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Original Research

A New Technology System to Support Occupational Activity and Mobility in People with Severe-to-Profound Intellectual Disability and Blindness

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Abstract

People with severe-to-profound intellectual disability and blindness tend to be sedentary and detached, given their orientation and mobility problems, often combined with their limited interest in their surroundings. An approach to address this problem may involve the use of technology systems guiding the participants through mobility and occupational activity (object use) with a combination of spatial/orientation cues, basic instructions for the responses required by the activity, and positive stimulation during the activity. This study extended the above-mentioned approach using a new technology system that entailed a barcode reader, a series of barcodes, a smartphone, mini speakers, and a special application controlling the presentation of orientation cues and response instructions. Six participants were involved in the study. They were (a) guided (through orientation cues and instructions) to take objects from three different desks in a large room and deposit those objects into the carton of a fourth desk available in the same room, and (b) provided with a brief period of preferred stimulation for each object deposited in the carton. The results showed that the participants were generally unable to collect, transport, and deposit objects during the baseline phase (i.e., when the technology system was unavailable). During the intervention phase (with the support of the technology system), they managed to collect, transport, and deposit a mean of about 10 to 18 objects per session. Sessions lasted about 25 minutes. These results suggest that the technology system might be a valuable resource to help people with severe-to-profound intellectual disabilities and blindness manage mobility and occupational activity.

Keywords

Technology system; intellectual disability; blindness; occupational activity; mobility

1. Introduction

People with severe-to-profound intellectual disability and blindness tend to be sedentary and detached, given their orientation and mobility problems often combined with their limited interest in their surroundings [1-7]. This condition can lead to a low level of ambulation and physical exercise. It can also force any possible activity engagement (objects use) to occur within a small environmental space such as a desk or room corner. Efforts to modify this situation and help people combine mobility (physical exercise) and forms of occupational activity that have the potential of becoming vocationally relevant (e.g., transporting and putting away objects) might be based on two different types of approaches. One approach might involve an increased level of staff supervision and guidance to ensure that people would manage to move to other places and use objects across those places (thus countering the risk of being confined to a small desk or room corner [8-11]). While apparently simple and possibly effective, this approach (a) may be expensive to apply in terms of staff time, and (b) may extend people's dependence on staff rather than promoting forms of self-determination and autonomy [12-15].

A different type of approach might involve the employment of technology systems guiding the participants through mobility and activity with a combination of spatial/orientation cues, basic instructions for the responses required for the activity (e.g., taking/collecting objects and putting objects away), and positive stimulation during the activity to motivate and consolidate their engagement over time [1, 16-22]. This latter approach aims to promote people's mobility and activity engagement independent of staff support and foster their self-determination with expectedly positive implications for their rehabilitation, occupational opportunities, and social image [9, 10, 15, 17, 22].

For example, Lancioni et al. [23] set up a program based on the use of (a) a smartphone with Android operating system, which was equipped with MacroDroid and Philips Hue applications, (b) Philips Hue indoor motion sensors, and (c) Bluetooth mini speakers. The program was to help participants with severe or severe-to-profound intellectual disability and visual impairment to collect objects from three different desks distributed within a large room, transport those objects to a central desk, and deposit them on that desk. At the start of each session, the participants were presented with verbal orientation cues from the mini speaker available on one of the desks.

The participants were to walk to that desk. Their arrival at the desk (detected by the motion sensor available in front of it) led the desk's mini speaker to emit verbal praise and the request to take an object. Subsequently, verbal/orientation cues were emitted from the mini speaker on the central desk. When the participants arrived at this desk and were detected by the motion sensor in front of it, the same mini speaker provided verbal praise, the instruction to deposit/put away the object, and 15 s of preferred stimulation. Following the end of the stimulation, the participants received verbal/orientation cues from one of the three desks from which they were to collect objects and the procedure described above was repeated for this second object and the other objects that the participants were to collect, transport and deposit at the central desk. The results showed that the seven participants involved in the study were successful in their mobility and object use independent of staff.

