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A Review of the Use of Touch-Screen Mobile Devices by People with Developmental Disabilities

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Abstract This article presents a review of the research on the use of mobile touch-screen devices such as PDAs, iPod Touches, iPads and smart phones by people with developmental disabilities. Most of the research has been on very basic use of the devices as speech generating devices, as a means of providing video, pictorial and/or audio self-prompting and for leisure activities such as listening to music and watching videos. Most research studies were small-n designs that provided a preponderant level of research evidence. There is a clear need for more research with younger participants and with a much wider range of apps, including educational apps.

Keywords Developmental disabilities · PDA · iPod · iPad · Smart phone

Introduction

While this article was being written, Apple announced that it had sold three million iPads in 3 days (Apple Press Info 2012). These figures, and others like them, illustrate the increasing popularity and availability of hand-held touch-screen electronic devices. Hand-held electronic devices have been shown to have potential for teaching students with disabilities and to increase their independence and their leisure options (Kagohara et al. 2013; Mechling 2007, 2011; Reichle 2011; Wehmeyer et al. 2008). Older hand-held devices such as some personal digital assistants (PDAs) or palm-top computers and early iPods were typically accessed through the use of hard buttons or through the use of a stylus on a touch screen. Studies have shown that participants with intellectual disability (ID) were able to use these kinds of hand-held devices (see for example Davies et al. 2002; Cihak et al. 2010), but touch-screen devices are more accessible and are much more in accord with the principles of universal design (Wehmeyer et al. 2008). These touch devices (such as the iPod Touch, iPads and other tablets, smart phones and some PDAs) have several advantages over older devices in that they are mainstream technology and hence their use is not stigmatizing. They are portable, can be used in many environments, are relatively inexpensive (compared to older PDAs and SGDs), have much longer battery life than older devices and there are an extremely large number of applications that can be installed (Cumming and Strnadova 2012; Douglas et al. 2012).

Although most information about touch device use by people with disabilities may be in the popular media (Cumming and Strnadova 2012), there is a research-base on the use of touch devices with people with developmental disabilities emerging. Recent reviews have had a relatively narrow remit and have covered the use of iPods and iPads in teaching programs for people with developmental disabilities (Kagohara et al. 2013), the use of portable devices including those without finger-operated touch screens for teaching cooking skills to people with moderate to severe disabilities (Mechling 2008), use by people with moderate ID and autism spectrum disorders (ASDs) (Mechling 2011), and use by people with cognitive deficits resulting from acquired brain injury (de Joode et al. 2010). As far as we know there has been no recent review of the

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use portable, finger-operated touch devices with people with developmental disabilities that takes a broad perspective in considering studies across a range of uses and contexts.

The purpose of study is to review the research relating to the use of portable devices with finger-touch access by people with developmental disabilities. In particular the research questions to be answered are:

1. What devices are used and for what purposes?
2. How successful is device use?
3. If device use has to be taught, what are effective intervention strategies?
4. What is the level of evidence provided by the reviewed studies?

Methods

Two searches were carried out in June and September 2012 using education, technology, medical/therapy and general databases (A+ Education, Academic Search Premier, CINAHL, Computers and Applied Science, Education Research Complete, ERIC, PsychINFO, PubMed, Web of Science and Google Scholar) and using the search terms 'iPad', 'iPod' or 'PDA' with 'disabilit*', 'autis*', or 'aac'. After duplicates were excluded, these searches resulted in 345 hits. In an effort to reduce publication bias, refereed conference papers, theses at or above Master's level and book chapters were considered for inclusion as well as refereed journal articles. Ninety-four hits were excluded because they were not refereed journal articles, refereed conference papers, theses or book chapters, leaving 251 hits. At the first screening step, both authors selected potentially relevant articles, papers and theses based on the titles and abstracts. Refereed articles, refereed conference presentations, theses and book chapters were included if they described the use of an iPad, iPod, PDA, or other hand-held electronic devices such as smart phones or tablets by a person with a disability and included outcome data relating to device use. Articles that used devices only for data collection, that provided descriptions and generic claims or which were review articles were not included. The final list from initial screening included 75 items and inter-rater reliability for item selection was 93.3 %, with all disagreements resolved by discussion. Following this selection, an ancestral search was made of the reference lists of these 75 articles and a further 12 articles were included.

