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Functional Technology for Individuals with Intellectual Disabilities: Meta-Analysis of Mobile Device-Based Interventions

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This study employs a meta-analysis of single-subject design research to investigate the efficacy of mobile device-based interventions for individuals with intellectual disabilities (ID) and to further examine possible variables that may moderate the intervention outcomes. A total of 23 studies, 78 participants, and 140 observed cases that met the inclusion criteria were included in the meta-analysis. The efficacy of interventions was measured by computing the percentage of nonoverlapping data points (PNDs) and compared across participants' characteristics, mobile device types, functions of mobile device use, target skills, and intervention strategies. The results showed that interventions with mobile devices for individuals with ID were very effective to acquire, maintain, and generalize the target skills. The magnitude of PNDs was not significantly affected by participants' characteristics, target skills, intervention strategies or types of mobile device use. Employment of the maintenance and generalization phases and the mastery criterion were significantly associated with PND scores. Mobile devices were mainly utilized as an instructional device for this population. The discussion includes suggestions for expanding the use of mobile devices to the daily activities of individuals with ID as functional technology (FT).

Keywords: *mobile device, meta-analysis, intellectual disability, developmental disability, assistive technology, instructional technology, functional technology*

Recent technological advances have led to mobile devices such as smartphones (e.g., iPhones) and tablet computers (e.g., iPads or Galaxy Tabs) that are practical and useful for all people. As of 2015, 68% of U.S. adults have a smartphone and tablet computer ownership has edged up to 45% among adults (Anderson, 2015). Mobile devices have multiple functions and capabilities including camera, personal organizer, and entertainment sources. Such all-purpose mobile devices appear to have enormous potential for reducing the need for external prompts as prompting devices (e.g., textual, auditory, pictorial, or video) and facilitating the independence of learners with intellectual or developmental disabilities (Douglas, Wojcik, & Thompson, 2012). Their portability and user-friendly operations require little or no adaptation to be used by individuals with significant intellectual disabilities. Mobile devices are also socially acceptable and commonly used by people regardless of disability status (Johnson, Blood, Freeman, & Simmons, 2013). Thus, mobile devices are more widely being adopted to educational and rehabilitation programs for people with intellectual disabilities (ID).

Recent literature reviews on mobile device-based interventions for individuals with moderate-to-severe disabilities indicate that mobile devices are effective and prompting technology devices for this population. Kagohara and colleagues (2013) reviewed the overall effectiveness of iPod/iPad-based instruction for individuals with developmental disabilities (DD). Fifteen studies published by 2012 show that the mobile devices were utilized as instructional prompts delivery, speech generating devices (SGD), and viable technological aids in the domains of academic, communication, employment, leisure, and transition across school settings. Lorah and colleagues (2015) reviewed the effectiveness of mobile devices as SGD in the acquisition of verbal behaviors for individuals with autism spectrum disorder (ASD) and found that 53 out of 57 total participants with ASD (93%) acquired the ability to communicate using the iPod or iPad as SGD. Stephenson and Limbrick (2015) reviewed the use of mobile devices for individuals with DD through a meta-analysis of 36 studies published by 2012 and reported strong effects of mobile devices. These reviews qualitatively report mobile device-based interventions' overall impact on targeted skills yet lack further investigation on possible moderating variables such as participant characteristics or intervention types that might affect the intervention outcomes.

Stephenson and Limbrick (2015) calculated the percentage of all non-overlapping data points (PND) to evaluate the efficacy of the intervention in the areas of communication, self-prompting, and leisure and concluded that the interventions are very effective overall. Although this study suggests the direction of future meta-analysis on this topic, it has its limitations in that the number of studies included in the analysis was small (n= 14), and that studies included only people with ID were first excluded. PNDs were averaged over multiple interventions in each study, which limits chances for further advanced analysis on PNDs and did not further investigate how the experimental effects can be moderated by other related variables. Thus, this meta-analysis aimed to expand the scope of mobile device-based intervention to include people with ID and to include papers published until the summer of 2015 for a more comprehensive analysis. In addition, by subdividing the units of analysis into observed cases in mobile device-based intervention, the study aimed at in-depth analysis of the overall efficacy and possible moderating effects of the relevant variables.

The Purpose

The purposes of this paper were to investigate the efficacy of mobile device-based interventions for individuals with ID and to further examine possible variables that may moderate the intervention outcomes.

Method

Data Collection

The literature search was conducted of published journal articles in the following databases: Educational Resources Information Center (ERIC) and PsychINFO databases. The search period was from the beginning of each database until 2015. The computer search strategy used a combination of following descriptors: iPhone, iPad, iPod, iOS, Android, tablet, mobile device, hand-held computer-assisted instruction, hand-held devices, personal digital assistant, cell phone, developmental disability, intellectual disability, moderate disability, severe disability, or autism. To locate additional studies that were not captured by the initial database search, an ancestral search of studies using the reference lists of the selected articles was conducted. A total of 167 studies were located after preliminary searches.