Lancioni et al. [24] assessed extensions of the program mentioned above, in which the motion sensors were replaced with more practical and easier-to-use webcams. The webcams detected the participants' arrival at the desks and triggered the occurrence of instructions, orientation cues, and stimulation as described above. The results obtained with two groups of four participants were positive, confirming that technology-aided programs involving verbal orientation cues, verbal instructions, and preferred stimulation may help people with intellectual and visual disabilities to engage in activity and mobility independent of staff support.

While the results of the two studies just summarized [23, 24] are encouraging, some questions may be raised about the technology systems used, particularly about the motion sensors and the webcams. The motion sensors are relatively complex devices, and, in addition, they are susceptible to being accidentally activated by other people sharing the activity context with the participants (i.e., other people who may be walking in the proximity of those sensors). The webcams are comparatively simple and thus allow one to overcome the complexity of the motion sensors [24, 25]. However, like the motion sensors, they are susceptible to being accidentally activated by people other than the participants who walk in the context. The purpose of the present study was to extend the technology-aided research line described above with the use of a technology system that was designed to avoid the weakness of the sensors used in the previous studies. The new system entailed a barcode reader, a series of barcodes marking the different desks where objects were to be collected or deposited, a smartphone, mini speakers, and a special application that controlled the presentation of orientation cues and response instructions. The study involved six participants and used a single-case research methodology.

2. Materials and Methods

2.1 Participants

The six participants, who are listed in Table 1 with their pseudonyms, were adults of 27 to 57 years of age with a diagnosis of intellectual disability and blindness. They attended rehabilitation and care centers and represented a convenience sample [26]. Their Vineland age equivalents for daily living skills (personal subdomain) measured on the second edition of the Vineland Adaptive Behavior Scales [27, 28] ranged from 2 years and 1 month to 3 years and 6 months (see Table 1). No IQ scores were available for them. The psychological services of the centers that they attended had classified their level of intellectual disability to be within the severe-to-profound range.

Table 1 Participants' chronological age and Vineland age equivalents for Daily Living Skills (Personal sub-domain).

Participants (pseudonyms)	Chronological Age (years)	Vineland age equivalents [1] (years, months)
Richard	42	3, 2
Travis	43	2, 2
Kathy	57	3, 10
Paul	34	3, 4
Daisy	27	2, 9
Lynn	28	3, 6

[1] Age equivalents are based on the Italian standardization of the Vineland scales [27].

The participants' inclusion in the study was based on several conditions, which had been previously documented through direct observations or staff interviews. First, they had serious difficulties orienting and moving within their daily context and, when no staff support was available, they tended to be sedentary. Second, they could follow auditory/verbal cues and use them as spatial orientation means to reach different areas of a large room. Third, they responded to simple verbal instructions concerning taking and putting away objects. Fourth, they were interested in environmental stimulation such as music and verbal praise. Hence, the assumption was that this type of stimulation could be used to motivate their mobility and activity engagement. Fifth, staff and caregivers supported using a technology system to facilitate the participants' independent mobility and activity.

2.2 Ethical Approval and Informed Consent

The general view of staff and caregivers was that the participants' involvement in the study would be a positive experience for them. They would have the opportunity to practice mobility and occupational activity, both considered beneficial forms of engagement. They could also access multiple occasions of preferred stimulation during the study sessions. Given the participants' low level of functioning, no specific effort was made to get their consent to be involved in the study. Indeed, obtaining a reliable answer from them was considered extremely difficult. The participants' legal representatives, who were called to act on the participants' behalf, recognized the beneficial aspects of the study and signed a formal consent authorizing the participants' involvement. The study was approved by the Ethics Committee of the Lega del Filo D'Oro, Osimo, Italy (P030820242). All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

2.3 Setting, Responses, Sessions, Research Assistants, and Musical Stimulation

The study was carried out in the rehabilitation and care centers that the participants attended. Specifically, a large room (at least 5 m × 5 m) of each center was used for the baseline and intervention sessions. The room was equipped with four different desks. Each of the first three desks contained a basket with six daily objects, which could change across sessions. The fourth desk contained a large carton where the participants were to deposit the objects that they collected from the first three desks (see Figure 1).

