggest that both groups were at or approaching follow-along status by that point. We may assume that the introduction of iPod Touch training for the 'Delayed' group after 12 weeks on the job would not lead to a marked drop-off in job coaching support hours that had already reached a low level. Indeed, this is what our analysis revealed, a gradual reduction in job coaching hours for both groups across Weeks 13–24. In seeking to optimize job coaching resources, then, it would appear that early introduction of the PDA training intervention is preferable to a delayed introduction.

Limitations

Participant, Job and Interventionist Characteristics

It is important to note that the participants in this study do not represent the full-range of symptoms or functional challenges associated with ASD, thus, they are not entirely representative of the adult ASD population. For example, the workers in this study all demonstrated functional cognition, vision, hearing and manual dexterity sufficient to interact with the iPod Touch without need of accessibility adaptations. Some people with ASD have cognitive, sensory or motor conditions that would make utilization of such a device problematic, though mobile device accessibility settings not available for this study are promising. The study participants exhibited a variety of vocational difficulties, including managing time and task transitions, task-sequencing, way-finding, communicating, reading, and conducting personal interactions on the job, and many displayed anxiety-driven behaviors that impacted work performance, yet all were able to perform their job duties with direct job-coaching supervision *before* the iPod Touch was introduced. In this study, the device did not serve as a vocational trainer, but as a tool to provide automated supports, allowing a reduction in the need for direct onsite supervision without a corresponding reduction in job performance.

The OT who performed the intervention has extensive experience in using PDAs as cognitive-behavioral aids for a variety of populations with cognitive challenges in community settings. Though OTs often serve as assistive technology practitioners, similar results would not be expected from a clinician who lacked training in the use of mobile technologies as cognitive aids.

Job coaches in this study were consented as co-participants in the iPod Touch intervention. It is the job coach's responsibility, under the DARS system, to match jobs to clients, manage accommodations and assure supports for job performance. It has been suggested that job coaches may have *artificially* reduced their support hours after the iPod Touch intervention, assuming that the device would provide automated supports in their stead. While this may have occurred in some cases, we feel that it is unlikely. Like DARS, we relied on the professionalism of the job coaches to assure necessary supports for their clients, as they are ultimately responsible for client vocational outcomes.

Group Matching

Participants in this study were randomized to one of the two treatment groups after achieving a vocational placement in cooperation with a DARS job coach. Consequently, the investigators did not attempt to match the characteristics of one group to the other. By the same token, the investigators played no role in selecting jobs for participants, and did not attempt to match jobs held by workers in the two groups. As noted in our analysis, however, there were no significant differences in demographic characteristics or functional independence at baseline between the two groups. As shown in Table 1, the types of jobs held by participants in the two groups roughly matched, but we recognize that despite our baseline comparison, it is possible that the task requirements or support needs of one group exceeded those of the other in some way that we did not measure, thus affecting our results.

Other Measurement Limitations

Ideally, researchers track all measured parameters by direct observation, but this is rarely practicable in a community-based study, especially in a vocational setting where attendance by a researcher over the course of a 24-week trial might bias participation and potentially interfere with work done on the job site. Our measures relied on the consented job coaches to accurately report their clients' performance and support needs and to accurately record their own direct support hours (as they do with all of their clients) and are limited by this constraint. The primary investigator served as the interventionist OT in this study, and his records of OT intervention hours were not independently verified. He conducted a final interview with all participants, using the FATCAT assessment measure, so that the section of the narrative reporting on device usage and social validity (summarized in Fig. 4) risks bias due to lack of an independent assessor.

Implications for Vocational Support Practitioners

This study reinforces prior research into the use of mobile devices as vocational support aids, incorporating as it does a flexible approach that addresses the individual needs of workers with ASD. As with any assistive technology intervention, it is important, we feel, to utilize an approach that is grounded in theory and follows a step-by-step collaborative assessment and intervention model. The HAAT model used by our researchers is recommended as one such approach. Smartphones, PDAs and tablets are evolving rapidly and new apps appear every day. Clinicians who wish to use these tools in vocational support for people with ASD or other cognitive-behavioral conditions are encouraged to seek training in their everyday use and in specific strategies for vocational accommodation before attempting to implement them as assistive technologies in the workplace. It may be helpful to consider, however, that no participant in this study used more than five apps on their iPod Touches for vocational support, but they typically used these apps frequently during the day. As shown in Fig. 3, all participants used iPod Touch-based task reminders to stay on task and/or transition between tasks. This finding highlights the important point that PDAs, designed originally as task organizers for the general population, can function similarly for workers with ASD. These individuals, however, may use the devices differently than others. Few people set six reminder alarms each day, but for a worker with ASD, this may be a minimum number of reminders to help her/him move from task to task across the workday. Similarly, the use of video for behavioral modeling, way-finding and task-sequencing is rarely used by the general population, but can play a key role in helping workers with ASD function more independently on the job.

The model followed in this study, incorporating the partnership of an OT familiar with mobile technologies and an employment specialist onsite, links assistive technology and personal supports in a way conducive to successful vocational outcomes. As mobile computers continue to evolve, our options for using them as assistive technologies grow as well. These tools are relatively inexpensive, portable in the workplace, and—as research has shown—can provide a myriad of supports. As practitioners explore their uses, it is important to share knowledge, discuss success stories and challenges, and learn from each other how best to leverage these technologies to support functional independence at work, at home, and in the community.

Future Research

Evidence for the use of assistive technologies by adults with ASD is sparse. Most research literature concerning individuals with ASD is only applicable to young children between the ages of three to 6 years old (Shattuck et al. 2012). Consequently, there is a very limited body of research to guide practice for vocational rehabilitation and employment support practitioners who are in desperate need of evidence-based models (Office of Autism Research Coordination 2012). Research into uses of mobile devices as vocational support aids for a challenging and underserved population, as in this study, may open doors for innovative and cost-effective supports that may improve vocational outcomes.

As noted in the Introduction, working age adults with ASD face challenges in finding competitive employment of any kind. The jobs found by participants in this study, most of which are in low-paying service industries (see Table 1), may reflect on the difficulties these individuals face in attaining and keeping jobs of any sort. Though this study supports the use of PDAs in reducing personal supports for this population, future researchers may wish to explore whether assistive technologies can promote access to better jobs.

This study—in which only six of 50 participants owned a smartphone or PDA prior to enrollment—follows an extensive body of research showing that people with disabilities lag the general population in access to computer technologies, even though these tools may afford them important, and in some cases life-changing, supports. Research and training efforts should be expanded to determine how best to use smart technologies as cognitive-behavioral aids, including how to assess needs and strategies, and to measure functional change at home, at work, at school, and in the community. Additionally, partnerships between device and application developers and people in the disability community should be fostered to better shape products that accommodate and support users with varied abilities. At the same time, policy efforts should be undertaken to provide access to smart tools, and training in their use, by the underserved disability community.

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Conflict of interest The authors declare that they have no conflict of interest.

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