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Effectiveness of technology types in employment-related outcomes for people with intellectual and developmental disabilities: an extension meta-analysis

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Abstract

The aim of this study was to extend a recently published meta-analysis that explored the impact of technology use to support employment-related outcomes for people with intellectual and developmental disabilities by focusing on the impact of types of technology and work settings. A further analysis of the same single-subject experimental design studies conducted from 2004-2016 was undertaken in this study. Percentage of non-overlapping data (PND) scores measuring the intervention effect were used and compared across types of technology and work settings. The relationships between the types of technology and the presence of universal design features were also examined. Findings revealed significant differences in the effects of the technology use between (a) pictorial prompts and (1) auditory prompting devices, (2) desktop and laptop computers, and (3) palmtops; and (b) real and simulated work setting. Significant relationships between the presence of universal design features and types of technology were also found. Devices using pictorial prompts had a lower frequency of universal design features present while the video-assisted training, palmtops, and desktop and laptop computers group had significantly greater frequency of the use of universal design features. Overall, the effect of the use of technology seemed to differ when viewed by type of technology or by work setting. Further research is required regarding (1) technology use to promote employment-related outcomes in real work settings, (2) the effect of more sophisticated types of technology in real work settings, and (3) the features incorporated into the technology.

Keywords: intellectual and developmental disabilities, applied cognitive technology, assistive technology, meta-analysis, employment-related outcomes.

Introduction

Applied cognitive technology device use has been shown to improve the quality of lives of people with intellectual and developmental disabilities by providing tools to participate in activities and tasks that are both common in and important to day-to-day life, from using cell phones (Stock et al. 2008), to navigating around one's community (Davies et al. 2010), to using social media (Davies et al. 2015). There is now considerable evidence that technology has a positive impact on individuals' with IDD self-determination (Wehmeyer et al. 2011), their well-being and community participation (Lancioni et al. 2014; Stock et al. 2011), and reducing the need for formal and long-term care (Owuor et al. 2017). From a positive rehabilitation perspective, technology use in daily living and typical community-based settings can enhance the independence, social inclusion, and meaningful participation of people with intellectual and developmental disabilities (Seelman 1993).

Further, it is now well understood that technology can provide meaningful supports to people with intellectual and developmental disabilities to participate successfully in work and employment-related tasks and settings. Meta-analytic studies by Wehmeyer et al. (2006) and Damianidou et al. (2018) of single-case design studies involving technology use by people with intellectual and developmental disabilities in work-related activities and contexts confirmed the positive benefits of the use of technology on employment-related outcomes, particularly when such technology incorporated features of universal design. Recent evidence indicated that technology improves task performance and behavior (Westbrook et al. 2015), longtime task-specific skills (Alexander et al. 2013), maintenance of acquired job skills after intervention (Chang et al. 2014), and vocational-task independence (Riffel et al. 2005). It has been also suggested that technology is promising to improve social and behavioral employability skills required in various work settings (Wehmeyer et al. 2006).

Rapid technological progress has resulted in the development and ready availability of numerous types of technology with more options for adaptations and accommodations to meet the needs of people with intellectual and developmental disabilities in employment tasks and settings. The types of technology used in respective interventions to support people with intellectual and developmental disabilities to improve employment-related outcomes has expanded over the years, ranging from less to more sophisticated modalities (Damianidou et al. 2018; Wehmeyer et al. 2006). The use of more sophisticated, portable, mainstream technology types (e.g. PDA's, iPod's, handheld devices, smartphones) is increasingly found to be effective in providing on-the-job support for people with intellectual and developmental disabilities (Davies et al. 2002). In addition to evidence supporting their efficacy, these technologies have the advantage of being non-stigmatizing, due to their ubiquitous use in society (Davies et al. 2002). Devices and applications that provide multiple modes of prompts and the presentation of instructions integrating high-quality audio, video, and/or text into graphic displays seem to have particular merit (Davies et al. 2002). Collins and Collet-Klingenberg (2017) found, in their review of the literature, that auditory prompts, pictorial prompts, and multiple presentation modes (particularly pairing audio prompts with video and/or picture and/or text) were the most common modes of prompting implemented. And yet, despite the aforementioned evidence of the benefit of technology use by people with intellectual and developmental disabilities, underutilization of such type of technology by people with intellectual and developmental disabilities remains a significant issue (Bouck and Flanagan 2016; Tanis et al. 2012).