These 87 papers were then checked further by both authors independently, using the full-text as required, to exclude papers that did not meet the criteria above (this was not always apparent from the title and abstract), papers that related to devices that were operated by using a stylus on the touch-screen or by hard buttons and not by finger touch and those where the device was provided to participants but they did not activate it, or only needed to press hard buttons, not a touch screen. Where it was not clear how a device was operated from a reading of the full paper, device manuals and other information about devices available on the internet were consulted by the authors independently. For two papers, neither author could make a decision about how the device was accessed and the authors were contacted for further information, and as a result one paper (Riffel et al. 2005) was included and one paper (Van Laarhoven et al. 2007) was excluded. For three papers (Mechling et al. 2009, 2010; Mechling and Seid 2011) participants could use either a stylus or their finger, but no specific indication was provided of how individual participants accessed the device. Given finger use was possible, these studies were included. Six papers were excluded because although a touch device using finger touch was used, the participants did not operate the device themselves (Burke et al. 2010; Canella-Malone et al. 2012; Cardon 2012; Jowett et al. 2012; Kagohara et al. 2012; Macpherson 2012). Inter-rater reliability for this selection was 92.8 % and all disagreements were resolved by discussion. As a result of this screening a further 40 papers were excluded.

Finally, the remaining 47 papers were examined (using the full text as required) to exclude those where the participants were not people with developmental disabilities such as ID, ASD, or attention deficit hyperactivity disorder (ADHD). Seven papers were excluded because they reported on people with disabilities such as traumatic brain injury, multiple sclerosis, dementia or hearing or vision impairment and three were excluded because the participants had reading difficulties/dyslexia. Where studies included people who did not have a developmental disability as well as people who did, they were included if data on the participants with developmental disability could be extracted. Inter-rater reliability for this selection was 97.9 % and the one disagreement was resolved by discussion. The full text of one thesis (Carpenter 2011) could not be obtained. This process left 40 papers that went forward for detailed data extraction and coding.

During data extraction one paper (Newton and Dell 2011) was excluded because it did not provide data from an intervention. One article (Price 2011) had been included twice because it was listed twice with different author initials and different abstracts. Four papers were excluded as there were no student outcome data. (Hourcade et al. 2012; Lee 2012; McClanahan et al. 2012; Tunney and Ryan 2012).

In addition, recent relevant review papers by Kagohara et al. (2013) and Mechling (2011) were reviewed and

resulted in the identification of three papers which we had excluded on our initial screening as the devices used were described as SGDs in the abstracts or titles, not as touch-screen devices. Thus a total of 36 papers were included in the review.

Information was extracted by the first author from all papers about the research design used, the aim of the study, the nature of the device and how it was used, the characteristics of the participants, the location of the study, the dependent and independent variables, data collection strategies and outcomes. The second author also extracted these data from eight randomly selected papers and inter-rater reliability for data extraction was 93.1 %. All studies were coded by the first author to enable a judgment about the quality of the evidence provided. Small-n studies were coded for the presence and/or quality of descriptions of participants, settings and selection procedures; of dependent and independent variables, of measurement and inter-observer reliability; of procedural reliability; of procedures for baseline and for acceptable research design with three demonstrations of control (or 75 %) and replication across at least three participants settings or materials. Group studies were coded similarly for information about participants, variables, inter-rater and procedural reliability and also for random selection and allocation of participants, attrition, and blinding of assessors. The second author coded the same set of 8 studies as for data extraction, and inter-rater reliability for research quality coding was 95.1 %.

The percentage of non-overlapping data points metric (PND) was calculated for all small-n studies where an intervention was used to teach touch device use (Scruggs et al. 1987). PND is a measure of the points in non-baseline phases that do not overlap with the range of points in baseline phases. This metric is an accepted method for synthesizing small-n research (Scruggs and Mastropieri in press). PNDs were calculated for the treatment phase and where data were provided for treatment plus maintenance and generalization this was also calculated. Where studies provided data on more than one intervention related to device use, PNDs were calculated for all interventions. For ABAB designs, the PND was calculated for A1 compared to B1, A2 compared to B1 and A2 compared to B2 and the mean PND of these was then calculated. A similar approach was taken with other multi-phase designs. Where data were provided on interventions to teach other skills, these data were not included. A third person calculated the PNDs for eight of the small-n studies and agreement was 84.4 %. Disagreements were mostly over very close data points and there was only one disagreement over more than one data point within a single study. Finally, mean PND was calculated separately for all interventions teaching device use, and for interventions teaching use for communication, self-prompting, and leisure.

Drawing on the framework used by Ramdoss et al. (2012) and Mulloy et al. (2010) and the criteria for quality research suggested by Gersten et al. (2005), Gersten and Edyburn (2007) and Horner et al. (2005), an overall judgment (see Table 1 for criteria) was made as to whether each study provided evidence that was suggestive, preponderant, or conclusive. A third person reviewed the research quality coding of eight small-n and two group design papers and made a judgment about the research quality. Agreement on these judgments was 90 % and the single disagreement was resolved by discussion.

