Helping people with multiple disabilities manage an assembly task and mobility via technology-regulated sequence cues and contingent stimulation

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Abstract

Purpose: This study evaluated the impact of a technology-aided program providing sequence/space cues and contingent stimulation on object assembling and mobility for eight participants with multiple disabilities. Method: The technology-aided program was introduced according to a non-concurrent multiple baseline design across participants. Pipe components were distributed over different desks. The program served to (a) guide the participants to collect and assemble those components in the right sequence via verbal or light cues automatically emitted by electronic boxes, and (b) deliver preferred stimulation as the participants

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put away a completed pipe. Results: The participants increased the mean frequencies of pipes assembled and put away accurately and independently from (virtually) zero during the baseline to between about 6 and 14 per 15-min session during the technology-aided program. This performance was maintained at a follow-up check. Twenty-four staff members surveyed about the program provided favorable ratings of it. Conclusions: These data indicate that the program may be an effective tool for supporting people like the participants of this study.

Keywords: Multiple disabilities; Technology; Assembly task; Mobility; Blindness; Deafness.

1. Introduction

People with severe and profound intellectual or multiple (i.e., intellectual and sensory or sensory-motor) disabilities tend to have serious occupational problems (Maes, Vos, & Penne, 2010; Duttlinger, Ayres, Bevill-Davis, & Douglas, 2013; Channon, 2014). They may fail to manage multistep activities relevant within their daily context due to poor response skills and/or memory deficits (Furniss, Lancioni, Rocha, Cunha, Seedhouse, Morato *et al.*, 2001; Mechling, 2007; Lancioni, Singh, O'Reilly, Sigafoos, Alberti, Boccasini *et al.*, 2015a). They may also show limited engagement motivation (i.e., limited interest in manipulating objects and using them for functional responses), and problems with spatial orientation and with transition from one response/place to the next (Schmit, Alper, Raschke, & Ryndak, 2000; Sterling-Turner & Jordan, 2007; Lancioni, Singh, O'Reilly, Sigafoos, Alberti, Perilli *et al*., 2014; Lancioni *et al*., 2015a).

Without supervision, many of these people are mainly passive and sedentary, thus displaying a condition that decreases their attention to the environment, hinders their social image, and is detrimental for their general health (Lancioni Singh, O'Reilly, & Sigafoos, 2009; Lanovaz, 2011; Warburton & Bredin, 2016). Providing these people with regular staff supervision might be practically challenging in most daily contexts, in which staff time resources are limited, and also undesirable for the people' social image. In fact, extensive supervision would emphasize the people's overall dependence and lack of self-determination (McDougall, Evans, & Baldwin, 2010; Curryer, Stancliffe, & Dew, 2015; Dean, Dunn, & Tomchek, 2015).

One way to tackle this difficult situation is to resort to the use of assistive technology (Lancioni *et al.*, 2014; Lancioni, Singh, O'Reilly, Sigafoos, Boccasini, La Martire *et al.*, 2016). The potential of assistive technology is increasingly recognized and technology-aided intervention programs have been reported for individuals with a wide spectrum of disabilities (Leopold, Lourie, Petras, & Elias, 2015; Mihailidis, Melonis, Keyfitz, Lanning, Van Vuuren, & Bodine, 2016). Programs aimed at promoting activity engagement in people with severe, profound or multiple disabilities have included, among others, picture and video instructions for the activity steps or spatial cues for indicating the activity areas as well as preferred stimulation (Furniss *et al.*, 2001; Cannella-Malone, Sabielny, Jimenez, Page, Miller, & Miller, 2015; Lancioni, Singh, O'Reilly, Sigafoos, Alberti, Boccasini *et al.*, 2015b). For example, Lancioni, O'Reilly, Seedhouse, Furniss and Cunha (2000) used a computer device with a single key that six adults with severe intellectual disability were to press to see picture instructions. Only one instruction was visible at a time. Occasionally, the device showed the picture of a preferred event (i.e., to motivate the participants' performance) rather than the instruction for an activity step. All six participants improved their activity performance with the use of the device.