In a recent meta-analysis, Damianidou et al. (2018) examined the use of applied cognitive technology (henceforth technology) and its impact on employment-related outcomes for people with intellectual and developmental disabilities. Applied Cognitive Technology is a term coined by Wehmeyer and Shogren (2013) referring to "technology supports that enable people with cognitive disabilities to successfully function in inclusive environments, to increase participation in tasks and activities in inclusive environments, and to promote social inclusion, self-determination, and quality of life" (p. 92). Traditional assistive technology, computer, electronic, and information technology are types of technology included under the umbrella of the term Applied Cognitive Technology. The findings of the meta-analysis (Damianidou et al. 2018), when compared with an earlier, similar meta-analysis (Wehmeyer et al. 2006), confirmed that (1) the use of technology to support employment-related outcomes was effective for people with intellectual and developmental disabilities, and (2) the presence of universal design features improved performance outcomes.

The importance of universal design features for technology to support employment for people with intellectual and developmental disabilities (Damianidou et al. 2018; Wehmeyer et al. 2006; Wehmeyer et al. 2008) and the importance of employment as an aspect of improved quality of life (Kober and Eggleton 2005) and self-determination (Wehmeyer and Palmer 2003; Wehmeyer and Schwartz 1997) all point to the need for more research on technology use and employment.

First, greater availability of types of technology and universal design features means the process of matching person and technology to meet the individual's needs for a given set of employment tasks can be complex, since people with intellectual and developmental disabilities are a heterogeneous group with a wide variety of skills, interests, abilities, and cognitive support needs (Davies et al. 2018). Scherer's (2005) *Matching Person and Technology* model highlights the importance of understanding the technology and its salient features in conjunction with people and environments (*milieu*) to make a good match. As such, further investigation regarding the impact of specific types of technology and the relationship between the presence of universal design features and these types of technology will add critical knowledge and assist the decision making process regarding this matching in order to assist both people with intellectual and developmental disabilities and their friends, families, and other supporters.

Second, context is obviously a critical part of understanding the impact of disability on full participation. The work settings or contexts included in the studies analysed by Damianidou et al. (2018) ranged from simulated to real settings, making it difficult to generalize findings to either one of the specific settings. An analysis of the impact of work setting on intervention effectiveness (PND scores) is, as such, important to further inform practice.

This study extended the Damianidou et al. (2018) findings to investigate (1) the impact of the use of specific types of technology used by people with intellectual and developmental disabilities to improve employment-related outcomes, (2) the impact of the different work settings in which these interventions have taken place, on the intervention effectiveness (PND scores) and, (3) the existence of a relationship between the type of technology and the presence of the universal design features.

Method

This method is described in eight parts. These are (1) literature search strategy, (2) criteria for inclusion of studies, (3) criteria for exclusion of studies, (4) search results, (5) information on the studies, (6) intervention effects, (7) PND and universal design reliability measures, and (8) statistical analysis. The first seven sections of the method were the same as the Damianidou et al. (2018), though the analysis differed in this study as a function of the research questions posed. Therefore, only a brief description of the first seven sections was provided in this study.

Literature Search Strategy

This study is based on the same group of articles previously reviewed by Damianidou et al. (2018). Data from the peer-reviewed articles used in the meta-analysis by Damianidou et al. (2018) were used in this study. The literature search examined published journals in EBSCO, ProQuest and Scopus. The search period was from the 2004 until 2016. The search strategy applied in the abstract section of the studies used a combination of keywords of the three following categories: diagnosis, technology, and employment. A total of 441 articles were located after preliminary searches.