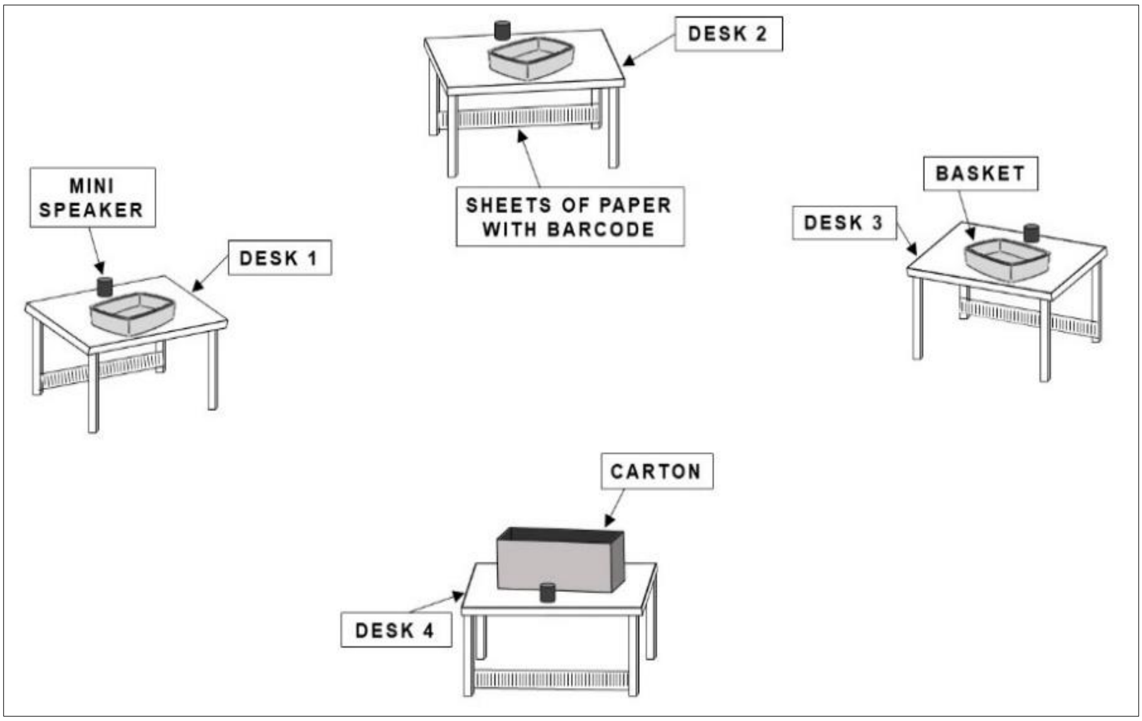

Figure 1 Schematic representation of (a) the first three desks with baskets, (b) the fourth desk with a carton, (c) the sheets of paper with specific barcodes, and (d) the mini speakers.

The responses consisted of collecting objects from the first three desks and depositing them in the carton on the fourth desk. The sessions were scheduled to last until the participants had collected and put away all the 18 objects available in the first three desks or a 25-minute period had elapsed (provided that any response started before the 25-minute limit had been completed). Sessions could be interrupted before the 25-minute time limit if participants required repeated research assistants' guidance (see below). There were one or two sessions per day, 4 to 6 days a week. Three research assistants were responsible for implementing the sessions and recording the data. The research assistants held a university degree in psychology and were experienced in working with people with extensive disabilities, implementing technology-aided programs, and recording data.

A stimulus preference screening procedure selected the musical stimuli (i.e., songs and tunes) to be delivered during the sessions. In practice, three brief segments of each song or tune recommended by staff were presented at least 10 nonconsecutive times (i.e., over different screening periods). Songs and tunes were selected if the research assistants and staff involved in the screening agreed that their segments produced a positive reaction (e.g., orienting and smiling) in at least 50% of the presentations [24].