Inclusion and Exclusion Criteria

The abstract or method section of each research study was examined to determine whether the study met the following inclusion and exclusion criteria:

1. The study must have used a mobile device as part of an intervention.
2. Participants were identified as having intellectual disabilities (ID) as a primary or secondary disability condition through psychometric score in cognitive functioning and adaptive behaviors or substantial evidence in qualitative descriptions. When participants were reported to have autism or developmental disability (DD) as a primary disability and their psychometric score in cognitive functioning showed their significant cognitive impairment, they were included in the study.
3. When the study included a combination of participants with other disabilities, outcome measures must have been individually reported to permit the calculation of effect sizes.
4. The study must have utilized a single-subject research design that demonstrates experimental control. According to Horner et al. (2005), "experimental control is demonstrated when the design documents three demonstrations of the experimental effect at three different points in time when a single participant (within-subject replication) or across different participants (inter-subject replication) (p. 168)." Experimental effects are demonstrated when the predicted variation of the dependent variable is covaried by manipulation of the independent variable. Thus, the study must have at least three points of the experimental effect for one participant or at least have three participants for the same target skill. The studies were excluded when they have only two participants for the multi-baseline across participants design (e.g., Achmadi et al., 2012).
5. Because "documentation of predictable pattern during baseline typically requires multiple data points without substantive trend, or with a trend in the direction opposite that predicted by the intervention" (Horner, Carr, Halle, McGee, Odom, & Wolery, 2005, p. 168), the study must have at least three data points during a baseline phase. Those students with less than 3 sessions for the baseline phase were excluded (e.g., Johnson, Blood, Freeman, & Simmons, 2013; Van Laarhoven et al., 2009). For example, Johnson et al. evaluated the effectiveness of teacher-implemented video promoting on an iPod Touch to teach

food-preparation skills to high school students with autism. During the baseline phase, the teacher verbally directed the student to complete the steps in the task analysis of food preparation. The student was given one chance to complete the required tasks.

6. The study was written in English and published in peer-reviewed journal.

Classification and Interrater Reliability

The first and second authors developed a coding system to classify the preliminary data. Each observed case was coded into the following categories and operational definitions of each category and its subtypes are described below: (a) device type; (b) device function; (c) target skills; (d) participant characteristics; and (e) intervention strategy.

Device type. Types of the device were operationally defined as the specific device type such as iPhone, iPod Touch, or iPad since the preliminary data only included such three types of devices.

Device function. The device function was operationally defined as the main function for the device use such as communication, personal organizer, or instruction. For example, van der Meer and colleagues (2012) used an iPod Touch as a speech generating device to teach the participants communication skills, where the mobile device functioned as a communication device. Uphold and colleagues (2016) trained the participants to follow the visual schedule programmed on the app of iPod Touch, whose function was a personal organizer. In Cannella-Malone and colleagues (2012), the participants learned how to sweep the floor through video prompting on iPod Touch, which was used as an instructional device.

Target skills. Target skills were operationally defined as dependent variables in the single-subject design research. After coding all dependent variables from the included cases, *content analysis* (Johson & LaMontagne, 1993) was conducted to categorize the target skills. Out of 35 separate dependent variables, the first content analysis produced 17 categories of target skills. After two additional content analyses, the target skills were categorized into four groups: *academics, communication, leisure, and vocation.*

Participants characteristics*.* Participants characteristics were classified as age, gender, and primary disability diagnosis. Primary disability diagnosis includes autism, intellectual disability, developmental disability, and multiple disabilities and was coded as reported in each study.

To establish interrater reliability for the coding procedure, 33% of the total cases from the preliminary data were randomly selected by the SPSS program and coded independently by the first author and the second author. The reliability rate was calculated by dividing the total number of agreements by the total number of agreements and disagreements multiplying by 100. The reliability rate ranged from 91.67% to 100% for each case. The average reliability rate was 95.79%. This interrater reliability check procedure eliminated additional 17 cases from the preliminary data because they did not meet the inclusion criteria. The final data included in the meta-analysis had 23 single-subject research design studies with 78 participants and 140 observed cases. Since some of the participants had more than one target skills, the number of observed cases outnumbered the number of participants.

Effect Size Calculation

The percentage of all non-overlapping data (PND) was calculated for each observed case, separate target skill for a participant in a separate intervention; the number of the PND effect sizes was the same as the number of the total observed case number (*N*=140). PND summarizes single-subject treatment efficacy by calculating the percent of data points that do not overlap with the highest or lowest baseline data point. One conceptual advantage of the PND metric is in its meaningfulness: a presentation of PND provides the reader with some meaningful information about intervention effectiveness (Scruggs & Mastropieri, 2013). PND scores above 89 represent very effective intervention scores; scores from 70 to 90 represent effective interventions; scores from 50 to 70 questionable; and scores below 50 are ineffective (Scruggs, Mastropieri, & Castro, 1987). Separate PND was calculated for the treatment, maintenance, and generalization phases, respectively, if they were reported.

Analysis

To explore if mobile device-based interventions were an evidence-based practice, a PND score was calculated for each observed case in the single-subject design research. Given the nonparametric nature of PND scores, either nonparametric *Mann-Whitney* or *Kruskal-Wallis* procedure was used to test for significant differences in PND scores across device type, device function, target skills, intervention strategy, and participant characteristics. For nonparametric correlation analysis, *Kendall's tau-b* was conducted.