Cannella-Malone, Fleming, Chung, Wheeler, Basbagill and Singh (2011) used a computer-aided system for presenting video clips of activity steps to seven children who were diagnosed with moderate to severe intellectual disability and autism spectrum disorder. During the intervention phase, the children were shown one instruction (video clip) at a time and had 30 s for carrying out the related activity step. Data showed that six of the seven participants had a clear performance improvement.

Lancioni and colleagues (Lancioni, Singh, O'Reilly, Green, Oliva, & Campodonico, 2013; Lancioni *et al*., 2014) devised a technology-aided program to help five participants with multiple disabilities engage in an assembly task and mobility. The participants, who could not benefit from picture or video instructions, were guided to a series of desks through electronic boxes emitting sound or light cues. At each desk, they were to take a specific component of the object to assemble and eventually they were to put away the object completed. In connection with the last response step, the technology ensured an automatic delivery of preferred stimulation and then started a new sequence. Data showed that all participants benefited from the technology-aided intervention.

The results obtained by Lancioni and colleagues (2013; 2014) may be relevant because they showed the possibility of designing a technology-aided program to (a) support constructive activity engagement with people for whom no obvious technology-aided solution exists and (b) promote mobility (i.e., walking across a series of desks) as part of the participants' activity situation. Mobility might be viewed as beneficial for these people who tend to be largely sedentary (Cavalieri, Straker, Gucciardi, Gardiner, & Hill, 2016; Lloyd, 2016). A problem with the afore mentioned results is that they are based on only five participants. Such a problem precludes general statements about the technology-aided program used and its overall applicability and calls for new research efforts in the area to gain extra evidence and clarify possible questions (Kazdin, 2011).

This study was one such research effort and included eight new participants who presented with moderate to severe/profound intellectual disability and sensory or sensory-motor impairments. Each of these participants was to assemble a five-component water pipe and put away each completed/assembled pipe. The pipe components were distributed over five separate desks that the participants could reach using verbal or light cues emitted by electronic boxes such as those mentioned above. Each pipe assembled was to be deposited at a sixth desk where the participants received preferred stimulation. At the end of the stimulation, the box of the first desk was automatically activated and a new response sequence started. The study also included a follow-up check and a brief staff survey.

2. Method

2.1. Participants

Table 1 reports the participants' pseudonyms, ages, levels of intellectual disability and sensory or sensory-motor impairments. The participants attended rehabilitation and care centers for persons with multiple disabilities and represented a convenience sample (Pedhazur & Schmelkin, 1991). Five of the participants were blind. Two of them (Dionne and Paula) also had leg impairments, and one of the two (Dionne) required ambulation support. The other three participants presented with deafness (Agnes was also affected by moderate leg impairment), but possessed functional vision and could successfully use visual cues to reach target areas within their environment. The psychological services of the centers that the participants attended had estimated their levels of intellectual disability to be moderate (Dionne) or to vary between moderate/severe and severe/profound (all others), but no formal testing had been carried out given their general conditions. The Vineland age equivalences for daily living skills were slightly above 4 years for Agnes and Nancy and about or below 3 years for the other participants (Sparrow, Cicchetti, & Balla, 2005).

Table 1 - *Participants' age, levels of Intellectual Disability (ID), and sensory or sensory-motor impairments*

Participants (pseudonyms)	Age (years)	ID	Sensory or Sensory-Motor Impairments
Lynn	57	Severe/profound	Total blindness
Dionne	36	Moderate	Total blindness and leg spasticity with need of physical support for ambulation
Francis	30	Severe/profound	Total blindness

Mat	19	Severe/profound	Total blindness
Paula	54	Severe	Total blindness and leg diplegia with no need of physical support for ambulation
Eddy	34	Severe	Functional vision with severe hearing loss
Agnes	56	Moderate/Severe	Functional vision with severe hearing loss and moderate leg impairment, but no need of physical support for ambulation
Nancy	65	Moderate/Severe	Functional vision with severe hearing loss

