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A Meta-Analysis of Mobile Technology Supporting Individuals With Disabilities

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Abstract

Mobile technology has become ubiquitous in the education and support of individuals with disabilities. While this practice is supported under the Universal Design for Learning framework, research in the area has yet to establish a solid evidence base. The majority of the studies in existence are single-subject design studies with a dearth of replication to support their results, and many do not meet the Council for Exceptional Children's *Standards for Evidence-Based Practices in Special Education* guidelines. The following is a meta-analysis of studies that have been conducted in the area of using mobile technology to support individuals with disabilities. Types of mobile technology, how technology is used, and the effectiveness of its use with this population are explored. The results indicated although there is some evidence of effectiveness to support the use of mobile technology, more research in the area is needed.

Keywords

mobile technology, disabilities, meta-analysis

Digital technology use in the education of students with disabilities has been studied for decades. The last decade has seen the introduction of mobile devices, such as personal digital assistants (PDAs), iPods, smartphones (iPhone, Galaxy), and tablets (iPad, Surface). These devices have become ubiquitous in society in general and thus have spurred a surge in the use of mobile technology in the field of special education (Gentry, Wallace, Kvarfordt, & Lynch, 2010). Although the research base for repurposing mobile devices as assistive technology for individuals with disabilities is still rather recent, researchers suggested that the built-in flexibility of these devices and their associated applications give them the potential to provide supports in a variety of areas for this population (Cumming & Draper Rodriguez, 2013; Cumming & Strnadova, 2012; Stephenson, 2015). For the purpose of this study, a person with a disability was defined as

> having intellectual disability [mental retardation], a hearing impairment (including deafness), a speech or language impairment, a visual impairment (including blindness), a serious emotional disturbance (referred to in this part as "emotional disturbance"), an orthopedic impairment, autism, traumatic brain injury, an other health impairment, a specific learning disability, deaf-blindness, or multiple disabilities, and who, by reason thereof, needs special education and related services. (Individuals With Disabilities Education Act, 2004, sec. 300.8)

Assistive technology has long been used to support individuals with disabilities in the areas of mobility, communication, behavior, and academics (Merbler, Hadadian, & Ulman, 1999). The purpose of implementing any assistive technology is to improve the accessibility of all environments for people with disability. While traditional low and high tech supports have accomplished this, they also have some drawbacks, including (a) stigmatization, (b) cost, (c) maintenance, (d) sustainability, and (e) lack of alignment with the principles of Universal Design for Learning (UDL; Wehmeyer, Palmer, Smith, Davies, & Stock, 2008). Mobile technologies have the potential to overcome these barriers (Douglas, Wojcik, & Thompson, 2012; Stephenson & Limbrick, 2015; Wehmeyer et al., 2008).

The full inclusion movement has given rise to strong support for UDL. UDL is based on research that guides the development of flexible learning environments (CAST, 2011). It is defined as

> a set of principles for curriculum development that give all individuals equal opportunities to learn. UDL provides a blueprint for creating instructional goals, methods, materials, and assessments that work for everyone—not a single,

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> one-size-fits-all solution but rather flexible approaches that can be customized and adjusted for individual needs. (para. 2)

The three guiding principles of UDL are (a) Provide Multiple Means of Representation, (b) Provide Multiple Means of Engagement, and (c) Provide Multiple Means of Action and Expression. The use of mobile technology is well suited for all three of these principles and has the potential to make educational, home, and community environments more accessible to people with disabilities by allowing them to individualize their supports and allowing students of all abilities to have every opportunity to learn in the style that works best for them in all settings. Mobile devices can increase accessibility by altering text, enhancing the presentation of concepts, and providing different ways for students to express themselves. Because mobile phones and tablets have become so ubiquitous, they lack the stigma associated with other forms of assistive technology, therefore posing a good option for people with disabilities (Cihak, Fahrenkrog, Ayres, & Smith, 2010). In addition, mobile devices are often less expensive than many traditional assistive technology devices. Kagohara, Sigafoos, Achmadi, O'Reilly, and Lancioni (2011) suggested that these technologies have the potential to improve behavior and communication for students with disabilities. The field of education has recognized this, and schools are already widely using the devices, leaving teachers with the task of choosing how to incorporate them into their pedagogy.

Teachers are under increasing pressure to close the research to practice gap by implementing evidence-based practices. At the same time, they are still responsible for implementing new initiatives, including the use of mobile technology, which has been increasingly adopted by schools globally in the last decade (Ng & Nicholas, 2013). After nearly 10 years' time, the concern remains that mobile technology use as an academic or assistive technology support still lacks a solid evidence base. The majority of the studies that have been conducted on mobile learning used small-n designs, and to the authors' knowledge, only a few meta-analyses on studies conducted on mobile learning for people with disabilities (Alzrayer, Banda, & Koul, 2014; Stephenson & Limbrick, 2015) currently exist in the literature, and these studies are limited to specific interventions, for example, communication or disabilities, for example, autism, and developmental disabilities. Single-subject design is an accepted and important research method, as it allows for the assessment of interventions in natural educational settings (Horner et al., 2005). For an evidence base to be provided via single-subject design studies, systematic replication of effects across multiple studies, with multiple participants, conducted by multiple researchers in multiple places are necessary (Horner et al., 2005). Meta-analyses can demonstrate that these conditions are present, along with calculating an overall effect size for the intervention. This type of review provides a foundation for determining what might be beneficial, may then be used for development or larger, more replicable studies.