Table1

Summaries of 23 studies, 78participants, and 140 observed cases

Study	Participants: age, gender, disability	Intervention/Targeted Skill	Met Mastery Criterion	PND*	Maintenance/ Generalization**
Bereznak et al. (2012) Multiple baselines design	18, M, Autism	Using video self-prompting with iPhone to acquire the skill of making a copy	Yes	100	3/No
		Using video self-prompting with iPhone to acquire the skill of making noodles	Yes	100	3/No
		Using video self-prompting with iPhone to acquire the skill of washing machine	Yes	100	1/No
	15, M, Autism	Using video self-prompting with iPhone to acquire the skill of making a copy	Yes	100	4/No
		Using video self-prompting with iPhone to acquire the skill of making noodles	Yes	100	2/No
		Using video self-prompting with iPhone to acquire the skill of washing machine	Yes	100	2/No
	15, M, Autism	Using video prompting with iPhone to acquire the skill of making a copy	Yes	100	3/No
		Using video prompting with iPhone to acquire the skill of making noodles	Yes	100	3/No
		Using video prompting with iPhone to acquire the skill of washing machine	Yes	100	2/No
Cannella-Malone et al. (2012) Alternating treatments design	15, M, ID	Using video prompting on iPod Touch to teach sweeping	No	100	No/No
		Using video prompting on iPod Touch to teach table washing	No	95	No/No
		Using video prompting on iPod Touch to teach sweeping with error correction	No	100	No/No
	15, F, ID	Using video prompting on iPod Touch to teach sweeping	No	100	No/No
		Using video prompting on iPod Touch to teach table washing	Yes	100	No/No
		Using video prompting on iPod Touch to teach sweeping with error correction	No	100	No/No
	15, M, ID	Using video prompting on iPod Touch to teach sweeping	No	80	No/No
		Using video prompting on iPod Touch to teach table washing	Yes	94	No/No
		Using video prompting on iPod Touch to teach sweeping with error correction	No	100	No/No
Cannella-Malone et al. (2013) Multiple baselines design	16, M, DD	Instructor-delivered video prompting on iPod Touch to teach table washing	Yes	100	No/No
		Self-directed video prompting on iPad to teach table washing	Yes	100	No/No
		Using a system of most-to-least prompt to teach how to use iPod Touch	NA	91	No/No
	16, M, DD	Instructor-delivered video prompting on iPod Touch to teach table washing	Yes	100	No/No
		Self-directed video prompting on iPad to teach table washing	Yes	100	2/No
		Using a system of most-to-least prompt to teach how to use iPod Touch	NA	83	No/No
		Self-directed video prompting on iPad to teach vacuuming	Yes	89	2/No
	15, M, DD	Instructor-delivered video prompting on iPod Touch to teach table washing	Yes	100	No/No
		Self-directed video prompting on iPad to teach table washing	Yes	100	3/No
		Using a system of most-to-least prompt to teach how to use iPod Touch	NA	83	No/No
		Self-directed video prompting on iPad to teach vacuuming	Yes	100	3/No
	17, F, DD	Instructor-delivered video prompting on iPod Touch to teach table washing	Yes	100	No/No
		Self-directed video prompting on iPad to teach table washing	Yes	100	No/No

Study	Participants: age, gender, disability	Intervention/Targeted Skill	Met Mastery Criterion	PND*	Maintenance/ Generalization**
		Using a system of most-to-least prompt to teach how to use iPod Touch	NA	100	No/No
		Self-directed video prompting on iPad to teach vacuuming	No	67	No/No
Cihak et al. (2010) Reversal design	6, M, Autism	Using video modeling on iPod Touch to improve transitional behaviors	Yes	100	1/No
	7, M, Autism		Yes	86	1/No
	7, F, Autism		Yes	79	1/No
	8, M, Autism		Yes	84	1/No
Couper et al. (2014) Alternating treatments	5, M, Autism	Using discrete-trial format to teach communication skills with iPod Touch	Yes	89	3/No
	12, M, Autism		No	50	No/No
	6, M, Autism		Yes	100	3/No
	7, M, Autism		Yes	78	No/No
Creech-Galloway et al. (2013) Multiple baselines design	16, M, ID	Using a simultaneous prompting procedure with an iPad to teach the Pythagorean theorem	Yes	100	2/1
	16, M, ID		Yes	100	3/1
	16, M, ID		Yes	100	5/1
	16, F, ID		No	100	No/1
Douglas et al. (2015) Multiple baselines design	19, M, ID	Using iPhone-based pictorial list prompting to improve accuracy in reading and locating shopping items	NA	100	No/10
	17, M, ID		NA	89	No/12
	17, F, ID		NA	89	No/12
	20, F, ID		NA	64	No/12
Flores et al. (2012) Reversal design	11, M, MD	Using iPod Touch to increase frequencies of communicational behaviors	NA	17	No/No
	9, M, ID		NA	100	No/No
	8, M, Autism		NA	50	No/No
Hammond et al. (2010) Multiple baselines design	14, F, ID	Via video modeling, how to operate movie on iPod	Yes	73	8/No
		Via video modeling, how to operate photo on iPod	Yes	100	6/No
		Via video modeling, how to operate music on iPod	Yes	100	6/No
	12, F, ID	Via video modeling, how to operate movie on iPod	Yes	53	5/No
		Via video modeling, how to operate photo on iPod	Yes	100	6/No
		Via video modeling, how to operate music on iPod	Yes	100	2/No
	14, F, ID	Via video modeling, how to operate movie on iPod	Yes	67	3/No
		Via video modeling, how to operate photo on iPod	Yes	100	3/No
		Via video modeling, how to operate music on iPod	Yes	100	1/No