2.4 Technology System

The technology system entailed (a) a barcode reader, (b) four barcodes marking the different desks where objects were to be collected or deposited, (c) a smartphone operating on Android and fitted with the MacroDroid application plus a special application serving to control the presentation of orientation cues and response instructions, and (d) four Bluetooth mini speakers. The barcode reader was a commercial device (NETUM Bluetooth 2D Barcode Scanner available via Amazon) fixed at the participants' ankles, was on continuous scanning mode, and worked in connection with the smartphone. The barcodes were produced through a free online barcode generator (https://barcorcode.tec-it.com) and printed on A-4 (29.7 × 21.0 cm) sheets of paper. Several A-4 sheets of paper with reproductions of one specific barcode were attached to the legs of each desk (see Figure 1). Each of the four mini speakers was on one of the four desks. The special application, which is freely available (https://osf.io/pgb23/?view_only=6be9eafdc61d4613adad0368bf02f0bb), was developed via Reactive Native Framework. The cues, instructions, and stimulation emitted by the smartphone (which was remote) were delivered to the participants by the mini speakers available on the desks.

At the start of a session, the mini speaker of one of the first three desks (i.e., with objects to be collected) started to present verbal orientation cues (see Figure 2). Those cues consisted of one- or two-word utterances (e.g., the name of the participant alone or combined with another word or two words such as "Over here"), which were emitted at intervals of 5-7 s. When the participant reached the intended desk, the barcode reader detected the barcode on the paper sheets attached to the desk legs. This led the speaker on the desk to present verbal praise followed by the instruction to take an object. About 3 s after the instruction, the mini speaker available on the fourth desk (i.e., the desk with the carton into which the objects collected were to be deposited) started to present verbal orientation cues. When the participant reached this desk, and the barcode reader detected the corresponding barcode on the paper sheets, the mini speaker presented verbal praise followed by the instruction to put the object in the carton. About 3 s after this instruction the mini speaker presented 15 s of preferred musical stimulation. At the end of this stimulation, the mini speaker of one of the first three desks started to present orientation cues. The process for collecting a new object, bringing it to the carton of the fourth desk, and receiving stimulation was the same as that described above. The same procedure was followed throughout the session for the other objects.