Council for Exceptional Children Standards for Evidence-Based Practices in Special Education

The Council for Exceptional Children (CEC) has developed quality indicators and criteria for categorizing the evidence base of special education practice. They apply to studies that examine the effect a practice has on student outcomes. For single-subject designs, the standards require that participants act as their own control and collect data on dependent variables over time to test the effects of the practice on student outcomes (CEC, 2014). There are eight standards and 28 quality indicators. CEC (2014, p. 2) states,

> Methodologically sound studies must meet all the quality indicators specified for the relevant research design. Requiring studies to address all quality indicators in order to be classified as methodologically sound will necessarily limit the consideration of studies conducted before quality indicators were developed and emphasized in published studies. However, this conservative approach increases the likelihood that only the highest quality and most trustworthy studies are considered when classifying the evidence base of practices.

Only nine of the included studies (32%) met all of the quality indicators. A percentage of quality indicators met by each study was calculated. These calculations revealed that out of the remaining studies, 16 met 95% and 5 met 91% of the quality indicators. Quality indicators 3.1 and/or 3.2 were the missing indicators in all cases. Quality indicator 3.1 concerns providing a description of the intervention agent and their role. In many cases, the intervention agent could be surmised to be a teacher or the researcher, but this was not explicitly stated. Quality indicator 3.2 pertains to providing a description of the training and qualifications of the intervention agent. While it can be assumed that if the intervention agent was the researcher or the teacher that they have the required qualifications to implement the intervention, this was not explicitly stated. Table 2 contains the details of the quality indicators by study and indicator.

The purpose of this study was to explore the ways mobile devices and their associated apps have been used to support people with disabilities, and to evaluate the effectiveness of those interventions. Support (for the purpose of this study) is defined as equipment and strategies specifically provided to enable people who have disabilities to participate in school, home, and community life.

The following research questions guided the study:

Research Question 1: What mobile devices are being used to support people with disabilities?
Research Question 2: How are mobile devices being used to support people with disabilities?
Research Question 3: How effective is mobile device use in supporting people with disabilities?

To answer these questions, a meta-analysis of single-subject design studies that implemented mobile technology with people with disabilities was conducted.

Method

An extensive search was carried out in August 2016 using A+ Education, Academic Search Premier, ERIC, EBSCOhost, Google Scholar, PsycINFO, and PubMed databases using the key search terms: disability, disabilities, autism with a combination of other key search terms: mobile technology, tablet, iPad, iPod, and PDA. Only refereed journal articles published after 2007 were considered for inclusion. The first author and a research assistant independently examined the abstracts of the 455 hits for the following inclusion criteria: (a) a peer refereed journal article written in English describing a study that used a single-subject research design (SSD), (b) the participants had identified disabilities, and (c) the participants received an intervention that was delivered via mobile technology. A total of 55 articles met these criteria. Interrater reliability for inclusion was 91.98%, calculated using the following formula: number of agreements / total number possible × 100%. Differences were resolved via discussion.

The 55 articles that met the search criteria were entered into a database, and information from each article was coded by (a) setting, (b) number of participants, (c) age of participants, (d) gender of participants, (e) disability, (f) type of mobile technology, (g) independent variable, (h) dependent variable, and (i) design. Of the articles, 15 were eliminated because they used a group design (this was not readily apparent from the abstracts). Forty studies that used single-subject design remained. This coding was completed by a research assistant and the first author. Interrater reliability was calculated to be 98% using the following formula: number of agreements / total number possible × 100%. Disagreements were again resolved by discussion.

The first and second authors then examined each article more closely, to ensure that each followed the CEC (2014) standards and was a SSD with at least 3 data points in baseline and intervention phases, had at least three phase changes, was not an alternating treatments design, and contained sufficient clarity of information (graphs and charts) to calculate effect sizes. As AB designs do not meet CEC (2014) standards, they were not included in this meta-analysis. This examination excluded 12 additional studies, leaving 28 articles to be included in the review. Interrater reliability was calculated at 100%. Of the remaining articles, 43% were multiple baseline design studies (n = 12), 39% (n = 11) used an AB multiple probe design, and 7% (n = 2) were ABAB reversal designs. The remaining 3 (10%) studies used some other design. See Table 1 for a more complete description of the characteristics of the studies.