Study	Participants: age, gender, disability	Intervention/Targeted Skill	Met Mastery Criterion	PND*	Maintenance/ Generalization**
Kagohara (2011) Multiple baselines design	19, F, DD	Via video modeling, learn to self-operate an iPod Touch to watch video	NA	100	2/No
	16, F, DD		NA	67	2/No
	15, M, DD		NA	67	2/No
Kagohara et al. (2011) Multiple baselines design	20, F, ID	Via video modeling, how to operate an iPod Touch to listen to music	NA	93	2/No
	16, F, DD		NA	100	2/No
	15, M, DD		NA	100	2/No
Kelley et al. (2013) Multiple baselines design	22, M, ID	Using picture prompts on iPod to teach pedestrian navigation	Yes	100	2/2
	21, M, DD		Yes	100	2/2
	26, M, DD		Yes	100	2/2
	20, F, DD		Yes	100	2/2
Plavnick (2012) Changing criterion design	4, M, Autism	Increasing video attending on an iPhone through shaping procedure	Yes	100	No/No
		Imitating behaviors from video models on an iPhone through shaping procedure	Yes	88	No/3
Scott et al. (2013) Multiple baselines design	19, F, MD	Video modeling on iPod to teach acquisition of ATM skills	Yes	100	2/1
	20, F, DD		Yes	100	2/1
	20, F, DD		Yes	100	2/1
Siegal & Lien (2015) Alternating treatments design	3, M, Autism	Using high-context photograph display on iPad to decrease duration of transition to toy play	NA	67	No/No
		Using No-context photograph display on iPad to decrease duration of transition to toy play	NA	92	No/7
	4, M, Autism	Using high-context photograph display on iPad to decrease duration of transition to toy play	NA	83	No/No
		Using No-context photograph display on iPad to decrease duration of transition to toy play	NA	100	No/7
	4, M, Autism	Using high-context photograph display on iPad to decrease duration of transition to toy play	NA	100	No/No
		Using No-context photograph display on iPad to decrease duration of transition to toy play	NA	100	No/6
Smith et al. (2015) Multiple baselines design	17, M, Autism	Using progressive time delay to initiate self-instruction with iPhone	Yes	63	4/No
		Using progressive time delay to watch video models on iPhone	Yes	100	3/No
		Using progressive time delay to perform untrained skills after watching videos on iPhone	Yes	100	4/No
	19, M, Autism	Using progressive time delay to initiate self-instruction with iPhone	Yes	75	4/No
		Using progressive time delay to watch video models on iPhone	No	60	3/No

Study	Participants: age, gender, disability	Intervention/Targeted Skill	Met Mastery Criterion	PND*	Maintenance/ Generalization**
		Using progressive time delay to perform untrained skills after watching videos on iPhone	No	75	2/No
	17, M, Autism	Using progressive time delay to initiate self-instruction with iPhone	Yes	75	3/No
		Using progressive time delay to watch video models on iPhone	Yes	100	2/No
		Using progressive time delay to perform untrained skills after watching videos on iPhone	Yes	100	2/No
	15, M, Autism	Using progressive time delay to initiate self-instruction with iPhone	Yes	67	3/No
		Using progressive time delay to watch video models on iPhone	No	43	2/No
		Using progressive time delay to perform untrained skills after watching videos on iPhone	No	75	1/No
Spooner et al. (2014) Multiple baselines design	12, M, Autism	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	77	6/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	100	6/No
	8, M, Autism	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	3/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	100	3/No
	11, M, Autism	Using systematic instruction with an iPad to teach task analysis of shared reading	No	94	1/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	100	1/No
	8, M, Autism	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	1/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	22	1/No
Spooner et al. (2015) Multiple baselines design	7, F, Autism	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	13/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	100	13/No
	8, F, Autism	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	10/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	100	10/No
	9, F, MD	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	11/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	75	11/No
	9, M, MD	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	9/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	88	9/No
	11, M, DD	Using systematic instruction with an iPad to teach task analysis of shared reading	Yes	100	6/No
		Using the iPad/shared story instruction to improve listening comprehension	NA	75	6/No
Stephenson (2016) Multiple baselines design	7, M, ID	Using the iPad app Choiceboard Creator to teach choice making /free play	Yes	80	No/No
		Using the iPad app Choiceboard Creator to teach choice making /morning circle	Yes	81	No/No
		Using the iPad app Choiceboard Creator to teach choice making /morning tea	Yes	100	No/No