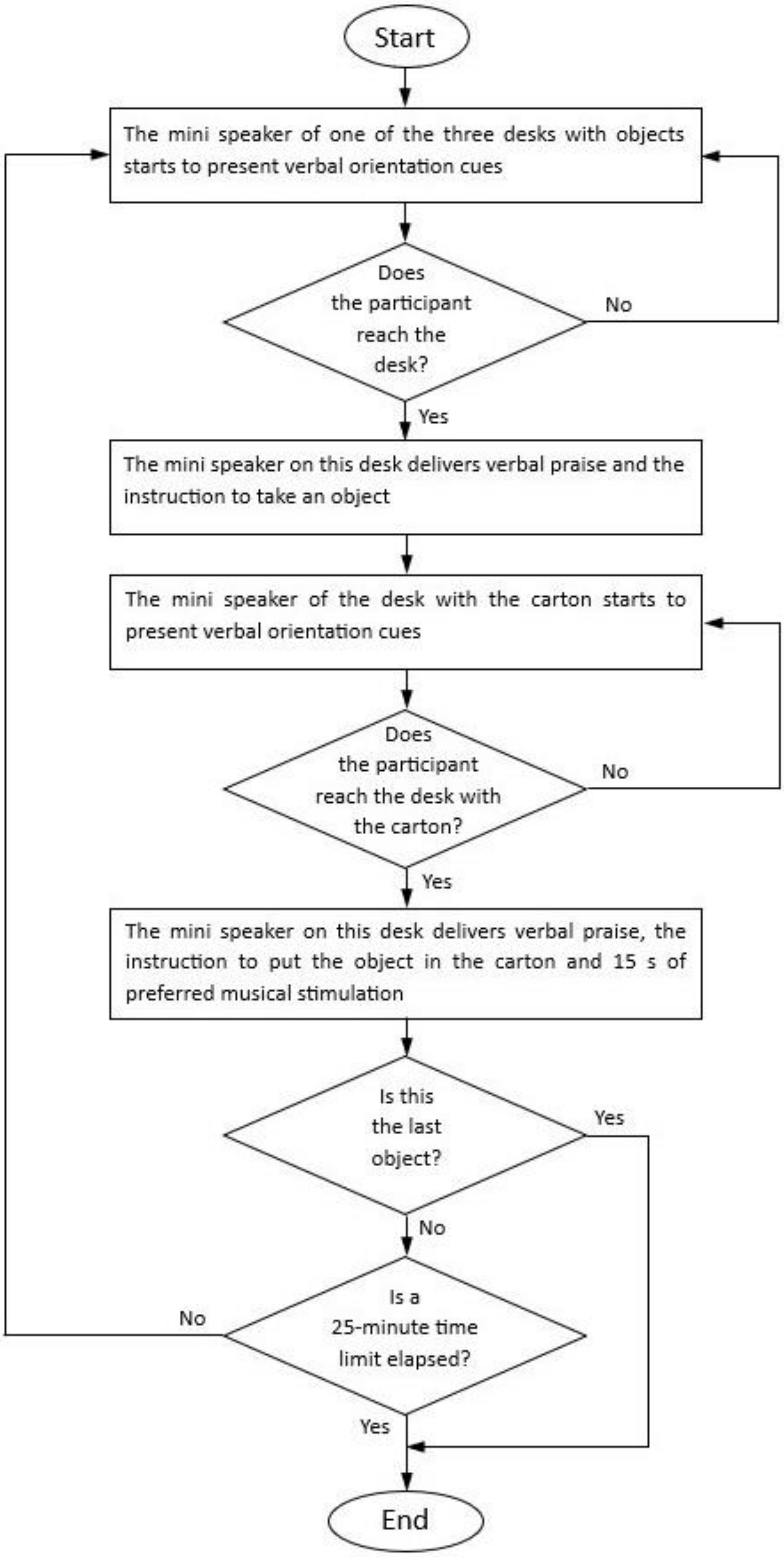

Figure 2 Flowchart summarizing the technology system's functioning.

2.5 Experimental Conditions and Data Analysis

A nonconcurrent multiple baseline design across participants was used to assess the impact of the technology system [29]. The study started with a baseline phase during which the technology system was unavailable. This phase included different numbers of sessions (i.e., between 5 and 9) for the participants, as required by the design. The baseline phase was followed by the intervention phase during which the technology system was available. The intervention phase included 54 to 79 sessions. To guarantee a high level of procedural fidelity [30] in the implementation of the sessions, the research assistants received two forms of support. First, they were supervised during the simulation of a few sessions preceding the start of the study. Second, they were given feedback on their implementation of the study sessions by a study coordinator who had access to videos of those sessions.

The participants' baseline and intervention data were reported in graphic form. The difference between the two data groups was evaluated using the Percentage of Nonoverlapping Data (PND) method [31]. This method, a straightforward tool to assess single-case research data, allows one to determine the percentage of intervention data points that exceed the highest baseline point for each participant.

2.5.1 Baseline

At the start of each baseline session, the research assistants guided the participants through the first three desks, making them touch the objects to be collected and transported. Then, they guided the participants to the fourth desk and made them feel the empty carton. Following this initial environmental recognition, the research assistants instructed/invited the participants to take an object and bring it to the carton. If the participants responded to the instruction, the research assistants provided extensive verbal praise. Then they presented a new instruction to take a new object and bring it to the carton. No real risk existed for the participants to hurt themselves as they walked slowly, and there were no specific obstacles in the area except for the desks that they were to reach and a few other furniture items along the room walls. Even so, the research assistants would always be available in the area to avert any possible danger. If the participants remained passive or did not make any progress in reaching one of the desks with objects for over 30 s, the research assistants guided them to take an object from one of the first three desks, to transport it to the fourth desk, and to put it in the carton available there. Thereafter, the research assistants instructed the participants again to take an object and bring it to the carton. Conditions were as described above. The session continued until the participants had collected, transported, and put away all the 18 objects available, a 25-minute time limit had elapsed, or research assistants' guidance had occurred for four consecutive responses (see the *Setting, Responses, Sessions, Research Assistants, and Musical Stimulation* section). In the last case, a negative score was recorded for the responses completed with research assistants' guidance and the responses not performed due to session interruption.

2.5.2 Intervention

During the intervention sessions, desks and objects were arranged as in the baseline. The fundamental difference was the presence of the technology system that worked as described in the *Technology System* section and summarized in Figure 2. Before starting the intervention sessions, the participants received two or three familiarization/practice sessions with the system. During these sessions, research assistants could provide frequent guidance to (a) facilitate the participants' completion of correct responses following the system's orientation cues and instructions and thus (b) allow them to experience the system's verbal praise and preferred musical stimulation. During the regular intervention sessions, no research assistants' guidance was scheduled to occur unless the participants showed particular difficulties making progress.