The participants possessed basic self-help skills and were able to carry out simple activities, such as assembling simple objects (i.e., with the object components presented individually to them) and transporting objects to different places (i.e., with auditory or visual orientation cues used to guide them). For Dionne, a rail or other means of physical support were also needed. Staff personnel and families viewed the participants' involvement in object assembling and mobility via a technology-aided programs an important objective to pursue (i.e., with relevant implications for the participants' occupational and social status). The participants could not sign a consent form for the study, thus their legal representatives had signed on their behalf. The study complied with the 1964 Helsinki declaration and its later amendments and was approved by a relevant Ethics Committee.

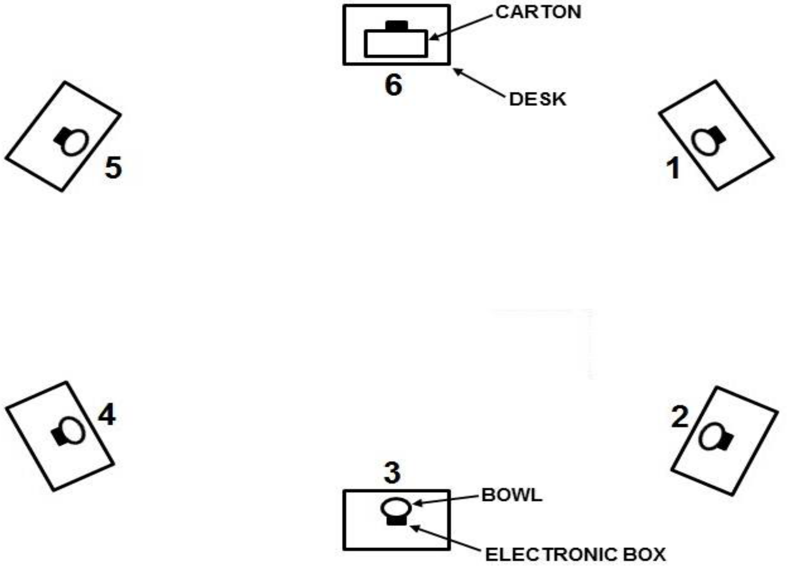
2.2. Setting, Sessions, Research Assistants and Data Recording

The study was carried out in the centers that the participants attended. Sessions were set to last 15 min, but they did not end until the participant had completed and put away the pipe that he or she had started to assemble before the 15-min limit. Three research assistants experienced in using technology-aided programs for persons with multiple disabilities, and specifically prepared to implement the experimental conditions of this study, were in charge of the sessions (i.e., of setting up the technology, using guidance, and recording the data). Data recording concerned the number of correct pipe responses per session (i.e., number of pipes assembled and put away accurately and independently of any prompting from the research assistant; see below). Inter rater agreement was assessed in about 20% of the sessions. Agreement required that the research assistant and a reliability observer involved in data recording reported matching numbers (which could also be zero). Agreement was reported in over 95% of the sessions for all participants.

2.3. Material, Technology and Stimuli

The material for the water pipe assembly task included a series of six desks, five bowls, multiple exemplars of each component of the water pipe, and a large carton. The desks, whose sides measured about 1 m, were at distances of 1 to 3 m from one another (i.e., based on participants' characteristics) and were arranged in a circular format (see Figure 1). The first desk contained a bowl with multiple exemplars of the first component of the water pipe. The participants were to take one of these exemplars. The second desk contained a bowl with multiple exemplars of the second component of the water pipe. The participants were to take one of these exemplars and connect it to the previous one. Each of the following three desks had exemplars of an additional component that was to be connected to the previous ones. The sixth desk had a carton in which the pipe assembled was to be deposited.