Criteria for Inclusion of Studies

The articles were examined to determine whether they met the following inclusion criteria: (1) the study had participants with intellectual and developmental disabilities based on either clinical diagnosis or an IQ assessment; (2) the study employed a single-subject experimental design (SSED) (i.e. pre-experimental (AB), withdrawal (ABA/ABAB), multiple baseline, multiple-probe, reversal, changing criterion, multiple-treatment, alternating treatments, adapted alternating treatments); (3) the intervention phase involved the use of technology; (4) the intervention phase aimed employment-related outcomes; (5) the results were presented in a line graph format consistent with the SSED's usual protocols; (6) the study was published in a peer-reviewed journal; (7) the study was published from 2004 up to and including 2016; and (8) the study was written in English.

Criteria for Exclusion of Studies

The articles were examined to determine whether they met the following exclusion criteria: (1) the study employed a group design, opinion articles, position statements, qualitative studies, group design studies, literature review article; (2) the study employed an inappropriate design (e.g., lack of baseline or fewer than 3 baseline scores and 2 baseline score for multiple probe design); (3) the study had participants with Autism Spectrum Disorder (ASD) with IQ score above 75; (4) the results were not presented in a line graph consistent with SSED's protocols; and (5) data involved "floor" or "ceiling" effects in graphed data making the calculation of the intervention effect inaccurate (Scruggs et al. 1987).

Search Results

The final studies included in the meta-analysis were the same 41 included in Damianidou et al. (2018). The three-step process followed in the meta-analysis to determine the relevant studies included: (1) the lead researcher (1st author) excluding studies that did not meet the inclusion criteria, (2) two expert colleagues (3rd and 4th author) working independently through a random sample of 12 (out of the 41) randomly selected studies (28% of total studies), and (3) the 3rd and 4th author cross-checking each study, measuring the application of inclusionary and exclusionary criteria.

Information on the Studies

The first author classified the preliminary data into the following categories: article title, authors names, journal name, volume number, page numbers, keywords, the type of technology used, the type of employment-related outcomes measured, the level and type of intellectual and developmental disabilities, the research design, the work setting, and the presence and nature of universal design features.

The degree to which any of seven universal design features was identified as present was coded. Thematic analysis was conducted to identify, extract and classify UD features from the studies reviewed. The classification was developed based on groupings informed by universal design literature (Connell et al. 1997). The universal design groups were: “equitable use”, “flexible use”, “simple and intuitive use”, “perceptible information”, “tolerance for error”, “low physical/cognitive effort”, and “size and space”. A theoretical approach to thematic analysis was undertaken in line with the phases outlined by Braun and Clarke (2006). Given that there was no intention to identify underlying assumptions and conceptualizations of the extracted data, a semantic approach was adopted. The essentialist/ realist approach was taken, whereby a one-way connection of meaning and experience and language was presumed (Braun and Clarke 2006).

Intervention Effect

As the research questions for this study emerged from the findings of the meta-analysis (Damianidou et al. 2018), the same metric (PND), appropriate for SSED studies, was employed, measuring the non-overlapping data between baseline and treatment phases. More specifically, a PND score measures the number of observations in the treatment phase that exceeds the highest point in the baseline phase as presented in a visual graph (Scruggs et al. 1987). The possible range of PND scores is from 0 to 100. Very effective interventions have PND scores above 90, while effective interventions’ PND scores range from 70 to 90. Questionable interventions have PND scores that range from 50 to 70 (Scruggs and Mastropieri 1998).

For all studies, each intervention phase and its preceding baseline was addressed as a unique case. The number of observed intervention phases outnumbered the number of participants since the majority of the participants had more than one intervention phases or target employment-related tasks. Therefore, in the 41 studies, 347 unique treatment phases resulted in PND scores.