Participants

The total number of participants from all studies equaled 89. The participants ranged in age from 5 to 46 years. Sixty-nine of the participants were male and 20 female. The reported disabilities of the participants are as follows: 14 with developmental disabilities, 46 with autism, 26 with intellectual disabilities, four with language-based disabilities, and four with hearing impairments. Some of the participants had more than one reported disability. For further detail on participant demographics, see Table 1.

Settings

The selected studies were conducted in a wide variety of settings. Nine were conducted in a community setting. This includes the participants' homes, places of employment, day care centers, and community college programs. Special schools were the setting for five studies. Fourteen studies were conducted in public schools (6 elementary, 2 middle schools, 6 high schools), with nine of those taking place in special education classrooms and five in general education settings. See Table 1 for more information.

Data Analysis

To conduct the meta-analysis, an effect size for each study needed to be determined. Methods for determining SSD effect size has moved beyond visual analysis to allow for calculations. The data available for this study were limited to the data published for each study. There are many more methods (e.g., percentage of nonoverlapping data, Tau-*U*) which can be used. For this study, two effect size methods were used to determine the effect size. Improvement rate difference (IRD) was used to determine the effect size for this study. An additional effect size measure was run for each study, Tau-*U*.

As Tau-*U* is able to correct for baseline data, it used the measure for the overall effect size. A random effect model of meta-analysis was used to determine the overall effect of mobile technologies for individuals with disabilities. A random effects model assumes that the difference in populations may impact the treatment effect size. The random effects model estimates the mean of distribution of effects. It is presumed that the random effect model produces a more balanced view of effect size than the fixed effects model.

Table 1. Summary of Study Characteristics.

Citation	Participants	Setting	Type of technology	Dependent variable	Independent variable	Design
Achmadi et al. (2012)	4 males aged 5–10 with developmental disabilities	Special education classroom in an elementary school	iPod	Making requests	Proloquo2Go speech generating app	Multiple baseline across participants
Bereznak, Ayres, Mechling, and Alexander (2012)	3 males aged 15–18 with autism	Self-contained classroom in a public high school	iPhone	Vocational/daily living skills	Video prompting	Multiple probe across behaviors
Burckley, Tincani, and Fisher (2015)	1 female aged 18 with autism	Grocery store	iPad	Shopping skills	Visual cues and video prompting	Multiple baseline across settings
Burton, Anderson, Prater, and Dyches (2013)	4 males aged 13–15 with autism and intellectual disabilities	Self-contained high school special education classroom	iPad	Functional math skills (money)	Video self-modeling	Multiple baseline across participants
Chai, Vail, and Ayres (2014)	1 male and 2 females aged 5–8 with developmental disabilities	Elementary school	iPad	Initial phoneme recognition	Constant time delay application	Multiple probe across behaviors, replicated with 3 students
Chang, Wang, Chen, and Ma (2012)	4 males 27–46 with intellectual disabilities	Community setting	PDA	Navigation error correction	GPS and anomaly detection software	ABAB reversal
Cihak, Wright, and Ayres (2010)	3 males aged 11–13 with autism	General education classroom	HP iPAQ handheld computer	Task engagement	Static picture self-modeling, self-recording	ABAB multiple probe across settings
Cihak, Fahrenkrog, Ayres, and Smith (2010)	3 males, 1 female aged 6–8 with autism	Elementary school general education classroom	iPod	Transitions	Video modeling	ABAB withdrawal
Creech-Galloway, Collins, Knight, and Bausch (2013)	3 males, 1 female aged 15–17 with intellectual disabilities	Self-contained high school special education classroom	iPad	Use of Pythagorean theorem	Video modeling	Multiple baseline across participants
Cumming and Draper Rodriguez (2013)	4 male English learners aged 7–8 with language-based disabilities	Self-contained special education classrooms	iPad	Sentence formation skills	Language Builder app	ABA across participants
Ganz, Hong, Goodwyn, Kite, and Gilliland (2015)	1 male aged 4 with autism	Autism clinic	iPad	Identification of a photo	Electronic photos	Multiple baseline across vocabulary words
Gardner and Wolfe (2015)	2 males, 2 females aged 13–14	Special education classroom in a public middle school	iPad	Daily living skills	POV modeling, video prompting with error correction	Multiple baseline across participants
Guardino, Cannon, and Eberst (2014)	3 males, 2 females English learners aged 14–22 with severe to profound hearing loss	State Residential School for the Deaf ESOL class	iPad	Knowledge of ASL vocabulary words	Electronic flashcards (Keynote)	Multiple baseline across 3 sets of 5 vocabulary words

(continued)

Table 1. (continued)