Figure 1 - *Schematic representation of the six desks used for the sessions, distributed as indicated by the numerals, with the electronic boxes, bowls, and carton*



The technology used during the intervention and follow-up sessions included six electronic boxes with optic sensors available at the six desks and a remote control device, which was radio linked to the boxes. Each of the first five boxes used for the participants affected by blindness had the following functions: (a) emitting one - or two - word verbal cues at intervals of 7 s, and (b) detecting the participant's arrival and providing verbal feedback (e.g., "arrived") about it. The time interval between the participant's arrival at a desk and the activation of the box of the next was adjustable (e.g., 3-9 s). The sixth box differed from the previous in that it (a) detected the participant depositing the assembled pipe into the carton, and (b) activated 20s of preferred stimulation contingent on that. After this stimulation period, the box at the first desk was automatically activated and a new response sequence began unless the 15-min session time had elapsed. The desks used for Dionne were connected via wooden bars, which allowed her to support herself while moving from one desk to another. The boxes used for the last three participants emitted visual cues (i.e., stroboscopic lights with one flash per second) rather than verbal cues.

The stimuli used contingent on the participants depositing assembled pipes into the carton included (a) music, comedy sketches, and recorded praising messages from family and other relevant persons (for the first five participants), (b) videos and/or light displays (for Agnes and Nancy) and (c) a food item such as cereal of chip (for Eddy). The stimuli were delivered automatically via the sixth electronic box or devices connected to it (i.e., screen, fiber lights or a small food dispenser). The stimuli had been selected according to a stimulus preference screening procedure. Two or three 10-s segments of each song, video, light display, and message, as well as each food item had been presented non-consecutively for at least 15 times. A stimulus was selected if the research assistant and staff in charge of the screening agreed that it produced positive reactions (i.e., alerting, smiling, or rapid consumption) in over 60% of the presentations.

2.4. Experimental Conditions and Data Analysis

The study was carried out according to a non-concurrent multiple baseline design across participants (Barlow, Nock, & Hersen, 2009). The participants received three to seven baseline sessions, which were followed by 91-110 intervention sessions. A 2 - or 4 - month follow-up check and a brief staff survey were also available. Individual baseline and intervention data were summarized/graphed as mean frequencies of correct pipe responses per session over blocks of sessions, and analyzed via the "percentage of non overlapping data" (PND) method (Parker, Vannest, & Davis, 2011; Scruggs & Mastropieri, 2013).

2.4.1. Baseline

During the baseline phase, the desks were aligned, touching one another, so that participants (particularly those with blindness) could walk along with a reduced risk of spatial disorientation. Each of the first five desks contained a bowl with exemplars of one component of the water pipe. The last desk contained the carton in which each assembled pipe was to be deposited. During the session, the research assistant provided verbal and physical prompting if the participant did not make any progress for more than 1 min. At the end of the sessions, the research assistant presented the participant with verbal or physical expressions of approval, and could add brief music or visual stimulation or an edible item.

2.4.2. Intervention

The desks were arranged in a circle and contained the bowls with water pipe components or the carton, and the electronic boxes, which worked as described in the *Material, Technology and Stimuli* section. Verbal and physical prompting from the research assistant occurred if the participant did not progress through the response sequence successfully. Prior to the start of the intervention, six to eight practice sessions were scheduled, during which the research assistant provided the participants with the prompting they needed to correctly manage the response sequence.

2.4.3. Follow-up check

This check was carried out with all participants except Mat and Eddy who were not available for it. After the intervention phase, the participants continued to have sessions such as those used during the intervention. Six or eight of those sessions taking place about 2 months (i.e., Paula, Agnes and Nancy) or 4 months (i.e., Lynn, Dionne and Francis) after the intervention served as the follow-up check.

2.4.4. Staff survey

Twenty-four rehabilitation and care staff aged 27-48 years answered a four-question survey regarding the suitability, effectiveness, and practicality/acceptability of the program (see Tab. 2). Three staff people were selected for each of the eight participants based on their familiarity with that participant and the program sessions carried out with him or her. They answered the survey in light of that participant's performance and their work context. Each staff received a survey form that was to be completed and returned anonymously. For each of the four survey questions, staff could provide scores of 1 to 5, which represented least and most positive values, respectively.