PND and Universal Design Reliability Measures

Interrater reliability for the PND scores was established. Three independent experienced raters measured the PND scores for each unique case of 29% of the total studies. A three-step process was followed: (1) the lead researcher measured the PND scores from all 41 studies and excluded the studies that did not meet the inclusion criteria; (2) author 4 worked collaboratively with the lead researcher through a random sample of 12 of the 41 studies and cross-checked the PND calculations; and (3) author 3 independently verified each decision by reviewing the same sample of 12 papers and the decisions made in the first two steps. The reliability rate was calculated by dividing the number of agreements by the total number of agreements and disagreements, multiplied by 100.

Interrater reliability was also calculated for the identification of the universal design features. The lead researcher (first author) became familiar with the data, read each article several times and, then, identified short phrases that symbolically assigned a salient attribute relating to a distinguished universal design feature across the entire data set. The same procedure was independently undertaken by the third and fourth authors for a random sample of 12 studies (29% of the total studies) to ensure the reliability of the process. The process was iterative, repeatedly returning to the raw data, to ensure that reported references to universal design features were rigorously explored. Multiple interpretations of universal design features were addressed through discussion until consensus was reached. Refer to Appendix A for the definition and description of the universal design features and a representative sample of extracted and classified data.

Statistical Analysis

The impact of two parameters (type of technology, and the work setting) on study outcomes (PND scores) was analyzed separately. A one-way Analysis of Variance (ANOVA) was employed to determine whether there were any statistically significant differences between the means of different types of technology and work settings in terms of PND scores. For post hoc analysis, Tukey-Kramer’s test was used to determine which types of technology were significantly different.

The relationship between the types of technology and the presence of universal design features was examined using Pearson’s chi-square analysis. For post-hoc testing, Bonferroni correction based on adjusted standardized residuals was used, starting with a significance level of .05/10=.005 for the lowest *p* value.

IBM SPSS Statistics 24 statistical software program was used (Crop., NY, USA). All statistical analysis was performed at the $p<0.05$ level of significance. Effect sizes have been calculated where appropriate consistent with current APA guidelines.

Results

Results are reported in three sub-sections: (1) descriptive statistics on types of technology and work settings, (2) statistical analysis, and (3) PND and universal design reliability measures.

Descriptive Statistics on Types of Technology and Work Settings

Overall, the 41 SSED studies used a variety of types of technology and work settings (see Damianidou et al. 2018 for details of the studies). The types of technology were: (a) auditory prompting devices (*n*=39), (b) video assisted training (e.g. DVD, iPod) (*n*=44), (c) palmtops (e.g. PDA, handheld computers) (*n*=141), (d) desktop and laptop computers (*n*=61), (e) pictorial prompts (*n*=48), (f) augmented reality device (*n*=3), (g) smartphones (*n*=4), and (h) watches (*n*=7). The frequencies of the different types of technology are shown in Table 2.

However, as shown in Table 1, PND scores varied by technology group, with PND scores for auditory prompting devices, desktop and laptop computers, augmented reality devices, smartphones, and watches indicating very effective treatments (94, 90, 100, 91, and 100 respectively). For the remaining technology groups—video assisted training (e.g. DVD, iPod), palmtops (e.g. PDA, handheld computers), and pictorial prompts—PND scores fell between 70 and 90, thus, indicating effective interventions (83, 89, and 74 respectively).

The work settings ranged from simulated (*n*= 248) to real (*n*=81). As shown in Table 2, when examined by the intervention work setting, the mean PND score for simulated work setting fell in the very effective intervention treatments range (92). Real work setting fell out of the very effective treatment range into the effective intervention range (71).