Results

There were 36 papers examined, covering 34 studies (see Table 2). Two studies reported in theses, Achmadi (2010) and Payne (2011) were also reported in journal articles (Achmadi et al. 2012; Payne et al. 2012). Of these studies, 25 were small-n designs (one of which, Chang et al. 2010 included case study data), four were case studies and five were group designs. Studies covered the use of iPod Touches, iPads and smart phones for communication (nine small-n studies and one case study); iPod Touches, iPhone, PDAs, PAQ Pocket PCs and palmtops for self-operated prompt systems (10 small-n studies, one of which included case study data and two group studies); iPod Touches and iPhones for leisure (three small-n studies, and one group study); iPads for teaching academic skills (one case study and two group studies) and two other case studies using iPads and iPod Touches that did not fall into these categories. The case studies will be described first, then the small-n design studies and finally the group studies.

There was one case study (Leo et al. 2011) in the communication area with three participants with autism (two male and one female), which compared the use of the app PixTalk on a smart phone with the use of the picture exchange system (PECS) that participants were already using. Teachers implemented the use of the smart phone and two teachers rated participant communication as being better with PixTalk than with PECS. Chang et al. (2010) provided information about a participant with ID and schizophrenia who learned to use a PDA to navigate within a building. Trinh (2011) reported on an adult female with cerebral palsy and speech impairment using an app to teach phonics on an iPad. She was reported to have improved on letter name knowledge, letter-sound correspondence, reading real words, blending real words, phoneme analysis and phoneme counting. Blending of non-words was slightly worse after intervention and there was no change in spelling real words. Abdullah and Brereton (2012) reported on iPad use to take photos at school to support a male

Table 1 Criteria for judgments on level of certainty of evidence provided by each study

Level of certainty	Criteria
Suggestive	Case studies with empirical data
	Small-n designs that are A-B, A-B-C, A-B-A, A-B-BC, or non-staggered multiple baseline designs
	Group designs with no comparison groups (pre-post only)
	Any study where the participants and participant selection, dependent variable(s), measurement strategies are poorly described, and/or could not be replicated from the description
	Dependent variable(s) not measured repeatedly in small-n designs
	No inter-observer reliability
	No information on statistical procedures if used
Preponderant	Experimental designs including group comparison designs
	Small-n multiple probe designs and ABAB with fewer than 5 points per phase
	Acceptable inter-observer reliability reported (at least 20 % of observations, with 80 % or more agreement)
	Sufficient detail (re participant selection etc.) provided for replication
	Some limitations in demonstrating experimental control are present (for example, only two demonstrations of effect in small-n designs; fewer than five baseline points in more than 2/3 of baselines in small-n designs)
Conclusive	Group designs with random assignment to control and comparison groups, acceptable attrition rates, and blinding of assessors
	Small-n designs such as ABAB (with at least five data points per phase), alternating treatments, multiple-baseline designs
	At least three demonstrations of effect in small-n designs.
	Baseline in small-n designs has at least five points (2/3 baselines acceptable)
	Acceptable procedural reliability reported (over at least 20 % of sessions, implemented with at least 80 % fidelity)

student with ASD to communicate about school with his parents. Gentry et al. (2012) reported on the use of a wide range of apps on an iPod Touch (including self-management at home and in the workplace and leisure apps) as cognitive-behavioral aids by a 21 year old male, a 60 year old female and a 20 year old female all with autism. After training, two participants no longer needed an on-site job coach and the other moved from needing direct supervision to indirect supervision.

Table 2 summarizes the participants, settings, devices and apps used, study aims, outcomes and PND (where appropriate) for small-n studies. For studies on communication, there were 26 participants, 22 males and 4 females aged between 4 and 23 years. Many participants (18) had an ASD or autistic-like behavior, and 12 participants had an ID. Two males (Sam and Steven) each participated in three studies (Achmadi 2010; Achmadi et al. 2012; Kagohara et al. 2010, 2012; van der Meer et al. 2011). All studies except one were implemented in schools or child-care centers. For studies on self-prompting there were 33 participants, 25 males and eight females aged between 10 and 27 years. Most (24) had an ID and 13 had an ASD or autistic-like behaviour. Studies were mostly implemented in schools. For studies on leisure there were six participants (three males and three females) aged 15–21 years, all with ID. Two studies (Kagohara 2011; Kagohara et al. 2011) used the same three participants (Jim, Sarah, and Mary). All were implemented in schools.