Table 2 - *Staff survey's questions*

1. Do you think that the participant is comfortable during the program sessions?
2. Do you think that the participant can benefit from the program sessions?
3. Do you think that the program is practical/simple to use?
4. Do you think that other staff can accept/support this program?

3. Results

The five panels of Figure 2 report the baseline and intervention frequencies of correct pipe responses (i.e., of pipes assembled and put away accurately and independently) for Lynn, Dionne, Francis, Mat and Paula, that is, the participants with blindness. The three panels of Figure 3 report the baseline and intervention frequencies of correct pipe responses for Eddy, Agnes and Nancy. Each bar represents the mean frequencies of correct pipe responses per session over a block of sessions. The number of sessions included in each block is indicated by the numeral above it.

During the baseline, the participants' mean frequencies of correct pipe responses per session were zero or virtually zero. During the intervention (which followed the six to eight introductory sessions and spread over periods of 3-5 months), those mean frequencies increased to between about 6 (Paula) and 14 (Nancy) per session. The differences in mean frequencies simply reflected the participants' performance speed. In fact, all participants were highly accurate and independent in their responding, and prompting from the research assistants was totally negligible. Comparisons of the baseline and intervention's session response frequencies, according to the PND method, showed indices of 1.0 for all participants, that is, all their intervention session frequencies exceeded their baseline levels. Moreover, the participants' intervention frequencies showed general stability over time.

Figure 2 - *Baseline and intervention frequencies of correct pipe responses for the participants with blindness*

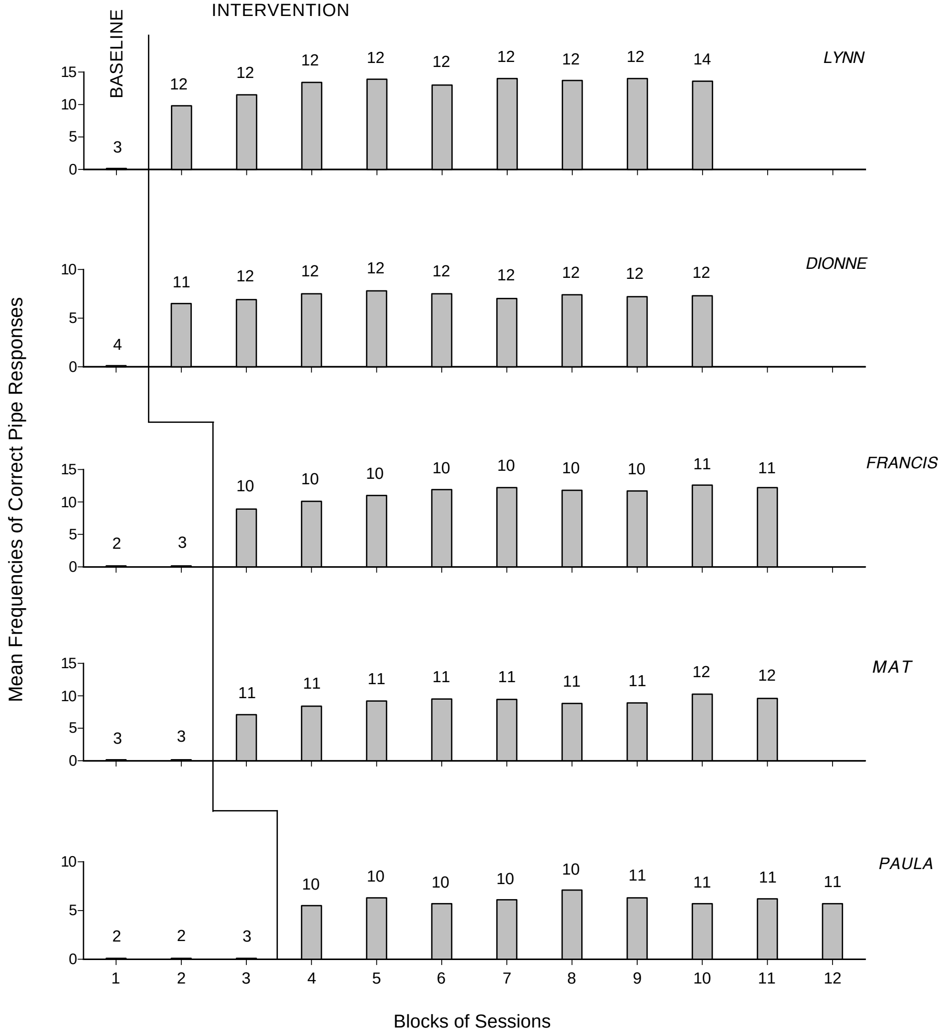
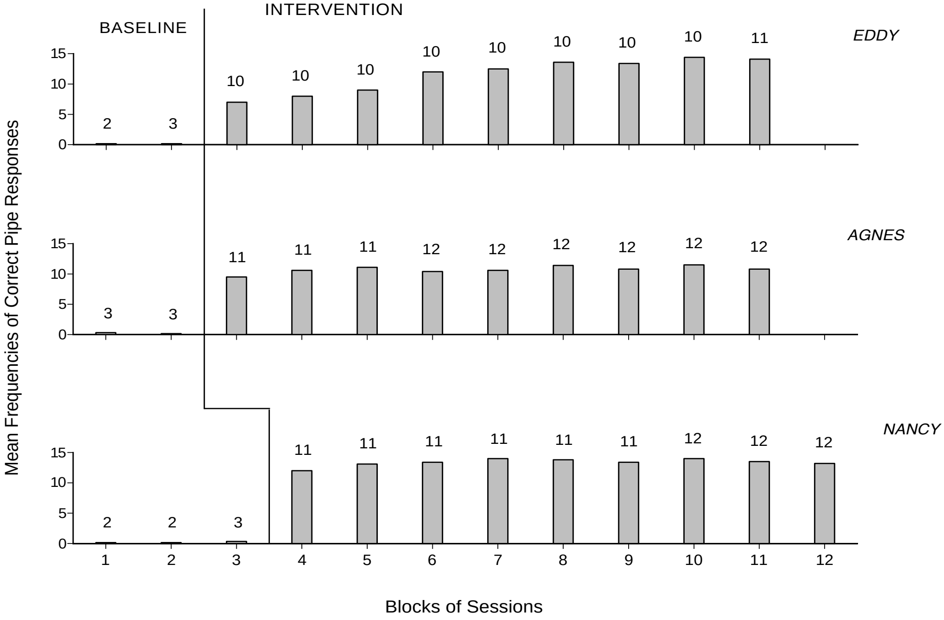