Intervention Effects Differences Viewed by Type of Technology

One-way ANOVA showed statistically significant differences between PND scores for the first parameter (i.e., types of technology) measured. The technology type groups “augmented reality devices”, smartphones”, and “watches” were removed from the analysis since they had few occurrences (3, 4, and 7 cases respectively). Significant differences on PND scores emerged by type of technology (i.e., auditory prompting devices, video assisted training (e.g. DVD, iPod), palmtops (e.g. PDA, handheld computers), desktop and laptop computers, pictorial prompts) using ANOVA, $F(4, 328) = 3.350$, $p = .010$, $\eta_p^2 = .039$. Post hoc analyses using Tukey-Kramer tests indicated differences between (a) auditory prompting devices and pictorial prompts ($p = .018$), (b) pictorial prompts and desktop and laptop computers ($p = .039$), and (c) pictorial prompts and palmtops (e.g. PDA, handheld computers) ($p = .021$). However, the other types of technology did not significantly differ from each other. Table 3 presents PND mean differences and statistical significance data from the post hoc analysis for all types of technology.

Intervention Effects Differences Viewed by Work Setting

Similarly, significant differences on PND scores emerged by the work setting in which the intervention has taken place (real or simulated) using ANOVA, $F(1, 327) = 29.581$, $p < .001$, $d = -0.29$. The interventions that has taken place in real work setting had a significantly lower average PND score (M =71, SD= 42.23) than those in the group in simulated work setting (M = 92, SD=23.65).

Presence of Universal Design Features Viewed by Type of Technology

A contingency table analysis of types of technology with the presence of universal design features revealed a significant relationship between these two variables, x^2 (4, N =333) = 164.61, $p < .001$, $V = .664$. Examination of a post-hoc adjusted standardized residuals analysis indicated that the presence of universal design features occurred in the group of pictorial prompts at significantly lower frequency than chance. In the groups of video assisted training, palmtops, and desktop and laptop computers group, the presence of universal design features occurred at significantly greater frequency than chance. In contrast, in the group of auditory prompting devices, the presence or absence of universal design features did not occur at a significantly greater or lower frequency than chance. Table 4 presents the results of the adjusted standardized residuals for all types of technology.

PND and Universal Design Reliability Measures

As reported in the Damianidou et al. (2018) meta-analysis, the reliability rate was 100% of the included and excluded articles and on the PND calculations of each case. The interrater reliability check procedure regarding the identified universal design features incorporated into the technology resulted initially in an agreement level of 82%. The raters came to a consensus on the remaining data point calculations in order to ensure the most accurate and representative result via two rounds.

Discussion

Overall, intervention effectiveness in the use of technology was identified as "effective" whether viewed by type of technology or by work setting. Further research regarding the technology use to promote employment-related outcomes must be undertaken in real work settings. In addition, the use of more sophisticated technology in this context requires further research in terms of intervention effectiveness in conjunction with the features incorporated into the technology. This study taken together with the original meta-analysis of Wehmeyer et al. (2006) and the updated meta-analysis of Damianidou et al. (2018) indicates that the use of such technology has considerable potential to support people with intellectual and developmental disabilities to improve employment-related outcomes within the large scope of rehabilitation protocols. The promise is significant and provides direction for future research in this area.

The Impact of Sophisticated Technologies

The majority of the participants (41%) were evaluated in "palmtops (e.g. PDA, handheld computers)". If the next most often used types of technology, "desktop and laptop computers", "pictorial prompts", "video assisted training (e.g. DVD, iPod)", and "auditory prompting devices", are added, 96% of the participants are accounted for. Only 5% of the participants were evaluated in technologies that are more 'sophisticated', such as "smartphones", "augmented reality", and "watches". A possible explanation for the latter low frequency might be that these types of technology are relatively new.

Nevertheless, the research findings for the more sophisticated types of technology (i.e., "smartphones", "augmented reality", and "watches") showed that they were the three most effective groups for which the PND scores rose to the very effective range (91, 100, and 100 respectively). A viable explanation might be that they have been developed to be more cognitively accessible, thereby providing various features such customization options that allow for adaptations to the unique needs of the people with intellectual and developmental disabilities to support employment-related outcomes. The limited number of studies with these types of technology commend caution in the generalization of the findings. However, given these promising findings, it is evident that more research is required on the features and the intervention effectiveness of these types of technology for people with intellectual and developmental disabilities.