Citation	Participants	Setting	Type of technology	Dependent variable	Independent variable	Design
Hart and Whalen (2012)	1 male aged 16 with autism, intellectual disability, and hearing loss	High school resource room	iPad	Academic responding in science class	Video self-modeling	ABAB reversal design
Jowett, Moore, and Anderson (2012)	1 male, 5 years old, with autism	Family home	iPad	Basic numeracy skills	Video modeling	Multiple baseline across numerals
Kagohara, Sigafoos, Achmadi, O'Reilly, and Lancioni (2011)	1 male, 2 females aged 15–20 with autism	Special school	iPod touch	Using the iPod to listen to music	Video modeling	Delayed multiple probe across participants
Kellems and Morningstar (2012)	4 males aged 20–22 with autism	Employment sites	iPod	Vocational tasks	Video modeling	Multiple probes across behaviors
Macpherson, Charlop, and Miltenberger (2015)	4 males, 1 female aged 10–11 with autism	Behavioral treatment center	iPad	Verbal and gestural compliments	Video modeling	Multiple baseline across participants
Neely, Rispoli, Camargo, Davis, and Boles (2013)	2 males aged 3–7 with autism	Family home and early childhood center	iPad	Challenging behavior	Academic instruction delivery	ABAB reversal
Payne, Cannella-Malone, Tullis, and Sabielny (2012)	2 males aged 18–19 with autism and intellectual disabilities	Special school	iPod touch	Daily living skills	Video prompts	AB multiple probe across participants
Purrazzella and Mechling (2013)	2 males, 1 female aged 24–28 with intellectual disabilities	Community college program	iPhone 4	Conveying location when lost	Video modeling and picture prompts	Multiple probe across participants
Smith Myles, Ferguson, and Hagiwara (2007).	1 male aged 17 with autism	High school general education classroom	PDA	Recording homework	Task recorder	Multiple baseline across settings
Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, and Ley Davis (2015)	2 males, 3 females aged 7–11 with autism, intellectual disabilities, and multiple disabilities	Self-contained classroom in an elementary school	iPad	Literacy	Shared story multiple exemplar training	Multiple probe across participants
Spriggs, Knight, and Sherrow (2015)	3 males, 1 female aged 17–19 with autism	High school	iPad	Transitioning within and between novel activities	Visual activity schedules with embedded video modeling	Multiple probe across participants
Vandermeer, Beamish, Milford, and Lang (2015)	2 males, 1 female aged 4 with autism	Day care facility	iPad	On task behavior	Social stories	Multiple baseline across participants
Van der Meer et al. (2012)	4 males aged 5–10 with developmental disabilities	Special education classroom in an elementary school	iPod	Making requests	Proloquo2Go speech generating app	Multiple baseline across participants
Van Laarhoven, Van Laarhoven-Myers, and Zurita (2007)	2 males aged 18 with intellectual disabilities	Competitive community-based settings	Pocket PC	Vocational tasks	Video rehearsal and feedback	Multiple probe across tasks and participants
Wu, Cannella-Malone, Wheaton, and Tullis (2016)	2 males aged 14–17 with intellectual disabilities	Special school	iPod touch	Daily living skills	Video modeling	Multiple probe across participants

Note. PDA = personal digital assistants; GPS = global positioning system; POV = point of view; ESOL = English as a Second Language; ASL = American Sign Language.

Table 2. CEC Quality Indicators Across Studies.

Study	1. Context and setting (1)	2. Participants (2)	3. Intervention agent (2)	4. Description of practice (2)	5. Implementation fidelity (3)	6. Internal validity (6)	7. Outcome measures (5)	8. Data analysis (1)
Achmadi et al. (2012)	1/1	2/2	0/2	2/2	3/3	6/6	5/5	1/1
Bereznak, Ayres, Mechling, and Alexander (2012)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Burckley, Tincani, and Fisher (2015)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Burton, Anderson, Prater, and Dyches (2013)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Chai, Vail, and Ayres (2014)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Chang, Wang, Chen, and Ma (2012)	1/1	2/2	1/2	2/2	2/3	6/6	5/5	1/1
Cihak, Wright, and Ayres (2010)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Cihak, Fahrenkrog, Ayres, and Smith (2010).	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Creech-Galloway, Collins, Knight, and Bausch (2013)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Cumming and Draper Rodriguez (2013)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Ganz, Hong, Goodwyn, Kite, and Gilliland (2015)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Gardner and Wolfe (2015)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Guardino, Cannon, and Eberst (2014)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Hart and Whalen (2012)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Jowett, Moore, and Anderson (2012)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Kagohara, Sigafoos, Achmadi, O'Reilly, and Lancioni (2011)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Kellems and Morningstar (2012)	1/1	2/2	0/2	2/2	3/3	6/6	5/5	1/1
Macpherson, Charlop, and Miltenberger (2015)	1/1	2/2	0/2	2/2	3/3	5/6	5/5	1/1
Neely, Rispoli, Camargo, Davis, and Boles (2013)	1/1	2/2	0/2	2/2	3/3	6/6	5/5	1/1
Payne, Cannella-Malone, Tullis, and Sabielny (2012)	1/1	2/2	0/2	2/2	3/3	6/6	5/5	1/1
Purrazzella and Mechling (2013)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Smith Myles, Ferguson, and Hagiwara (2007)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, and Ley Davis (2015)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Spriggs, Knight, and Sherrow (2015)	1/1	2/2	2/2	2/2	3/3	6/6	5/5	1/1
Van der Meer et al. (2012)	1/1	2/2	2/2	1/2	3/3	6/6	5/5	1/1
Vandermeer, Beamish, Milford, and Lang (2015)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Van Laarhoven, Van Laarhoven-Myers, and Zurita (2007)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1
Wu, Cannella-Malone, Wheaton, and Tullis (2016)	1/1	2/2	1/2	2/2	3/3	6/6	5/5	1/1