Study	Participants: age, gender, disability	Intervention/Targeted Skill	Met Mastery Criterion	PND *	Maintenance/ Generalization**
Uphold et al. (2016)	57, M, ID	Using an ePAS app on an iPod Touch to schedule exercising	No	100	No/3
	22, M, ID		Yes	100	No/3
	22, M, ID		Yes	88	No/2
Reversal design	21, M, Autism		No	100	No/2
	23, M, ID		Yes	89	No/3
	20, F, Autism		Yes	100	No/3
van der Meer et al. (2012)	10, M, Autism	Using Prologue2 Go on iPod Touch to make augmented request	Yes	71	No/No
	5, M, MD	Using Prologue2 Go on iPod Touch to make augmented request	No	100	No/No
		Using Prologue2 Go on iPod Touch to make augmented request w/least-to-most prompts	No	100	No/No
Alternating treatments		Using Prologue2 Go on iPod Touch to make augmented request w/30-time constant delay	Yes	100	No/No
	7, M, DD	Using Prologue2 Go on iPod Touch to make augmented request	No	83	No/No
		Using Prologue2 Go on iPod Touch to make augmented request/Mass training	Yes	91	No/No
	5, M, DD	Using Prologue2 Go on iPod Touch to make augmented request	Yes	100	No/No
Walser et al. (2012) Multiple baselines design	21, F, DD	Using video modeling to teach how to take a picture with iPhone	Yes	31	No/No
		Using video modeling to teach how to look at pictures with iPhone	Yes	75	No/No
		Using video modeling to teach how to watch a movie with iPhone	Yes	57	No/No
	17, M, DD	Using video modeling to teach how to watch a movie with iPhone	Yes	71	No/No
		Using video modeling to teach how to look at pictures with iPhone	Yes	100	No/No
	18, M, ID	Using video modeling to teach how to look at pictures with iPhone	Yes	59	No/No
		Using video modeling to teach how to watch a movie with iPhone	Yes	42	No/No
		Using video modeling to teach how to take a picture with iPhone	Yes	100	No/No
Wu et al. (2016) Multiple baselines within a reversal design	14, M, Autism	Using the fade video prompting on iPod Touch to teach window washing	Yes	100	3/3
		Using the fade video prompting on iPod Touch to teach table washing	Yes	100	3/3
	17, M, DD	Using the fade video prompting on iPod Touch to teach window washing	Yes	100	3/3
		Using the fade video prompting on iPod Touch to teach table washing	Yes	53	3/3

Note. M= male, F= female, DD = developmental disability, ID= intellectual disability, MD= multiple disability
*PND during treatment phase
** Number of sessions during generalization/maintenance phases, No= no sessions

Results

Twenty-three studies included in the meta-analysis had a total of 78 participants with intellectual and developmental disabilities and produced 140 observed cases that met the inclusion and exclusion criteria. Since some participants had multiple targeted skills with different interventions, the observed cases outnumbered the number of participants. Detail information about studies, participants, and observed cases included in the meta-analysis is listed in Table 1.

Study Characteristics

Multiple-baseline designs (over participants or target behaviors) were the most implemented single-case experimental design (n=15, 65%). Alternating treatments (n=4), reversal (n=3), and multiple-baseline with reversal design (n=1) were implemented. Three types of mobile devices including iPad, iPhone, and iPod Touch were used: iPod Touch was the most popular device (n=14, 60.9%) followed by iPad (n=6) and iPhone (n=3). Sixteen studies (69.6%) implemented the mobile device as an instructional device; 4 (17.4%) as a communication device; and 3 (13%) as an organizer. Twenty-one (91.3%) out 23 studies were conducted in a school setting. The rest two studies (Scott et al., 2012; Uphold et al., 2016) were conducted in a community setting.

Participants

The primary disability of participants was based on the authors' report. If the author(s) reported autism as the primary disability and intellectual disability as secondary disability, autism was counted as the primary disability. However, more than half of the participants (*n*=42) reported a comorbidity of two or three disorders/disabilities conditions. For example, 11 out 30 participants with autism had an intellectual disability as a secondary disability and 11 out of 19 participants with a developmental disability reported to have an additional disability. Although the participants with ID shared common characteristics such as significantly below-average cognitive functioning, limited communication skills, and deficits in adaptative skills, the presence of autistic-like characteristics separated the participants into two groups. Thirty-five participants (49.1%) had either a formal autism diagnosis or autistics behaviors/characteristics. The participants' age ranged from 3 to 21 with the average of 14.2. There were no significant age differences across gender, primary disability or autistic characteristic, as shown in Table 2.

Intervention Characteristics by Target Skills

Since some participants had different interventions for multiple target skills, the analysis unit was an observed case where a participant had a separate intervention for a different target skill: A total of 140 observed cases were extracted for the final analysis. In Table 3 device types, device functions, and intervention types were grouped by the type of target skills including academics (e.g., reading, math); communication (e.g., requesting, speaking); leisure (e.g., watching a video, listening to music, taking a picture); and vocational skills (e.g., table washing, vacuuming, using ATM). More than a half of the observed cases (n=72) targeted promoting participants' vocational skills, which were followed by leisure skills (n=29) and academic skills (n=22), and then communication skills (17).

Table 2
Participants' Characteristics

		n (%)	*Age M(SD)*	*Age Range*
Gender	Female	19(25.7)	15.5(4.6)	7-21
	Male	55(74.3)	13.9(8.2)	3-57
Primary Disability	Autism	30(40.5)	10.5(5.3)	3-21
	Developmental Disability	19(21.6)	16.3(4.8)	5-26
	Intellectual Disability	24(31.1)	18.4(9.1)	7-57
	Multiple Disabilities	5(6.8)	10.6(5.2)	5-19
Autistic Characteristic	No	43(55.1)	17.8(7.2)	9-57
	Yes	35(44.9)	10.1(5.2)	3-21
Total		78(100)	14.2(7.6)	3-57