Types of Technology and the Presence of Universal Design Features

Technology use has generally been found to be fairly effective, whether viewed by type of technology, or by work setting. Nevertheless, there are exceptions to this overall conclusion. When examining the PND scores of technology use by category, “low-tech” type of technology (i.e., pictorial prompts) had a PND score in the lower half of the effective range. The findings indicated that this type of technology incorporated universal design features at significantly lower frequencies. Nevertheless, more sophisticated types of technology (i.e., “palmtops (e.g. PDA, handheld computers)” and “desktop and laptop computers”), were found to have significantly higher PND scores and to incorporate significantly more universal design features. Subsequent issues pertaining to the presence of universal design features or the lack thereof can account for the intervention effectiveness, although there is no mechanism to attribute causality inherent in this study design.

It cannot be concluded that differences related to the extent of universal design features might have stemmed from differing functioning levels of people using the technology (whether high or low tech). This is because participants with severe/profound IDD also used high tech types of technology (i.e., “palmtops”, “desktop and laptop computers”, and “augmented reality devices”). It should be noted though that the sample size of this group of participants was small. That is, 6% of the cases (21 cases out of 347) referred to participants with severe/profound IDD.

The Functional Impact of Work Setting

With regard to work setting, although PND scores generally ranged in the effective category, the most striking outcome was that three quarters of the participants (76%) were evaluated in simulated work settings. Similarly, Wehmeyer et al. (2008), in a separate meta-analysis investigating the impact of technology use in studies combining employment-related outcomes and other various use areas (e.g., independent living, leisure etc.) found that the percentage of participants evaluated within actual community-based setting was almost one quarter (25%). Therefore, we could conclude that very little is known about the use of technology by people with intellectual and developmental disabilities in real work settings and more research is required.

As the nature of the work tasks undertaken in real and simulated settings were similar and there were still significant differences in intervention effect sizes, there is a possible efficacy difference in these two settings. This might be because simulated work settings are more accommodating to intervention while the complexity of real work settings may affect the result. That is, external factors are controlled and limited in a simulated setting whereas in real work settings are not (e.g., the interpersonal dynamics between colleagues/customers).

Limitations

The findings of this study are subject to four discernible limitations. First, the studies included in this meta-analysis were limited to SSED studies. SSED studies have a rich history, are ideally suited to and extensively used in several applied research programs in intellectual and developmental disabilities, due to the range of levels of impairment. However, it is recommended that further research be undertaken in more adventurous group experimental research design studies to extend the scope and findings of this study.

Second, despite PND's ease of calculation and its strong and wide history as one of the most popular non-overlap outcome metrics in meta-analysis of SSED studies (Maggin et al. 2011), methodological concerns have been associated with its use. The calculation of p-values and confidence intervals (CIs) around PND scores is impossible due to PND's lack of a known sampling distribution (Parker et al. 2011). Another point of criticism of PND's usefulness is the use of a single point to summarize all phase data (Parker et al. 2011). Further research to measure the effectiveness of each of three areas, including overall technology use, technology use focused on types of technology and technology use focused on work setting, through different and more stringent metrics is suggested.

Third, physical examination of the technology used in the studies has not been employed to evaluate the presence or absence of the universal design features. It might be due to the method used to identify these features, identification of the universal design features that are explicitly reported, discussed or identified in the studies, that some of these features may not have been considered. The findings regarding the universal design features should be interpreted with caution.

Fourth, as noted by Damianidou et al. (2018), the initial interrater agreement regarding the presence or absence of the universal design features as they were discussed or identified by the authors of each study was 82%, falling into the reasonable range. However, the three raters noted the challenges in objectively ascertaining the use of universal design principles in the context of technology used to support employment-related outcomes for people with intellectual and developmental disabilities. A more specific evaluation tool focused on interpreting and associating the universal design principles with the features of technology devices, software or applications is required to make the evaluation more accurate.