Figure 3 - *Baseline and intervention frequencies of correct pipe responses for participants with deafness*



The follow-up data (not reported in Figures 2 and 3) showed continuity with the intervention data for all six participants exposed to the follow-up check. The staff survey's mean scores varied from 3.6 (fourth question) to 4.0 (second question), indicating a favorable staff opinion about the program.

4. Discussion

The technology and procedural conditions used in the study supported the participants' (a) successful engagement in an assembly task, which also involved mobility (i.e., a dimension presumably relevant for their physical wellbeing), and (b) maintenance of the positive engagement over the follow-up period (Pierce & Cheney, 2008; Kohn, Belza, Petrescu-Prahova, & Miyawaki, 2016; Taylor, Taylor, Gamboa, Vlaev, & Darzi, 2016). These results and the outcome of the staff survey extend previous evidence in the area (Lancioni *et al.*, 2013; 2014) and appear encouraging as to the possibility of developing technology-aided programs for individuals with multiple disabilities who tend to be left behind in the absence of practical intervention solutions (Van der Putten & Vlaskamp, 2011). In light of the above, a number of considerations may be put forward.

First, the technology-aided program applied in this study relied mainly on two automatically regulated components, that is, cues to guide the participants from one desk to the next (i.e., to complete and restart the response sequences) and preferred stimulation after the last step of each sequence. One could easily argue that the cues were essential for the participants with total blindness, given their spatial orientation problems. It might be similarly reasonable to claim that the cues were important or the participants with functional vision as well (albeit no data are available to support this claim). In fact, the cues guided these participants to focus their feeble attention on one specific desk at a time, and to restart the sequence correctly after every stimulation period thus avoiding breaks in performance, drifting problems, and sequence errors (Lancioni *et al.*, 2014). Future research will need to investigate this point directly and determine the role of the cues over time.