There were 14 small-n studies (eight for communication, two for self-prompting and three for leisure) that taught the use of a touch device and provided intervention data. Six self-prompting studies did not provide intervention data, but provided descriptions of intervention strategies. Interventions ranged in length from three to 28 sessions and a total duration of 15–170 min. Sessions were most commonly implemented 2–3 days per week and were between 5 and 10 min in length. Most to least prompting was used in two studies, least to most in seven studies, time delay in eight studies and delayed prompting in three studies. (Further detail is available in the supplementary tables.)

There were only five group studies, and none addressed communication. Two studies explored self-prompting (Davies et al. 2010; Davies, Stock, and Wehmeyer 2002), with a total of 33 participants (22 males and 11 females) all aged 18 or over and all with ID. One study explored leisure activities (Davies et al. 2008). Two studies explored the use of iPads for academic learning (Price 2011; Venkatesh et al. 2012), with a total of 61 participants with autism. Three were comparison studies (Davies et al. 2002, 2008, 2010). (Further details are available in the supplementary tables.)

Table 2 Summary data for small-n design studies

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
Communication studies					
Achmadi (2010) and Achmadi et al. (2012) Multiprobe multiple base-line across participants	2 males Sam 13 years, severe ID and autism; Steven 17 years, autism, OCD and ADHD Implemented by researcher, school setting	iPod Touch as an SGD Proloquo2Go (for AAC) displaying line drawings	To evaluate an intervention to teach students to turn on and unlock the iPod touch and navigate through the pages to locate icons to make multi-step requests when asked "Let me know if you want something" with toys and snacks in view	Learned to activate iPod, indicate if they wanted a snack or a toy then select a specific item out of three options use back button to begin a new request	91.3 For intervention 1
Flores et al. (2012) A-B-A-B-A	5 males Max 9 years, ASD; Nick 8 years, ASD, moderate ID; Len 8 years, ASD, mild ID; Al 9 years, mild ID; Sam 11 years, moderate ID, orthopedic impairment Implemented by teacher, school summer program	iPad as an SGD Pick a Word (for AAC) displaying six icons)	To compare the use of the Apple iPad as an SGD for making requests with a non-electronic picture system the students were already using. Items were visible and the teacher asked students what they wanted. Students could make up to three symbol utterances	All learned to request snack items with the iPad, but no intervention data provided Al, Nick and Max communicated more with the iPad	Mean PND across comparisons 71.8
Kagohara et al. (2010) ABCDAD	1 male Steven 17 years, autism, OCD and ADHD Implemented by researcher, school setting	iPod Touch as an SGD Proloquo2Go (for AAC) displaying three line drawings	To determine if a behavioral intervention could remedy a difficulty activating the speech output when he was asked to request a visible snack item	Learned to press iPod Touch so as to activate speech output and maintained 10 weeks later	100
Kagohara et al. (2012) Multiple probe across participants	2 males. Sam 13 years, severe ID and autism; Steven 17 years, autism, OCD and ADHD Two studies implemented by researcher, school setting	iPod Touch in Study 1 and iPad in study 2, as SGDs Proloquo2Go (for AAC) displaying four icons on iPod and six on iPad	To evaluate the effects of a systematic instructional intervention to teach naming of pictures using an iPod Touch (Study 1) and an iPad (Study 2), when presented with relevant instructional questions (What is this? What do you see?). The effect on speech of teaching SGD use was also explored	Both learned to select icons to name photos when asked "What is this?" Sam learned to respond when asked "What do you see?" No increase in intelligible spoken words during intervention	Device use Intervention 1 (closed question) 97 (97) Intervention 1 (open questions) 78.8 (80.6) Intervention 2 (closed questions) 100