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Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical Approval

Research does not involve any human participants and/or animal.

Informed Consent

Research does not involve any human participants and/or animal.

Author Contributions

DD: designed the study, developed the methodology, implemented the original literature search, collected the data, performed the analysis of all the included articles, and wrote the manuscript. JF: collaborated with the editing on the draft and final manuscript. MAK: provided edits on the draft and final manuscript and reliability checks on a randomly selected sample of the included articles. GL: provided reliability checks on a randomly selected sample of the included articles. MW: provided expertise in conceptual principles around the field of technology use for people with intellectual and developmental disabilities and collaborated with the editing of the final manuscript.

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Tables

Table 1 Descriptive statistics (frequency and mean PND scores) of types of technology

Technology Type	M	SD	N
Audio	93.85	23.012	39
Picture	73.90	43.241	48
Video-based (DVD)	83.07	35.129	44
Handheld, PDA, iPod	89.13	24.493	141
Computer	90.26	28.729	61
Watch-Time	100.00	.000	7
Smartphones	91.00	18.000	4
Augmented- Reality	100.00	.000	3
Total	87.32	29.899	347

Table 2 Descriptive statistics (frequency and mean PND scores) of work settings

	M	SD	N
Real Work Setting	71.25	42.228	81
Simulated Work Setting	91.65	23.653	248
Total	86.62	30.556	329

Table 3 ANOVA for the types of technology

Technology Type	Technology Type	MD	p-value
Audio	Picture	19.950	.018
	Video-based (DVD)	10.778	.476
	Handheld, PDA, iPod	4.718	.908

	Computer	3.584	.977
Picture	Audio	-19.950	.018
	Video-based (DVD)	-9.172	.585
	Handheld, PDA, iPod	-15.232	.021
	Computer	-16.366	.039
Video-based (DVD)	Audio	-10.778	.476
	Picture	9.172	.585
	Handheld, PDA, iPod	-6.059	.768
	Computer	-7.194	.743
Handheld, PDA, iPod	Audio	-4.718	.908
	Picture	15.232	.021
	Video-based (DVD)	6.059	.768
	Computer	-1.135	.999
Computer	Audio	-3.584	.977
	Picture	16.366	.039
	Video-based (DVD)	7.194	.743
	Handheld, PDA, iPod	1.135	.999

Table 4 Chi-square with standardised adjusted residuals between types of technology and the presence of universal design (UD) features

			No UD features	1+ UD features	*p* value
Technology Type	Audio	Count	13.00	26.00	
		Percentage within Technology Type	33.33	66.67	
		Adjusted Residual	2.19	-2.19	.02852
	Picture	Count	33.00	15.00	

	Percentage within Technology Type	68.75	31.25	
	Adjusted Residual	9.08	-9.08	.00000
Video-based (DVD)	Count	21.00	23.00	
	Percentage within Technology Type	47.73	52.27	
	Adjusted Residual	4.90	-4.90	.00000
Handheld, PDA, iPod	Count	.00	141.00	
	Percentage within Technology Type	.00	100.00	
	Adjusted Residual	-7.85	7.85	.00000
Computer	Count	.00	61.00	
	Percentage within Technology Type	.00	100.00	
	Adjusted Residual	-4.34	4.34	.00001

Appendices

Appendix A

Definition of universal design features and a representative sample of examples from the reviewed papers