Tau-U. Tau-*U* is a method of determining single-subject effect size which measures the nonoverlap between the data from A phase to B phase (Parker, Vannest, Davis, & Sauber, 2011). Because it is common for data to be nonconforming to parametric assumptions in single case research, Tau-*U* is the most appropriate method for analyzing these data because it uses a nonparametric technique that is distribution-free. When data conform to parametric assumptions, Tau-*U* has a statistical power of 91% to 95% of ordinary least squares linear regression, and when data are nonconforming, Tau-*U* can have power up to 115%. For this study, Tau-*U* was calculated using a web-based calculator (Vannest, Parker, & Gonen, 2011), which has the advantage of being able to analyze data for all of the phases of a single design, then average them for an overall effect size, or Tau (Vannest et al., 2011). Because Tau-*U* accounts for the trend found in data, this is the score which was used to account for overall effect size. The following qualitative interpretations are suggested for Tau-*U* scores .65 or lower: weak or small, .66 to .92: medium or high, .93 and above: large or strong (Parker & Vannest, 2009; Rispoli et al., 2013).

IRD. A secondary analysis of the effect size was also calculated. IRD is also a nonparametric of nonoverlap (Parker, Vannest, & Brown, 2009). IRD is the difference between the two "improvement rates" for a Baseline and a Treatment phase. While Tau-*U* and IRD are closely related, IRD does not account for trend in data. This effect size measure was modeled after the risk difference concept often used in medicine. IRD has high interscorer reliability. For this study, IRD was calculated using a web-based calculator (Vannest et al., 2011), which has the advantage of being able to analyze data for all of the phases of a single design, then average them for an overall effect size, or IRD (Vannest et al., 2011). The qualitative indicators suggested for IRD are 50% or lower: small or questionable, 51% to 70%: moderate, and 71% or above: large/very large (Parker et al., 2009).

Results

Type of Technology and Its Uses

For the purpose of this study, mobile technology is defined as any handheld electronic computing device. These devices include cellular telephones, tablet computers, mp3 players, and PDAs that can usually access the Internet through a Wi-Fi connection or cellular network. The mobile technologies utilized in the studies in this meta-analysis included iPads (n = 15), iPods (n = 7), PDAs (n = 2), iPhone (n = 2), and other (n = 2). The technology was used to support individuals in seven different areas: (a) daily living and life skills (n = 9), (b) academic skills (n = 6), (c) communication skills (n = 6), (d) task engagement and completion (n = 4), (e) transitions between activities and settings (n = 4), (f) vocational skills (n = 2), and (g) reducing challenging behavior (n = 1). Further details of these interventions are available in Table 1.

Synthesis of Intervention Effects

Table 3 shows the findings of the effects as measured by Tau-*U* and IRD for each study. Statistical measures of effect size showed mixed findings for mobile technology for students with disabilities. Total effect sizes were calculated using Tau-*U* in the areas of Academic Skills, Transitions, Daily Living Skills, Challenging Behaviors (only one study met criteria), Vocational Skills, Task Completion and Engagement, and Communication. In the area of Academic Skills (Literacy and numeracy), the overall effect size was 0.90, which indicates a medium effect. In the area of Academic Skills, five of the six studies had large/very large IRD effects and ranged from .94 to 1.0. The sixth study had an IRD, which fell in the small range, with a .51 IRD. The three studies in the areas of Transitions yielded a total effect size of .98, which is a large effect. All of the IRD effect sizes in Transitions were in the large/very large range and were from .76 to 1.0. In Daily Living Skills, the total Tau-*U* effect size was 0.87, which indicates a medium effect. The IRD effects in this area ranged from small (.43) to large/very large (1.0). The one study in the area of Challenging Behaviors yielded an effect size Tau-*U* of 1.0, which is a large effect. This was also found in the IRD effect, which was 1.0 and large/very large. The total Tau-*U* effect size of the three studies measuring Vocational Skills was 0.93, which indicates a large effect. All of the IRD effect sizes were in the large/very large range, as they were .97 or 1.0. In Task Completion, four studies resulted in a Tau-*U* of 0.88, which is indicative of a medium effect size. Three of the studies had a large/very large IRD effect (1.0) while the final study had an IRD effect in the small range (.29). The last area analyzed, Communication, included seven studies and yielded a Tau-*U* score of 0.69. This shows a weak effect. The IRD effect sizes in this area ranged from small to large/very large and were .12 to .90.