Table 2 continued

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
van der Meer et al. (2012) (Note: incorrect graphs included in published article, correct graphs obtained from authors) Multiple probe across participants with embedded alternating treatments design with each phase	2 males Joe 12 years, ASD; Sam 6 years ID, childhood disintegrative disorder2 females Saskia 10 years, Angelman syndrome; Nicky 13 years, PDD-NOS Implemented by researcher, childcare center	iPod Touch as an SGD Proloquo2Go (for AAC)	To compare the acquisition of use, and preference for an SGD, manual signing, and picture exchange. Asked to request a snack or toy when a tray of items shown i.e. select one symbol from two, corresponding to shown items	All learned to use iPod Touch Joe could activate iPod Touch with only one icon Others could choose snacks or play items depending on what was offered. Joe and Saskia preferred the iPod	For iPod intervention 81.3 (83.6)
Lorah (2012) Alternating treatments with initial baselines replicated across participants	5 males Joel 5 years 5 months; Axel 4 years 3 months; Aaron 4 years 1 month; Peter 3 years 10 months; Rick 5 year 11 months. All with autism Implemented by two masters and one doctoral student, school setting	iPad as an SGD Proloquo2Go (for AAC) displaying one symbol	To evaluate the effects of an intervention to teach the use of an iPad as SGD, and to compare it with the effects of an intervention to teach picture exchange. After participant reached to one of three items, required to activate device	Joel, Alex, Aaron, Peter mastered both exchange and iPad with more responding on the iPad and preferred the iPad Rick preferred picture exchange and did not master iPad use	100 for device use
van der Meer et al. (2011) Multiple probe across participants	2 males Sam 13 years, autism, severe ID; Jim 14 years, severe ID 1 female Zoe 23 years, severe ID, seizures Implemented by two trainers, school setting	iPod Touch as an SGD Proloquo2Go (for AAC)	To evaluate an intervention to teach use of an iPod Touch as an SGD for requesting. When shown a tray of snacks or toys and asked to make a request, had to activate the corresponding icon from a choice of three	Sam and Jim mastered use Zoe did not master Only Jim maintained use at 10 week follow-up	No data collected during intervention
van der Meer et al. (2012) Multiple probe across participants with embedded alternating treatments	4 males David 10 years, ASD; Tom 5.5 years, multi-system developmental disorder with autistic-like behaviors; Zac 7 years. ASD; Eli 5.5 years, myotonic dystrophy, autistic-like behaviors Implemented by a trainer, school setting	iPod Touch as an SGD Proloquo2Go (for AAC)	To determine whether the participants made greater progress, showed increased communication ability, and showed better maintenance of their preferred AAC system (iPod compared to manual sign) Taught to request by touching corresponding icon from three (snack items for David, play items for others) when items shown	All learned to activate the icons when shown desired items David, Tom and Zac maintained at follow up Tom, Eli and Zac preferred the IPod	90.5 (92.8)

Table 2 continued

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
van der Meer et al. (2012) Alternating treatments, non-concurrent multiple baseline across participants	3 males Jason 4 years, global delay; Jack 4 years; Ian 10 year ID, DCD, epilepsy 1 female Hannah 11 years, ID, severe global developmental delay All with autism Implemented by parents at home and teacher assistant (Hannah only) at school	iPod Touch for Jason, Jack and Ian. iPad for Hannah and Jack as SGDs Proloquo2Go (for AAC)	To determine if children could be taught by their parents and general teaching staff to use specific requesting forms with three different AAC modes, the iPod, manual sign and picture exchange and to compare the effects of each mode. Had to request a displayed item when asked, with a choice of four photographs	Jack did not master either iPod or iPad Jason and Ian mastered iPod Hannah mastered iPad Jason and Ian preferred iPod	78.4 (87.5)
Self-prompting studies					
Bereznak et al. (2012) Multiple probe across tasks replicated across participants	3 males Aaron 18 year 6 months, ASD, severe ID speech/language impairment; Mike 15 years 5 months, ASD, severe ID, speech/language impairment; Hugh 15 years 5 months, severe ID Implemented by researcher, school setting	IPhone 3G iOS 4.2.1 in horizontal orientation to deliver video prompting App as installed	Explored whether students with ASD could learn to use an iPhone as a video self-prompting tool to teach themselves vocational and independent living tasks and whether would they learn to independently complete daily living and vocational tasks when using video prompting	Aaron and Mike learned to use the iPhone and to do tasks through use of self prompting of iPhone	100 for completion of recipes with self-prompting
Blood et al. (2011) A-B-BC	1 male 10 year old, emotional/behavior disorder, fetal alcohol, complex post-traumatic stress and ADHD Implemented by researchers, teacher and teacher aide, school setting	iPod Touch to deliver video model and as a timer for self-monitoring. Picture Scheduler for self-delivery of video model Timer app to signal for self-monitoring	To determine if video modeling, delivered on an iPod Touch, used alone or in combination with self-monitoring (using a timer app), would result in increased appropriate behavior during small group instruction.	Student learned to use iPod Touch (no data provided on intervention to teach use). On task behaviour increased and disruptive behavior decreased with video modeling alone Was almost 100 % on task with self monitor and model	100 on task 100 disruption 100 self monitor