Connell et al., 1997) **Current Studies**

Universal Design	**Definition**	**Guidelines** Any one of the following:	**Representative examples from the studies**
Equitable use	The design is useful and marketable to people with diverse abilities	1a. Provide the same means of use for all users: identical whenever possible; equivalent when not. 1b. Avoid segregating or stigmatizing any users. 1c. Provisions for privacy, security, and safety should be equally available to all users. 1d. Make the design appealing to all users.	*"One advantage of using the iPod Touch devices is …they are ubiquitous in our society"* Cannella-Malone et al., 2012 *"This method allows job coaches to deliver feedback to students privately and immediately through a bug-in-ear device"* *"job coaches…delivered prompts discreetly through bug-in-ear devices"* Gilson & Carter, 2016 *"The prompting system in this study demonstrated the use of commercial off-the-shelf*

			products and leveraged their many advantages, such as….low concern about social stigma" Chang et al., 2011
Flexible use	The design accommodates a wide range of individual preferences and abilities	2a. Provide choice in methods of use. 2b. Accommodate right- or left-handed access and use. 2c. Facilitate the user's accuracy and precision. 2d. Provide adaptability to the user's pace.	*"An auditory prompt was recorded directly onto the PDA and played when the picture block was touched by the student (using a finger or the stylus)"* Mechling et al., 2010 *"The Visual Assistant program … enables a user with special needs to view step-by-step pictures paired with auditory instructions on the palm screen at his or her own pace"* Riffel et al., 2005
Simple and intuitive use	Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level	3a. Eliminate unnecessary complexity. 3b. Be consistent with user expectations and intuition. 3c. Accommodate a wide range of literacy and language skills. 3d. Arrange information consistent with its importance.	*"To reduce the amount of background noise that was present in the original video files, the volume of the video files were muted and voice over narrations were added"* Van Laarhoven et al., 2009 *"The task step was considered a success if the participant placed the correct item in the right bin with the help of game feedback within 3 s[seconds]"* *"Incorrect items were highlighted in red on the screen, whereas misplaced items were highlighted in yellow."*

		3e. Provide effective prompting and feedback during and after task completion.	Chang et al., 2014
Perceptible information	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities	4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information. 4b. Provide adequate contrast between essential information and its surroundings. 4c. Maximize "legibility" of essential information. 4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions). 4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.	*"Portable electronic AT has been used successfully to increase the independent completion of employment-related tasks among those with ID via the use of video rehearsal, feedback, pictures, or audio instructions"* Collins et al., 2014 *"The VSM videos also included…signalling, by adding arrows to focus on essential parts of the video"* Goh & Bambara, 2013 *"All buttons were the same color (silver) and a piece of masking tape was placed on the "pause" but ton to help students visually discriminate between the buttons"* Mechling & Stephens, 2009
Tolerance for error	The design minimizes hazards and the adverse	5a. Arrange elements to minimize hazards and errors: most used	*"The game-based intervention…issued an audio cue and displayed an error when a step was performed incorrectly"*

	consequences of accidental or unintended actions	elements, most accessible; hazardous elements eliminated, isolated, or shielded. 5b. Provide warnings of hazards and errors. 5c. Provide fail safe features. 5d. Discourage unconscious action in tasks that require vigilance.	Chang et al., 2014 *"The ARCoach system issued an audio cue and displayed an error when a step was performed Incorrectly"* Chang et al., 2013
Low physical/cognitive effort	The design can be used efficiently and comfortably and with a minimum of fatigue	6a. Allow user to maintain a neutral body position. 6b. Use reasonable operating forces. 6c. Minimize repetitive actions. 6d. Minimize sustained physical effort.	*"Mouse click action will be intercepted as soon as the mouse is clicked, the cursor will jump to the target center automatically, and then the intercepted mouse click action will be sent out"* Shih et al., 2010 (Shih, Shih, & Chiu, 2010) *"Therefore, the function of this mouse was only to transfer their right hand swing into rapid cursor movements amongst the pre-defined targets, instead of using the standard cursor movement"* Shih et al., 2010 (Shih, Shih, Wu, 2010)

Size, and space	Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility	7a. Provide a clear line of sight to important elements for any seated or standing user. 7b. Make reach to all components comfortable for any seated or standing user. 7c. Accommodate variations in hand and grip size. 7d. Provide adequate space for the use of assistive devices or personal assistance.	NR*

*NR: Nothing Reported