To determine the overall effect of mobile technologies for individuals with disabilities, a random effect model of meta-analysis was used because this model assumes that the difference in populations may impact the treatment effect size. The random effects model estimates the mean of distribution of effects. It is presumed that the random effect model produces a more balanced view of effect size than the fixed effects model. For the overall effect size calculation, a random effect model was used on the Tau-*U* scores. The Total Effect of mobile technology on the various skills of individuals with disabilities was 0.86, which indicates a Medium effect size.

Discussion

The results of this study provide an overview and some direction on future implications for the use of mobile

Table 3. Intervention Categories and Effect Sizes.

Category/citation	Tau-*U*	Variance	95% CI	Tau-*U* effect	IRD	IRD effect
Academic skills (literacy and numeracy)						
Burton, Anderson, Prater, and Dyches (2013)	1.0*	0.19	[0.62, 1.38]	Large	1.0	Large/very large
Chai, Vail, and Ayres (2014)	0.63*	0.09	[0.45, 0.82]	Weak	0.51	Small
Creech-Galloway, Collins, Knight, and Bausch (2013)	0.97*	0.19	[0.60, 1.34]	Large	1.0	Large/very large
Guardino, Cannon, and Eberst (2014)	0.95*	0.14	[0.67, 1.23]	Large	0.94	Large/very large
Jowett, Moore, and Anderson (2012)	0.98*	0.12	[0.76, 1.21]	Large	0.99	Large/very large
Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, and Ley Davis (2015)	1.0*	0.12	[0.77, 1.23]	Large	1.0	Large/very large
Academic total	0.90*	*SE* = 0.15	[0.62, 1.18]	Medium to high		
Transitions (between activities and settings)						
Cihak, Fahrenkrog, Ayres, and Smith (2010).	1.0*	0.14	[0.78, 1.31]	Large	0.76	Large
Spooner et al. (2015)	1.0*	0.12	[0.77, 1.23]	Large	1.0	Large/very large
Spriggs, Knight, and Sherrow (2015)	0.94*	0.18	[0.58, 1.29]	Large	1.0	Large/very large
Transitions total	0.98*	*SE* = 0.21	[0.56, 1.4]	Large		
Daily living/life skills						
Burckley, Tincani, and Fisher (2015)	0.88*	0.18	[0.53, 1.23]	Medium	0.79	Large
Chang, Wang, Chen, and Ma (2012)	0.59*	0.14	[0.32, 0.85]	Weak	0.43	Small
Gardner and Wolfe (2015)	1.0*	0.16	[0.78, 1.42]	Large	1.0	Large/very large
Kagohara, Sigafoos, Achmadi, O'Reilly, and Lancioni (2011)	0.94*	0.22	[0.51, 1.38]	Large	0.92	Large/very large
Payne, Cannella-Malone, Tullis, and Sabielny (2012)	1.0*	0.15	[0.78, 1.37]	Large	0.98	Large/very large
Purrazzella and Mechling (2013)	1.0*	0.22	[0.58, 1.42]	Large	1.0	Large/very large
Smith Myles, Ferguson, and Hagiwara (2007)	0.53*	0.15	[0.22, 0.85]	Weak	0.51	Moderate
Van Laarhoven, Van Laarhoven-Myers, and Zurita (2007)	0.90*	0.11	[0.68, 1.21]	Large	0.97	Large/very large
Wu, Cannella-Malone, Wheaton, and Tullis (2016)	0.97*	0.12	[0.74, 1.2]	Large	0.97	Large/very large
Daily living total	0.87*	*SE* = 0.13	[0.61, 1.12]	Medium		
Reducing challenging behavior						
Neely, Rispoli, Camargo, Davis, and Boles (2013)	1.0	0.18	[0.64, 1.35]	Large	1.0	Large/very large
Vocational skills						
Bereznak, Ayres, Mechling, and Alexander (2012).	0.99*	0.13	[0.74, 1.26]	Large	1.0	Large/very large
Kellems and Morningstar (2012)	.91*	0.12	[0.67, 1.15]	Medium to High	1.0	Large/very large
Van Laarhoven et al. (2007)	0.90*	0.11	[0.69, 1.12]	Medium to High	0.97	Large/very large
Vocational total	0.93	*SE* = 0.20	[0.53, 1.33]	Large		
Task engagement and completion						
Cihak, Wright, and Ayres (2010)	1.0*	0.11	[0.78, 1.22]	Large	1.0	Large/very large
Kellems and Morningstar (2012)	.91*	0.12	[0.68, 1.15]	Medium	1.0	Large/very large
Neely et al. (2013)—ENGAGEMENT	1.0*	0.18	[0.64, 1.35]	Large	1.0	Large/very large
Vandermeer, Beamish, Milford, and Lang (2015)	0.50	0.20	[0.11, 0.89]	Weak	0.29	Small
Task engagement total	0.88	*SE* = 0.19	[0.50, 1.26]	Medium		
Communication						
Achmadi et al. (2012).	0.80*	0.16	[0.47, 1.12]	Medium	0.69	Moderate
Cumming and Draper Rodriguez (2013)	0.50*	0.14	[0.22, 0.79]	Weak	0.31	Small
Ganz, Hong, Goodwyn, Kite, and Gilliland (2015)	0.64*	0.15	[0.33, 0.94]	Weak	0.50	Small
Hart and Whalen (2012)	0.86*	0.20	[0.45, 1.27]	Medium	0.43	Small
Macpherson, Charlop, and Miltenberger (2015)—COMPLIMENTS	0.83*	0.17	[0.50, 1.16]	Medium	0.80	Large
Macpherson et al. (2015)—GESTURES	0.29	0.17	[−0.04, 0.62]	Weak	0.12	Small
Van der Meer et al. (2012)	1.0	0.16	[0.69, 1.31]	Large	0.90	Large/very large
Communication total	0.69*	*SE* = 0.15	[0.39, 0.99]	Medium		
Total	0.86*	*SE* = 0.07	[0.71, 0.99]	Medium		