Table 2 continued

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
Brooks (2012) Multiple probe across participants	4 males Sam 16 years, nonspecific neurological problem consistent with cerebral palsy; Matt 16 years, developmental disability; Phil 15 years, Down syndrome, aphakia, patent ductis arteriosis; Kevin 15 years 2 females Kayla 13 years, autism; Jenny 17 years, ADHD, pervasive developmental disorder All had moderate to severe ID Implemented by researcher, school setting	iPod Touch to deliver audio and video prompts inPromptu	To explore the use of prompting delivered from an iPod Touch for teaching daily living skills and whether the participants would learn to use the iPod Touch to deliver their own antecedent prompts and generalize the skills to an untrained task, and acquire the skill with minimal support from an instructor	Matt, Phil and Jenny mastered use of the iPod Touch and the tasks Those who mastered iPod maintained Kayla and Kevin did not learn the task with other-operated prompts on iPod	92.8 for iPod use 100 for task using self-prompt (post training with instructor using iPod)
Chang et al. (2010) Included a design described as multiple probe across subjects with alternating treatments, but appears to be an ABC design	1 male 26 years, ID Community setting within a large building	ETEN X800 PDA for navigation within a building Installed GPS software and photo display	To compare navigation using a paper map with PDA activated by a shadow and with a PDA activated by scanning a RFID tag at each decision point	Pre-taught to use device and much more successful with the PDA with location cues sent by shadowing team or by scanning than with paper map	0
Chang et al. (2012) ABAB	1 male Ben 27 years, ID On buses in the community	ETEN X8000 PDA to signal travel errors Built in GPS and Real-time Anomaly Detection for Traveling Individuals (RADTI)	To determine if signaling of travel errors would help people deal with unexpected situations en route, without staff intervention	Pre-taught to use device. Participant detected all travel errors when using device but not when travelling without it	0

Table 2 continued

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
Kellems and Morningstar (in press) Multiple probe across behaviors replicated across participants	4 males Sam 20 years, Asperger syndrome; Alex 22 years, autism; Tom 22 years, Asperger syndrome; Kyle 22 years, autism Implemented in workplace	iPod Touch with headphones to deliver video modeling iTunes as installed and Notes in museum mode	To explore the effects of video modeling delivered through an iPod on learning independent vocational tasks	Pre-taught to use iPod Touch (no intervention data) All learned the first two tasks Three mastered third task All mastered tasks were maintained	100 (100)
Mechling et al. (2009) Multiple probe across sets of cooking recipes	3 males Eddie 17 years 6 months, moderate ID; Daryl 16 years 4 months; Kelly 17 years 10 months, moderate ID All with mild autism Implemented by instructor, school setting	iPAQ Pocket PC to deliver picture, audio and video self-prompts. Cyrano Communicator installed Used stylus or finger to activate	To evaluate the use of a self-prompting PDA offering different prompt levels for independent completion of multi-step tasks	All learned to use the PDA to self-prompt (no intervention data provided). Maintained at follow up Self-faded prompt levels Instructors only provided prompts to use the PDA	100
Mechling, Gast, and Seid (2010) Multiple probe across three recipes duplicated across students	1 male Andy 15 years 11 months, autism 2 females Monica 17 years 3 months, mild hearing loss; Wanda 17 years 9 months All with moderate ID Implemented by instructor, school setting	iPAQ Pocket PC to deliver picture, audio and video self-prompts. Cyrano Communicator installed		All learned to use the PDA to self-prompt (no intervention data provided) Maintained at follow-up Self-faded prompt levels	100
Mechling and Seid (2011) Multiple probe across three destinations replicated with three students.	3 males Farah 20 years 3 months; Jackie 21 years 11 months; Madison (21 years 11 months) All with moderate ID Implemented by an instructor, transition program for young adults	iPAQ Pocket PC to deliver picture, audio and video self-prompts Cyrano Communicator installed	To evaluate the use of a self-prompting PDA offering different prompt levels for independent travel on foot to a number of destinations	All learned to use the PDA (no intervention data provided) to travel the routes Two self-faded the prompts	100