Table 3
Intervention Characteristics by Target Skills

		Target Skills: Academics	Target Skills: Communication	Target Skills: Leisure	Target Skills: Vocation	Total *N (%)*
Device Type	iPad	22	4	0	6	32(22.9)
	iPhone	0	0	8	15	23(16.4)
	iPod Touch	0	13	21	51	85(60.7)
Device Function	Communication	0	17	0	0	17(12.1)
	Instructional device	22	0	14	68	104(74.3)
	Organizer	0	0	15	4	19(13.6)
Intervention Strategy	App use	0	3	6	0	9(6.4)
	Picture display	0	0	0	14	14(10.)
	Speech generating device(SGD)	0	7	0	0	7(5.0)
	Systematic prompting/instruction	22	4	0	18	44(31.4)
	Video play	0	3	23	40	66(47.1)
Total	N (%)	22(15.7)	17(12.1)	29(20.7)	72(51.4)	140(100.0)

Types and functions of mobile devices. iPod Touch was the most popular device, which was followed by iPad and iPhone. There was a significant association between the type of device and target skills, $\mathcal{X}^2(6) = 95.9, p = .000$ on the *Kentall's* *tau-b* test. Twenty-two out of 32 iPad uses targeted academic skills only and iPhone was only used for leisure and vocational skills. It was noted that iPhone and iPod Touch were not utilized for teaching academic skills. Three functions were reported: communication device (n=17), instructional device (n=104), and organizer (n=19) and the function type of devices was significantly associated with the type of target skills, $\mathcal{X}^2(6) = 184.0, p = .000$. The devices functioned only as a communication device when the interventions were targeting communication skills. The devices were utilized as an organizer only for leisure and vocation skills. Overall, the dominant function of mobile devices was an instructional device (74.3%).

Intervention types. Out of 17 distinct intervention types (See Table 2 for detail information), five common types of intervention strategies were reported: (a) how to use apps; (b) picture prompts or cues; (c) use of speech generating device (SGD); (d) systematic prompting (e.g., constant time delay, progressive time delay, least-to-most system) or systematic instruction; and (e) use of video play including video-modeling and video prompting. Use of video play was the most implemented instructional strategy (47.1%), followed by systematic prompting or instruction strategy (31.4%). The type of intervention strategies was strongly associated with the type of the target skills, $\mathcal{X}^2(12) = 146.7, p = .000$, on the *Kentall's tau-b* test. Picture display on devices (e.g., pictorial prompting, picture cues) was only employed for vocational skills and the strategy of systematic prompting/instruction was the only intervention strategy for targeting academic skills.

Table 4
Average Number of Sessions for Treatment, Maintenance, and Generalization Phase

	M (Range)	*n*	Percent
Treatment	11.4 (3-65)	140	100.0
Maintenance	3.6 (1-13)	78	55.7
Generalization	3.9 (1-12)	29	20.7
Treatment only	16.0 (3-65)	47	33.6
Treatment & Maintenance	12.5 (4-26)	64	45.7
Treatment & Generalization	13.4 (5-26)	15	10.7
Treatment, Maintenance, & Generalization	16.6 (6-46)	14	10.0
Total		140	100.0

Treatment, maintenance, and generalization phases. Out of 140 cases, 64 cases had treatment and maintenance phases; 47 cases had treatment phase only; 15 cases had treatment and generalization phases; and only 14 cases had all of three phases. Table 4 shows an average number of sessions for treatment, maintenance, and generalization phases.

Effect size: PND Scores

The PND scores were calculated for each observed case (*N=140*), as some participants had multiple interventions for different target skills. Table 5 shows a mean and median score of PND during the treatment, maintenance, and generalization phase each. The average PND score of 140 observed cases was 91.8, which means mobile device-based intervention was a very effective intervention for individuals with ID. PND size was significantly affected by conducted phases, *H (3) =12.4, p= .006*. *Mann-Whitney test* was used to follow up this finding and PND size, when only treatment phase was conducted, was significantly lower than when all three phases were conducted, *U=-36.3, p=.006.*

Since 77.1% (n=108) of the observed cases employed the mastery criterion for the target skills, a separate PND was calculated according to whether the mastery criterion was not employed (n=32) and, if the mastery criterion was implemented, whether the mastery criterion was met (n=88) or the mastery criterion was not met (n=20). For the association between the three categories of the mastery criterion variable and the PND scores, nonparametric correlation test, *Kendall's tau_b*, was conducted. There was a positive relationship between the mastery criterion variable and the PND scores, $\tau = .168$, $p = .023$, which indicates that PND scores increase across the categories of the mastery criterion and such a trend is illustrated in Figure 1. There were no significant differences in PND scores across participants' characteristics, device types/functions, intervention types, and target skill types. Overall, the average PND size of mobile device-based intervention ranged from 84.7 to 100: Mobile device-based interventions for individuals with ID were very effective.

