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Interactive Technology to Help People with Multiple Disabilities Practice Relevant Physical Responses within an Occupational Task

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Abstract

This study adapted a new interactive technology system to help six participants with intellectual disability and visual and motor impairments to exercise relevant physical responses as part of an occupational task. The task was to place objects into different containers from a sitting position. The responses, which changed across sessions, consisted of the participants (a) stretching the left arm and shoulder to place objects in a container located to their left, (b) stretching the right arm and shoulder to place objects in a container located to their right, or (c) stretching one or both arms and shoulders forward and upward to place objects in a container located high up in front of them. The technology, which entailed a portable computer, a webcam, and a mini speaker, monitored the participants' responses, gave brief periods of preferred stimulation contingent on the responses, provided verbal encouragements/prompts in case of no response, and assisted in data recording. The study was carried out according to a non-concurrent multiple baseline across participants design and included baseline and intervention sessions of 10 min. During the baseline (when the technology system only served to monitor and record the responses), the participants' mean frequency of responses varied between near zero and about 10 per session. During the intervention (when the technology system was fully operational), the participant's mean response frequency increased to between about 29 and 46 per session. In light of the results, one might consider the technology system a useful support tool to help people with multiple disabilities engage in relevant physical responses.

Keywords
Interactive technology; physical activity; intellectual disability; visual impairment; motor impairment; preferred stimulation; encouragement; prompts

1. Introduction

Physical activity is typically considered essential for a healthy life. People with intellectual disability, however, tend to have low levels of physical activity [1-5]. Reduced physical activity may be even more frequent and challenging when intellectual disability is combined with visual and motor impairments [6-8]. Intellectual disability (particularly when severe) may imply that people (a) have no genuine appreciation of the importance of physical activity and the benefits it may produce and, thus, (b) lack any motivation to engage in physical activity, especially when that engagement costs apparent effort [8-11]. Visual and motor impairments may significantly limit people's opportunities to move within the context, interact with other people and objects, and engage in forms of activity that require some physically relevant responses [7, 8, 12-14].

Intervention options to help people with intellectual and multiple disabilities increase their physical activity may involve staff or caregivers' supervision and interactive technologies [8, 15-19]. Staff and caregivers' supervision typically consists of the presentation of verbal and physical prompts to guide the participants through their activity engagement [15, 16]. Interactive technologies entail the use of devices designed to monitor the participants' activity engagement and respond to such engagement with positive feedback (i.e., with preferred stimulation) [17-19].

The use of those technologies may be considered advantageous compared to the use of staff or caregivers' supervision for several reasons. First, the technologies' systematic delivery of positive stimulation during the activity may help motivate participants with no personal interest in physical activity to independently engage in such activity [6-8, 20]. Second, the participants' acquisition of independent engagement would ensure that they exercise and strengthen forms of self-determination, which (a) make them look more mature and advanced in comparison to a situation of dependence on external supervision and (b) prevent them from experiencing stress and anxiety (i.e., conditions that may accompany a situation of strict supervision involving repeated prompting and guidance [7, 21-25]). Third, participants' ability to independently engage in physical activity would make such activity feasible also within daily contexts, where staff time is generally limited [8, 26, 27].

Two main groups of interactive technologies are available. One group relies on the use of brief periods of positive stimulation contingent on the performance of physical responses considered functional/beneficial for the participants [28-33]. The other involves using video games (exergames), in which the participants are called to perform game-related responses and receive extra stimulation for them [34-38]. The first group of technologies is generally used for people with severe and profound intellectual and multiple disabilities. In contrast, the second group of technologies appears particularly suitable for people with mild or moderate intellectual disabilities and/or autism [8, 35, 36, 39].