Table 2 continued

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
Payne (2011) reported on all participants Payne et al. (2012) reported on Chuck and Dennis only Multiple probe across students	3 males Matt 16 years, autism, moderate to severe ID; Chuck 18 years, autism, pervasive developmental disorder; Dennis 19 years, mild to moderate ID, pervasive developmental disorder, OCD, ADHD, and mood-disorder NOS 1 female Marta 20 years, autism, moderate to severe ID, Down syndrome Implemented by researcher, school setting	iPod Touch plus speaker to deliver video prompts inPromptu	To evaluate the use of the iPod Touch to deliver video prompting for teaching daily living skills and whether participants can learn to use the iPod Touch to deliver their own antecedent prompts and then learn an untrained task with self-prompting	Participants learned two tasks with video prompting on an iPod operated by another person. Matt did not receive intervention to teach iPod use Only Dennis mastered use of iPod	97.4 for steps of tasks completed independently with self-operated prompts
Riffel et al. (2005) Multiple probe across participants	1 male C 16 years, moderate ID, autism, OCD 3 females A 20 years, moderate ID, cerebral palsy, mild vision impairment; B 20 years, moderate ID, cerebral palsy; D 20 years, with mild ID Implemented by teachers, school setting	Cassiopeia palmtop to deliver video prompts Visual Assistant program	To evaluate the effects of the use of the Visual Assistant program on task completion, productivity, and independence	A, B, and D learned to use the device independently (Intervention data not provided), required fewer teacher prompts to complete tasks, completed more steps correctly with just the device prompts Skills maintained Task duration was not affected	77.2
Leisure studies					
Kagohara (2011) Delayed multiple probe across participants	1 male Jim 15 years, severe ID 2 females Sarah 19 years, severe ID, epilepsy; Mary 16 years, severe ID, cerebral palsy Implemented by interventionist, school setting	iPod Touch for watching videos Installed video software	To examine whether participants can learn to self-operate an iPod Touch to watch entertaining videos	All learned to use Maintained after 2 and 10–11 weeks. Were still able to use when icon location was changed, so were able to discriminate icons	BL 1 comparison 95.9 (96.4) BL 2 comparison 90 (91.1) (Two different baseline measures were provided)

Table 2 continued

Study and design	Participants and setting	Device and app or software	Aim	Outcome	PND Treatment (Treatment + maintenance and generalization)
Kagohara et al. (2011) Delayed multiple probe across participants	As above, but Sarah now 20 years Implemented by trainer, school setting	iPod Touch to listen to music Installed music software	To determine if participants who had learned to use an iPod Touch to watch video could learn how to independently operate an iPod Touch to listen to music	All learned to use the iPod Touch. Maintained (4/5 and 9/10 weeks later)	97.7 (98.0)
Walser et al. (2012) Multiple baseline across behaviors	2 males Jake 17 years 9 months, Fragile X; Norman 18 years 1 female Holly 21 years 5 months, Down syndrome All with moderate ID Implemented by researcher, school setting	iPhone iOS4 to take and view photos and view video Photo (slideshow) and video (iTunes) as installed	To evaluate an intervention to teach viewing of photos in a slideshow, and viewing a video in iTunes with minimum screen buttons and to determine if students who acquire the skills will generalize without training to a screen filled with icons	All mastered the skills Generalized when more icons were added to the screen	56

PNDs were calculated for small-n intervention data only, and where appropriate for intervention plus any follow up data. For communication interventions (10 PNDs available) the mean PND (including follow up data when available) was 90.5 and without follow-up data was 88.9. For self-prompting only one study (Brooks 2012) provided intervention data for teaching iPod use and PND was 92.8. Mean PND for intervention data on task completion using self-prompting on a touch device was 79.7, but of the ten studies that provided this data, six had PNDs of 100 (Bereznak et al. 2012; Blood et al. 2011; Brooks 2012; Kellems and Morningstar in press; Mechling et al. 2009, 2010; Mechling and Seid 2011) and two (Chang et al. 2010, 2012) had PNDs of 0 owing to ceiling performance in baseline. One leisure study (Kagohara 2011) provided two different baseline measures. Using the first baseline measure, intervention only had a PND of 95.9 and with follow up data was 96.4. For the second baseline PND was 90 and 91.1.

The majority of the studies reviewed were judged as providing preponderant evidence. All of the case studies, four small-n designs (Blood et al. 2011; Chang et al. 2010, 2012; Kellems and Morningstar in press) and two of the group designs (Price 2011; Venkatesh et al. 2012) were rated as providing suggestive evidence only. The majority of the small-n designs used multiple probe designs, which preclude a rating of conclusive.

Discussion

It is clear from the dates of the included studies that this is an area of rapidly expanding research, although relatively few apps have been examined. There were more studies using the iPod Touch than any other device, but research on iPads is emerging. Interventions involving touch devices that have been evaluated using small-n designs must be regarded as effective, since the mean PNDs for the groups of studies (communication, self-prompting and leisure) ranged between 79.7 and 92.8, when a PND of 90 or greater is regarded as very effective and over 70 as effective (Scruggs and Mastropieri 1998). Similarly, the group designs all found positive effects for touch device use, as did the case studies. Apart from the case studies, and six other studies, the certainty of evidence provided was preponderant.