2.6 Measures and Data Recording

The measures concerned the number of responses completed correctly and the session duration. During the intervention, a response was completed correctly if the participants (a) reached the desk with objects from which the orientation cues were emanating and collected an object there, (b) followed the orientation cues and reached the fourth desk, and (c) deposited the object transported in the carton of the fourth desk. During the baseline, a response was completed correctly if, following the instruction of the research assistants (take an object and bring it to the carton), the participants reached one of the first three desks, collected an object, transported it to the fourth desk and deposited it in the carton. The research assistants carried out data recording. Interrater agreement on data recording was checked in more than 20% of the sessions of the single participants with the involvement of a reliability observer. The percentage of interrater agreement (computed by dividing the number of sessions in which research assistants and reliability observer reported the same number of correct responses and session durations varying less than 1.5 minutes by the total number of sessions in which interrater agreement was checked and multiplying by 100%) was above 90% for all participants.

3. Results

The six graphs in Figure 3 summarize the baseline and intervention data of the six participants. Data points represent the mean frequency of responses completed correctly per session over blocks of sessions. The blocks (which allowed a simplified graphic presentation of the participants' data) include two sessions during the baseline and three sessions during the intervention. Blocks with a different number of sessions are marked with a numeral that specifies how many sessions they include.

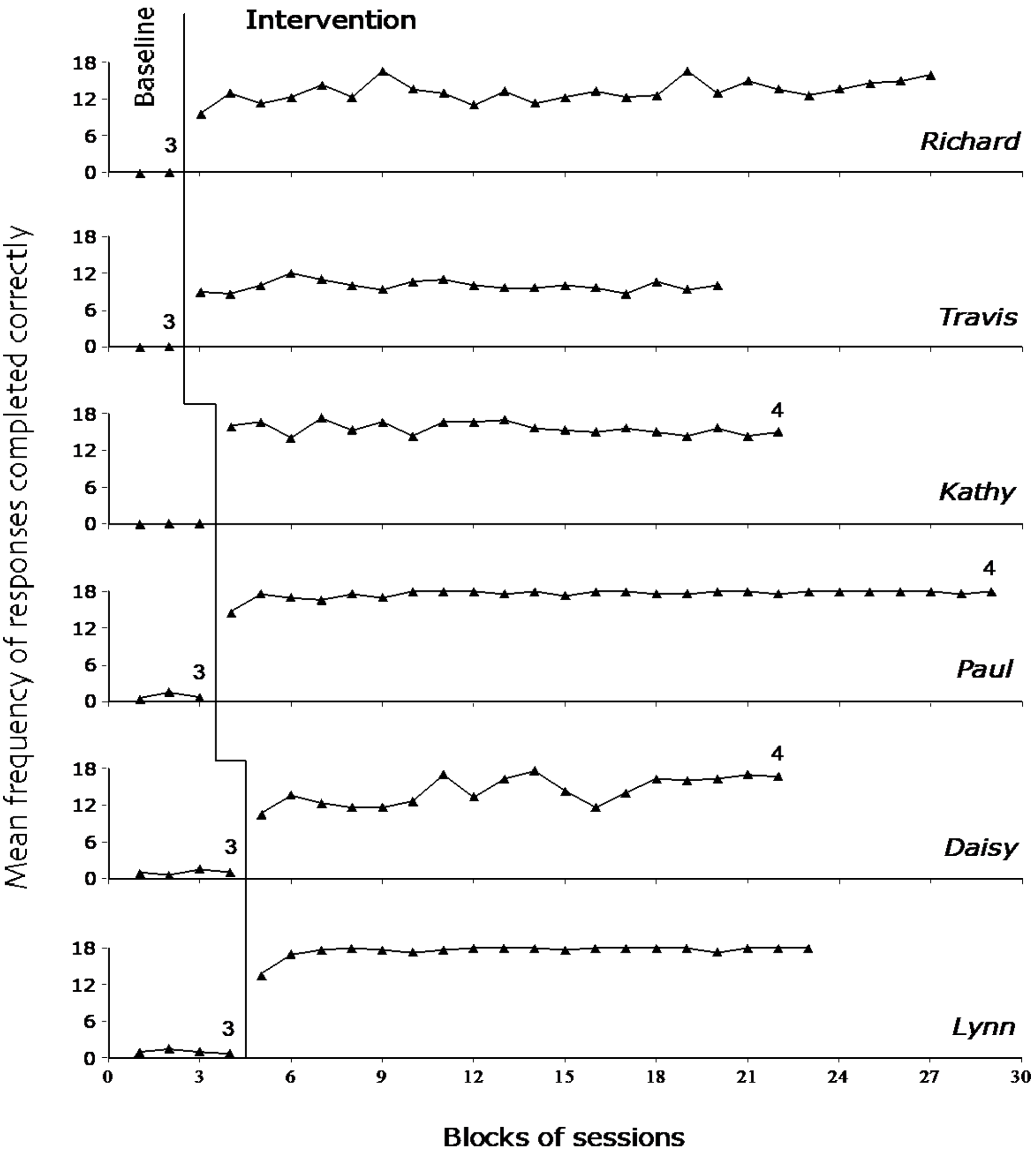

Figure 3 The six graphs report the baseline and intervention data of the six participants. Data points represent the mean frequency of responses completed correctly per session over blocks of two sessions during the baseline and three sessions during the intervention. Blocks with a different number of sessions are marked with a numeral that specifies how many sessions they include.

During the baseline phase, the participants' mean frequency of responses completed correctly per session varied between zero (Richard, Travis, and Kathy) and about 1 (Paul, Daisy, and Lynn). Thus, all sessions were prematurely ended (i.e., after four consecutive responses requiring research assistants' guidance). During the intervention phase, all participants used the technology system profitably and consequently completed responses correctly. The mean frequency of responses completed correctly per session varied from about 10 (Travis) to nearly 18 (Paul and Lynn), with session ranges of 7-13 (Travis) to 16-18 (Lynn). It may be noted that the above-mentioned mean frequency values per session computed over the entire intervention phase (i.e., 10-18) were always within 1 point of the participants' mean frequency values computed over their last 10 sessions of the phase. Research assistants' guidance was (virtually) absent (Travis, Kathy, Paul, and Lynn) or occurred very sporadically (Richard and Daisy).