Table 5

PND of the Treatment, Maintenance, and Generalization Phases

	n	Mean	Median	Range
Treatment	140	88.6	100.0	17.0-100.0
Maintenance	78	99.8	100.0	83.0-100.0
Generalization	29	100.0	100.0	100.0-100.0
Treatment only	47	84.7	95.4	16.7-100.0
Treatment & Maintenance	64	94.5	100.0	61.1-100.0
Treatment & Generalization	15	96.6	100.0	82.1-100.0
Treatment, Maintenance, & Generalization	14	98.9	100.0	84.2-100.0
Total	140	91.8	100.0	16.7-100.0

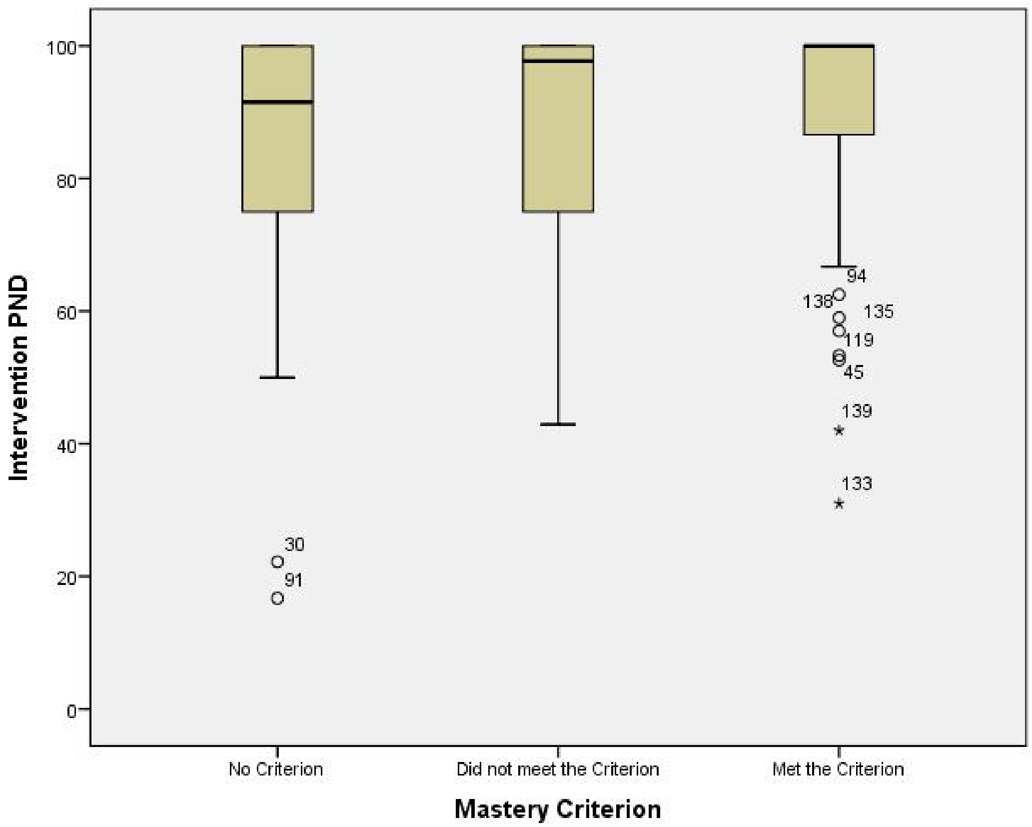

Figure 1
Treatment PND and Mastery Criterion

Discussion

Overall, this meta-analysis indicates strong effects for mobile device-based interventions on targeted skills in individuals with ID: The mean and median of the PND scores of 140 observed cases were 91.8 and 100 respectively. Twenty-three studies had 78 participants with ID: The participants shared significantly-below-average cognitive functioning, limited communication skills, and deficits in adaptive behaviors skills. Fifty-three percent of the participants reported to have more than one disability and almost a half of the participants had either a diagnosis of autism or autistic characteristics. The intervention outcomes were not affected by the participants' age, gender, primary disability or the presence of autistics characteristics.

Differences in outcome effects were only observed in the study design conditions: adoptions of the maintenance and generalization phases and the mastery criterion. Mobile device-based interventions were effective to acquire, maintain, and generalize the target skills according to PND scores during treatment, maintenance, and generalization phases. More than half of the observed cases had the maintenance phase and over 20% adopted the generalization phase. It was noted that when the observed cases had all three phases, the intervention outcome effect was significantly stronger than when they had the treatment phase only. This difference appears to be due to the maintenance and generalization phases being accompanied only if the treatment effect is certain. Both Kelley and colleagues (2013) and Scott and colleagues (2013) implemented all three phases and their average PND score during the treatment phase was 100. This trend also has influenced where or not to adopt the maintenance phase. In Cannella-Malone and colleagues (2013), three adolescents with DD had the maintenance phase for self-directed video prompting on iPad to learn vocational skills because they met the performance criterion during the intervention phase, whereas one participant who did not meet the criterion did not have the maintenance phase. The variable of mastery criterion, (i.e., no criterion, did not meet the criterion, or met the criterion), had a significant association with PND scores. The PND scores were higher when the mastery criterion was set, and much higher when the mastery criterion was met because the mastery criterion was set at least 80% performance in three consecutive sessions.

Target skills were categorized into four domains, i.e., academics, communication, leisure and, vocation, and PND scores did not significantly differ across the target skill domains. Intervention effects were not affected by mobile device types, functions, or intervention types. However, distinct trends in the use of mobile devices were observed. The mobile devices including iPhones, iPod Touchs, and iPads were dominantly implemented as instructional devices to teach the participants with ID the target skills. That is, the current mobile devices-based interventions for individuals with ID are more likely to use mobile devices as instructional technology (IT). The mobile devices also functioned as AT devices by replacing traditional AAC devices. On the other hand, only three studies utilized the mobile devices as a personal multiple organizer, which is the most preferred application of the mobile devices in the general population. For example, Uphold and colleagues (2016) instructed six adults with ID to schedule exercising routines using an ePAS app on an iPod Touch. Kelley and colleagues (2013) used picture prompts on iPod to teach four young adults with ID how to navigate a college campus. The students were able to generalize their skills to navigate to various locations on the campus relying on iPod Touch. In these cases, the mobile devices were used for their intended purposes by the participants with ID.