Note. CI = confidence interval; IRD = improvement rate difference.
*Statistically significant.

technology and individuals with disabilities. This study sought to discover what mobile devices are being used to support people with disabilities. As stated above, iPads were by far the most popular devices currently being used in research studies conducted in the area of mobile devices and individuals with disabilities. This is most likely due to the immediate popularity and adoption of the iPad upon its release. Although results demonstrated that the second most popular device was the iPhone, the majority of those studies were conducted earlier than the studies using iPads. It should also be noted that the type of mobile technology utilized did not seem to affect the effectiveness of the interventions; therefore, teachers should choose devices based on the needs of their students.

Although the special education literature offers little guidance in the way of choosing a device, advice can be found in the assistive technology and occupational therapy literature. Burgstahler, Comden, Lee, Arnold, and Brown (2011) suggested that the first consideration when choosing a mobile device to assist an individual with disabilities should be the individual's performance skills and ability to access devices. The iPad may prove more advantageous to those with fine motor limitations or low vision, while the portability of the iPhone may be better suited to others without those limitations, especially if it is a device they already own and are familiar.

Erickson (2015) cautioned that although an individual may have access to technology, cognitive features such as impaired memory on how to use the technology, decreased attention and concentration, or difficulties remembering topics may limit the effectiveness of the device use. She adds that in addition to the individual characteristics, the built-in accessibility features of the device in question must be considered, so that the use of mobile devices is not dismissed based solely on individual limitations. Voice activated controls and low vision adaptations are built into most mobile devices, as is the ability to lock the device into using one specific application. Last, user preference needs to be a priority. Some individuals may prefer to use a mobile device as assistive technology, while others may prefer the assistance of others (Erickson, 2015). It must be remembered that if individuals are using mobile devices with the support of others, that the supporting individuals must be trained on the maintenance and use of the device and its associated applications.

When the manner in which the devices were being used to support individuals with disabilities was examined, the results of the literature search and subsequent coding identified seven areas of use. The answer to this question is best considered with the answer to the third research question, as it determined what areas mobile device use were effective in supporting individuals with disabilities.

The use of mobile devices to support individuals with disabilities demonstrated mixed results. Overall, mobile technology was somewhat effective in supporting individuals with disabilities. However, it is clear that these findings varied according to the area in which the technology was used. Only two of the areas, academics and daily living skills, met the criteria of five published studies across three researchers, at least three geographic locations, and a minimum of 20 participants across studies to establish an evidence-based practice (Horner et al., 2005)

Studies in the area of academics had a total of 22 participants, across six studies, with six different groups of researchers. All but one study had a large Tau-*U* and large/very large IRD effect. The one that had a small effect used a constant time delay application to improve initial phoneme recognition of three young students with developmental disabilities. Of the others, three used video modeling, one used electronic flashcards, and one used shared story multiple exemplar training. A meta-analysis of studies in this area produces evidence (Horner et al., 2005) to support the use of mobile technologies to increase academic skills.

There were a total of nine studies that explored the use of mobile technology to support students with disabilities in learning daily living skills. These studies included a total of 22 participants, most (15) were 18 years old or over. Six studies used mobile technology to provide video models, five used mobile technology for visual cues and video prompting, one study used mobile technology to provide participants with a global positioning system (GPS), and one used mobile technology to record tasks. The task recording and GPS studies had weak Tau-*U* and moderate to small IRD effect sizes, respectfully. These results are logical, as visual cues and video modeling have a large research base to support their use, and the other two do not (Bellini & Akullian, 2007; National Professional Development Center on Autism Spectrum Disorders, 2010). Literature in the field of mobile technology and disabilities recommends integrating mobile devices into existing evidence-based practices (Cumming, 2013; Stephenson, 2015; Strnadová, Cumming, & Draper Rodriguez, 2014).