The increase in the frequency of responses completed correctly was quite immediate (i.e., it was visible from the first intervention session, which followed two or three familiarization/practice sessions with the system). The level of change was significant. The last three baseline sessions presented mean frequencies of responses completed correctly not exceeding 1 for any participants. In comparison, the first three intervention sessions provided mean participants' frequencies varying from 9 to 16. The PND method showed indices of 1 for all participants. There was no overlap between their baseline and intervention response frequencies and all the intervention data points exceeded the highest baseline value. These indices, together with the immediacy and level of the change that occurred during the intervention, can be taken to confirm the strong impact of the technology system.

The intervention sessions were about 25 minutes long for all participants. For Paul and Lynn, the sessions' end mostly coincided with having collected, transported, and put away all the 18 objects available. For the other participants, the sessions ended after the 25-minute time limit (i.e., ensuring that any response started before that limit was completed). The difference in the frequency of responses completed correctly was basically due to participants' performance speed, particularly to the speed with which they moved from one desk to the other.

4. Discussion

The results of this study suggest that the new technology system effectively supported the participants' correct completion of responses involving mobility and object use. More specifically, the results indicate that a technology based on barcodes, a barcode reader, a smartphone, and mini speakers was adequate for guiding the participants through their responses and providing them with praise and preferred musical stimulation. Based on these results, a few considerations may be helpful.

First, the new technology system may be as effective as the technology systems used in previous studies [23, 24] while presenting a specific advantage over those systems. The advantage is that its functioning is not influenced by people other than the participants walking within the context (i.e., contrary to what would happen with previous systems relying on motion sensors or webcams). An additional advantage is that it replaces complex or relatively complex sensors with barcodes reproduced on sheets of paper, which may remain in place between sessions (thus avoiding preparatory work for the sessions). The above-mentioned advantages will likely make the new technology system suitable and acceptable in contexts such as workshops and residential areas (i.e., contexts where this type of technology may offer people with extensive intellectual and visual disabilities fresh occupational opportunities). Research evidence is needed to corroborate this point, which for now can only be taken as a reasonable work perspective.