There can be little doubt as to the role that the stimulation played in motivating the participants' response performance and possibly in making the cues salient events (Pierce & Cheney, 2008; Catania, 2012; Chang, Chang, & Shih, 2016). Evidence of a lasting saliency of the cues and enduring power of the stimulation events was noticeable in the consistent responding observed during the intervention phase and the follow-up period. This responding could be taken to indicate a substantial satisfaction of the participants with the program and their involvement in the sessions (Sunderland, Catalano, & Kendall, 2009; Harr, Dunn, & Price, 2011).

Second, arranging an activity situation that also involves mobility (physical exercise), as in this study, may be viewed as desirable. In fact, people with multiple disabilities are known to have lower levels of physical exercise and higher levels of health complaints than their typical counterparts (Bartlo & Klein, 2011; Queralt, Vicente-Ortiz, & Molina-Garcia, 2016; Dixon-Ibarra, Driver, Vanderbom, & Humphries, 2017). Consequently, an increase in physical exercise is strongly advocated for these people as a way to improve their health condition, while maintaining their opportunities of constructively using their time, enhancing positive environmental input, and boosting their social image (Ayres, Mechling, & Sansosti, 2013; Hill, Gardiner, Cavalheri, Jenkins, & Healy, 2015; Kohn *et al.*, 2016).

Third, the effectiveness of the technology in promoting positive results may need to be analyzed in light of its cost and the possibility of arranging simpler, cheaper versions of it. The cost of the present technology may be estimated at about 2500 US dollars. This cost might be seen as (a) reasonable if one thinks that the same technology can be used for several individuals and, possibly, across a variety of tasks, and (b) problematic if one thinks that not all care and rehabilitation contexts or wok settings may be able to afford substantial economical investments (Dahlin & Rydén, 2011; Wallace, 2011). A cheaper version of the technology might need to be assessed with the use of a smartphone at the participant's waist and small commercial sound or light boxes combined with frequency-code labels at the desks (Ricci, Miglino, Alberti, Perilli, & Lancioni, 2017).

Fourth, the fairly positive scores obtained in the staff survey seem to emphasize the overall suitability and effectiveness of the program as well as its perceived practicality and acceptability (Callahan, Henson, & Cowan 2008; Lancioni *et al*., 2014). Favorable staff ratings could be considered an essential endorsement of the program and an encouraging signal for the potential, future adoption of the program within daily contexts managed by regular staff personnel (Luiselli, Bass, & Whitcomb, 2010; Lenker, Harris, Taugher, & Smith, 2013).

Fifth, several limitations of the study may need to be mentioned here. One limitation is the small number of participants included. New research with additional participants and possible upgrades of the technology would be required to progress in this area (Kazdin, 2011; Makel & Plucker, 2014). A second limitation is the absence of a direct investigation of the program's plausible generalization effects across settings and tasks (Pierce & Cheney, 2008). Another apparent limitation of the study is the lack of reliability checks on the research assistants' procedural fidelity (Ledford & Gast, 2014). With regard to this point, the assumption was that the experience and preliminary preparation of the research assistants could guarantee their performance fidelity.

In conclusion, the study showed that people with multiple disabilities successfully engaged in relevant activity and mobility through a technology-aided program that staff personnel seemingly endorsed. Notwithstanding these positive results, the limitations of the study listed above recommend caution in drawing general conclusions. New research would need to address those limitations and collect new evidence as to the potential of the program, its usability and possible implications within daily contexts. Other points for new research could concern an extended social validation assessment of the program, an analysis of the program components, and an upgrading of the technology (Callahan *et al*., 2008; O'Rourke, Ekins, Timmins, Timmins, Long, & Coyle, 2014; Ricci *et al*., 2017).

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