These results are not surprising as many studies have used touch devices for functions or interventions that have been shown to be successful with other technology such as the use of iPods and iPads as SGDs and to deliver video prompts, and have used behavioural instructional strategies, such as time delay and systematic prompting hierarchies, that are also known to be effective. The studies have explored only a small number of the available apps, and have demonstrated limited achievement with some of those apps. High quality studies tended to be those derived from a behavioural perspective, with tightly defined criteria for successful use. Other studies with a focus on a wider range of uses tended to use weak designs or case study approaches.

Within the communication area, studies were restricted to three apps, with eight studies using Proloquo2Go, one using Pick a Word and one Pixtalk. Within the studies using Proloquo2go (all small-n designs), only very limited skills were taught, mostly requesting, and two participants (Sam and Steven) were included in four studies. These two participants, as reported across articles (Achmadi 2010; Achmadi et al. 2012; Kagohara et al. 2010, Kagohara et al. 2012; van der Meeret al. 2012) learned to activate the device, navigate across pages and select whether they wanted a toy or snack and then select a specific item from a choice of three. They also learned to name pictures on the iPod and iPad, making selections from four (iPod) and six (iPad) icons. Of the other 23 participants in small-n studies, three participants did not learn to use the devices (Lorah 2012; van der Meer et al. 2011, 2012), three acquired use but did not maintain it (van der Meer et al. 2011, 2012b) and nine could only use the device with one icon displayed (Lorah 2012; van der Meer et al. 2012a, c). The four participants in van der Meer et al. (2012) learned to use one icon (discriminating from three). The five successful participants in Flores et al. (2012) were able to discriminate between six photos in the app Pick a Word.

No spontaneous use for communication was observed, and for four studies, participants only had the option of touching the icon for an item, or group of items that was visible to them (van der Meer et al. 2011; van der Meer et al. 2012a, b, c). In eight studies (all except Flores et al. 2012) students were verbally cued to request or to name. There were more older participants with only nine participants aged five or younger. There is clearly a need for research on other apps with younger participants and for more work on teaching spontaneous communication for a range of pragmatic functions using more symbols in more natural settings.

The use of touch devices for video self-prompting was also successful and reflects the generally successful use of video prompting and modeling (see for example, Kagohara 2010). Again the focus was use with older participants (the youngest was 10 years old), mostly young adults, in both small-n and group designs. Some of these studies did not report any detail about how device use was taught, and this suggests learning to use the device may not be an issue for older participants with mild to moderate ID or ASD. Future avenues for research could include the use of apps for other visual support strategies (such as schedules) and the use of

self-delivered video, picture and audio prompts with younger participants and those with more severe disabilities.

It is also apparent that people with disabilities can learn to use the devices for leisure activities, but again the range of activities researched was very limited and included none of the many gaming apps available. The participants in these studies were also mostly young adults, with the youngest being 15 years old. There is an obvious need for research on teaching the use of age-appropriate gaming apps.

Surprisingly, given the number of educational apps available, there were very few studies on the teaching of academic skills and they only provided suggestive evidence. This is another area for research, as apps such as that in the Venkatesh et al. (2012) study appear to be able to present discrete trial, match-to-sample activities to teach basic concepts and to adjust the presentation of tasks based on student performance.

Although the findings are largely positive, a possible source of bias is that much the research has been conducted by related groups of researchers. Within the ten studies in the communication area, eight were carried out by groups including Achmadi, Kagohara, Lancioni, O'Reilly, Sigafoos, and/or van der Meer. The same group was also active in the leisure area and carried out two out of the four studies reviewed. In the area of self-prompting, out of 13 studies, Mechling and Gast were involved in three studies, Chang and Chen in two studies, and Davies and Stock in three studies. It is also a concern that two participants were each involved in three separate studies in the communication area.

The use of portable touch devices is a rapidly growing area of research and there is scope for many more studies examining the potential of these devices for use with people with disabilities. To date, only a limited number of apps have been investigated and it will be important in future work to tease out the effectiveness of the devices from the effectiveness of the apps. It seems actual operation of the devices is not difficult for many people with developmental disabilities, but the use of different apps would present different challenges. More work needs to be carried out with younger participants and work needs to explore the full range of apps available on the market. In addition, comparison studies between the use of touch devices and more traditional means of instruction are required, the relative costs and benefits of touch devices need to be explored and further research on how people with disabilities are using these devices and apps outside of formal intervention settings is needed. The positive results suggest that the lives of people with disabilities could be enriched in many ways by the use of these devices to support independent activities, communication and leisure.

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