Second, aside from supporting the effectiveness of the new technology system, the results of this study confirm that people with severe-to-profound intellectual disability and blindness can successfully engage in activities involving mobility and object use if provided with orientation cues, basic response instructions, and positive stimulation contingent on their responses [7, 24, 32-34]. Participants' engagement independent of staff support can be considered (a) valuable for their constructive occupation, their self-determination, and their physical exercise, and (b) practical (affordable) within daily contexts in which staff resources may be limited [35-37]. Moreover, achieving a higher level of independence and a healthier living would be critical for the participants' well-being and quality of life and totally in line with their rights [38-43].

Third, no evidence is available as to the impact (necessity) of all the components that the system included to support the participants' engagement. Yet, one might speculate that the orientation cues were critical to guide the participants in their mobility, ensuring that they would reach the correct destination in an efficient, essentially accurate, and relaxed (not anxious) manner [20, 23, 24, 44]. The instructions were undoubtedly crucial at the start of the study but perhaps were not necessary during its later stages [18]. Even if not required, their presence might still have played a role in alerting the participants and countering possible attention declines, thus limiting the risk of errors. As to the praise at the arrival at the desks and the preferred songs/tunes after putting away the objects, different views could be expressed. On the one hand, it may be argued that both stimulation components could have been trimmed after the initial part of the intervention phase [45, 46]. On the other hand, it could also be argued that the continuing availability of the two components might have (a) increased the participants' motivation to perform the responses and (b) made the sessions a fair and enjoyable occupational period for them, increasing their level of satisfaction [47, 48].

4.1 Limitations and Future Research

The study limitations concern the fact that it did not assess maintenance and generalization of the intervention effects, did not carry out an evaluation of the participants' satisfaction with the intervention sessions, and did not verify the staff's perception of the system. To address the first limitation, new studies must extend the data collection period to determine whether the participants' performance remains stable and robust over time [33, 49]. They would also have to extend the implementation of the sessions to different settings to determine whether the participants would continue to show positive performance across those settings [50, 51]. To address the second limitation, new studies could resort to two possible assessment forms. One such form could concern the recording of the participants' indices of happiness/satisfaction (e.g., smiling) during the sessions and other daily activity situations [52, 53]. The other could concern the arrangement of choice situations where participants could select the sessions or other daily activities [54, 55]. To address the third limitation, new studies could use social validation checks, in which staff and other rehabilitation professionals could be shown videos of the intervention sessions and asked to rate the effectiveness of the system, its friendliness to the participants, and its applicability in daily contexts [56, 57].

Including a relatively small number of participants might be considered another limitation of the study. However, two considerations can be made about this point. First, given the use of a single-subject research design, one could argue that the evidence acquired in the study is sufficient to confirm the internal validity of the data showing the effectiveness of the intervention condition [58, 59]. Second, single-case replication studies and group research studies could represent essential further steps to assess the external validity of the data reported [59, 60].

5. Conclusions

The results suggest that the new technology system, which is more convenient than previous technology systems used in the area, effectively supports the participants' correct completion of responses involving mobility and object use. These results can be highly encouraging and motivate new efforts to improve technology solutions that can support constructive occupational performance and enhance the well-being and quality of life of people with severe and profound intellectual and multiple disabilities. New research efforts would also have to address the limitations of the present study to determine the representativeness of the present findings.

Author Contributions

GL was responsible for setting up the study, acquiring and analyzing the data, and writing the manuscript. GA and CF collaborated in setting up the study and the technology system, contributed in acquiring and analyzing the data, and in editing the manuscript. NS, MO'R, JS, and SB collaborated in setting up the study, analyzing the data, and writing/editing the manuscript.

Competing Interests

The authors declare that they have no conflicts of interest. The special application used during the study is freely available
https://osf.io/pgb23/?view_only=6be9eafdc61d4613adad0368bf02f0bb.

Data Availability Statement

The original data contributions presented in the study are reproduced in the graphs of Figure 3. Datasets are available from the authors on request.

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