The provisions of the Individuals with Disabilities Education Act (IDEA) mandate that the Individualized Education Program (IEP) team must consider whether an individual with a disability needs assistive technology (AT) devices or services which are designed to increase, maintain or improve the functional capabilities of the individual with a disability (20 U.S.C. 1401 (11)). Thereby, the main purpose of AT has been assisting individuals with disabilities in compensating their limitations or deficits caused by the disability. For example, augmentative and alternative communication (AAC) devices such as Dynavox V® and GoTalk Communicators® enhance the communication skills of children who are either non-verbal or have minimal speech skills. However, such specialized AT devices often require efficient and skilled partners to make them fully functional for individuals with disabilities (Shire & Jones, 2015). Although a student with a disability is entitled to consideration for AT devices or services, a majority of special education teachers do not consider or request AT evaluation when planning the student's IEP due to their limited knowledge and competency in technology (Alkahatani, 2013; Coleman & Cramer, 2015). As technology pervades all aspects of the classroom, special educators need to make a decision about whether they are going to stick to specialized AT or adopt some of the "mainstream one" that general population are using. Whereas AT used to be considered a highly specialized field, now AT is blurring with IT (Schaffhauser, 2013). For the individuals with ID, a true meaning of functional technology need to be applied and implemented through mobile device-based interventions.

The New Paradigm: Functional Technology

Technology has become an important part of American life. People use various technological devices to acquire and maintain information and to communicate with others on a daily basis. Teachers use technology to improve various aspects of children's educational outcomes by enriching learning experiences. It is important to extend the use of mobile devices to the daily activities of people with ID, improving skills in communication, academics, social interactions, and personal management. Proficient use of technology will increase integration opportunities for students with disabilities in schools and will create the future jobs where none were possible before. Technology is necessary for everyone for it continues to increase in importance in all aspects of life.

Recognizing the importance of preparing students to work and live in a technological society, U.S. Congress enacted the Technology-Related Assistance for Individuals with Disabilities Act (Tech Act) in 1988. The act acknowledged that all individuals with disabilities should increase engagement or performance of tasks at home, school, workplace, and in the community as they benefit from technological advances. The IDEA also mandates the use of Assistive Technology (AT). The purpose of AT is increasing, maintaining, or improving the functional capabilities of individuals with disabilities.

Currently, most implementation of technology policy and initiatives has targeted providing hardware and software for the limited number of students who are qualified to receive AT. The specificity of existing AT tends to focus on improving functional capabilities in the area of sensory needs such as vision, hearing, or mobility of people with disabilities. This meta-analysis study of mobile devices concurs that these devices have been utilized mainly as instructional devices or as replacements of AAC for people with intellectual disabilities.

Moreover, seldom have they articulated a vision of how technology can empower people with disabilities in all phases of their lives and daily routines, especially work and community. While AT augmentation of the physical and sensory capacities of people with disabilities has contributed to their integration into community, it has not been fully utilizing the function of technology. The technology illiteracy will soon create the issue of cyber segregation for people with disabilities. For example, many teens and adults use social media websites and mobile apps to maintain friendships, form new relationships, and create an outlet for self-expression (Subrahmanyam, Reich, Waechter, & Espinoza, 2008). When students with ID do not have the technology skills beyond AT, they will become isolated from the network of peers and resources in the social media.

It is crucial that all people with disabilities are equipped and become self-sufficient in the use of technology which is beyond the use of AT. The functional technology should be the new paradigm for people with disabilities, helping them to proficiently use technology, including mobile devices, in daily activities and in various environments. Functional technology is "the process of implementing any assistive technology in daily routines, managing and navigating the network, and manipulating software that addresses the specific needs of individual with disabilities, to enhance their learning outcomes and quality of life in immediate and in future integrated environments." (Kimm, 2016).

Intellectual disability (ID) is better understood as a state of limited functioning characterized by the need for support in order to participate in school and society on a par with people from the general population (Shalock et al., 2010). From this perspective, people with ID have strong needs for functional technology (FT) that supports their social integration in addition to the needs for AT. Kim and Kimm (2016) emphasized that mobile devices are not only valuable as FT for people with ID, but also in accomplishing normalization with the general public. For example, traditional AT accentuates the differences in persons who use it due to their disabilities. However, the use of a mobile device, with its universal handheld design that is used by the general public, will minimize the focus on the user's disability and ease the process of normalization.

Research in the effectiveness of mobile devices in various settings and functions, beyond instructional technology in the classroom, is in a beginning stage. By exploring and implementing appropriate apps and internet resources, the positive effects of mobile devices will be maximized in improving the integration and the quality of life of people with disabilities. Moreover, people with ID will become active agents in learning and implementation of functional technology, rather than passive recipients of instruction. New versions of Smartphones and Tablet PCs are being introduced. To meet the requirements of the IDEA, more research should be conducted to investigate the effectiveness of FT for people with ID and the use of mobile devices as FT. Researchers and practitioners should proactively use FT such as mobile devices in the daily activities of people with ID in various settings in order to improve their independence and integration on and off the cyber communities.

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