Although the studies focused on using mobile technology to support the communication of individuals with disabilities met the number of studies (7) and participants (24) to constitute an evidence base, the studies' results were quite mixed, with only a medium effect size overall, with over half of the studies having a weak Tau-*U* effect and small IRD effect, and only one of the studies had a large effect size (Van der Meer et al., 2012). This result was interesting, as popular media (such as newspaper articles and parent blogs) and early literature in the field viewed mobile technology to support communication very favorably. A Google search using the phrase "iPad as a communication device" reaped nearly 2,000,000 hits. This indicates that many are using, or considering the use of mobile technology for communication. Educators should be very cautious when implementing mobile technology in this area for students with disabilities. Future research in this area needs to meet CEC and the What Works Clearinghouse design recommendations so that a more thorough evaluation may occur. The popularity of mobile technology use in this area highlights the importance that a solid evidence base be established for its use.

The remaining four areas did not meet Horner et al.'s (2005) criteria for establishing an evidence base. Three studies explored the use of mobile technology to support the transition skills of 13 participants, all with large Tau-*U* and large/very large IRD effects. These results are promising, and support future research in the area to establish an evidence base for using mobile technology to support students with disabilities in times of transition. Only one study included in the meta-analysis explored the use of mobile technology as a behavioral support. Although the results of this single study were promising, this can only be viewed as preliminary work in the area of mobile technology to reduce challenging behavior. The use of mobile technology to teach vocational skills was explored in three studies, with a total of nine participants. The studies used mobile technology as a vehicle for video modeling, video prompting, and video rehearsal and feedback. Although the results of all three studies suggest that using mobile technology in these manners effective, it is another area that requires further investigation. Four studies with a total of 12 participants explored the use of mobile technology to improve task engagement and completion. The mobile interventions used were video modeling, video rehearsal and feedback, and a combination of static picture self-modeling and self-recording. Again, the results of these studies were promising, but more research in the area is necessary before it can be considered evidence-based.

Generally, the results indicate a positive future for mobile technology use to support individuals with disabilities. There is still room for much study in the area and the establishment of a solid evidence base. It is predicted that as mobile technology use, particularly in educational settings, increases, so will the evidence base for its use to support students with disabilities. Future avenues of study should include the use of a variety of different applications in each area, as there was a lack of diversity in the applications used in the current studies (e.g., Proloquo2Go for communication, Keynote for vocabulary). Stephenson and Limbrick (2015) also made this observation, along with a call for studies that separate the effect of the devices from the effect of specific apps. Special education has its own category in Apple's App Store, and more applications are added daily. This highlights a need for an evidence base that could contribute to the design of an application evaluation framework. This would allow teachers and other professionals to choose applications with features that have been shown to be effective to support individuals with disabilities.

Conclusion

The findings from this study can be used to inform future directions of research regarding the use of mobile technology for people with disabilities. There are limitations to these findings that must be considered. There is a potential for bias in all meta-analyses because of publication bias. The majority of research without significant findings does not get published. Due to this, the current study did not include gray literature, which may have contained non-significant results. It is possible that other research in these areas was conducted but not published. This would lead to lower effect sizes than were found. Future studies should include non-significant results and gray literature to produce a more balanced view of effectiveness. The authors did not have access to the original charted data for the studies that were part of the meta-analysis; all data were derived from the published visual representation.

The studies included in this meta-analysis were conducted across a diversity of settings, with individuals of different ages and ability. Technology use by individuals of different ages and abilities would naturally differ. The answers to Research Question 2 that illustrated how mobile technology was being used to support people with disabilities produced a heterogeneous sample of studies and data to answer Research Question 3. A random effect model was used to negate this comparison of "apples to oranges," but heterogeneity among studies may affect the pooled estimate of effectiveness. To establish a solid evidence base, future research should attempt to replicate the participant characteristics, settings, and research designs. Another related and significant limitation is the lack of multiple studies in each area. Due to the limited amount of studies in some areas, that is, transitions, vocational, and engagement, care must be taken to not assume that the effect sizes in these areas constitute an evidence base.

This current study attempted to demonstrate the effectiveness of mobile technology (e.g., iPhone, iPad, Galaxy) as an intervention for individuals with disabilities. It was determined that while mobile technology had an impact on the learning of those with disabilities, educators and associated practitioners must further investigate the specifics related to the desired outcomes before determining whether mobile technology is the best choice of intervention. There remains a need for further examination of the impact and effectiveness mobile technology can have in supporting the learning and independence of individuals with disabilities.

In general, the methods and findings of this study suggest that more research conducted according to the CEC (2014) standards is vital for definitive answers. This study is one piece of what will become a larger literature base that builds an evidence base for the use of mobile technology to support individuals with disabilities. There were discrepancies between overall effect sizes in some of the areas analyzed (e.g., Academic Skills, Daily Living Skills, Communication); overall, the effect sizes were larger in studies that used mobile technologies to support practices with an established evidence base. This suggests that future research should focus on whether using mobile technology is more effective than more traditional methods of implementing evidence-based practices to provide teachers with guidance for making informed instructional decisions.

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