Research studies using the first group of technologies have primarily focused on promoting a specific/simple physical response (e.g., leg stretching or object manipulation) and have (a) monitored the response through the use of a sensor connected to the participants' body or the material involved in the response and (b) delivered the stimulation through an electronic device (e.g., computer, tablet or smartphone) interfaced with the sensor [19, 31-33, 39]. A recent study has tried to target a complex response (i.e., a response involving a sequence of beneficial body movements), which was part of a familiar and meaningful task for the participants, and to monitor such response from a distance (i.e., without sensors tied to the participants or the material they used [40]). Specifically, the task consisted of placing objects into containers. Each response involved body and legs bending to collect an object from the floor or a low shelf and shoulders and arms/hands stretching to place the object in a container high up in front of the participants. The responses were monitored from a distance via a webcam linked to a portable computer. Every response was followed by preferred stimulation regulated by the computer and delivered via mini speakers in the activity areas. Verbal encouragements/prompts to respond were also delivered in case of no response.

This study was an attempt to adapt the intervention described above to participants who, in addition to intellectual and visual disabilities, had motor impairments that forced them to use a wheelchair or to require physical support for standing and walking briefly. The task was again placing objects into containers but from a sitting position. The response changed across sessions and consisted of the participants producing one of the following movement schemes: (a) stretching the left arm and shoulder to place objects in a container located to their left, (b) stretching the right arm and shoulder to place objects in a container located to their right, or (c) stretching one or both arms and shoulders forward and upward to place objects in a container located high up in front of them. Physiotherapists had recommended these movement schemes because they are considered highly beneficial for the participants and rarely present in their daily routines. The different movement schemes were monitored and followed by brief periods of preferred stimulation through the same technology used by Lancioni et al. [40]. As in that study, the technology also provided verbal encouragements/prompts in case of no response.

2. Materials and Methods

2.1 Participants

Table 1 lists the six participants involved in the study through their pseudonyms and reports their chronological age, visual and motor condition, and Vineland age equivalents for daily living skills (personal sub-domain). The participants represented a convenience sample [41]. Their chronological age ranged from 37 to 46 years. Their Vineland age equivalents measured through the Italian version of the second edition of the Vineland Adaptive Behavior Scales [42, 43] varied between 1 year and 7 months and 3 years and 2 months. Four participants were blind (i.e., Lucas, Parker, Eden, and Henry), while the other two (i.e., Mason and Adam) had minimal residual vision. All of them also had motor impairments. Specifically, three could not walk and used a wheelchair, while the others could walk only briefly and with some physical support (see Table 1). They attended rehabilitation and care centers and were considered by the psychological services of those centers to be in the moderate-to-severe (Eden) or the severe (all others) range of intellectual disability. No IQ scores were available for them.

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

Participants (pseudonyms)	Chronological Age (years)	Visual and Motor Condition	Vineland age equivalents [1, 2] (DLSP)
Lucas	43	Blindness; Ambulation with support	2;4
Mason	45	Minimal residual vision; Ambulation with support	1;8
Parker	44	Blindness; Ambulation with support	2;6
Eden	43	Blindness; Use of wheelchair	2:11
Henry	46	Blindness; Use of wheelchair	1;7
Adam	37	Minimal residual vision; Use of wheelchair	3;2

[1]The age equivalents are based on the Italian standardization of the Vineland scales [42]. [2]The Vineland age equivalents are reported in years (number before the semicolon) and months (number after the semicolon).

They were included in the study in light of the following points. First, they were known to have very low levels of physical activity, and there was a request for an increase in those levels. In particular, physiotherapists had indicated that they would benefit from their exercise of movement schemes involving arm stretching and torso straightening. Second, they were known to enjoy environmental stimulation (e.g., music and songs), and it was thought that such stimulation could be used during the intervention phase of the study to motivate their physical activity engagement. Third, they were reported to show forms of alerting and body activation in relation to verbal prompts. Fourth, staff (a) supported the idea of having the participants involved in a program aimed at helping them increase their physical activity engagement and (b) considered the use of a technology-aided intervention favorably (i.e., a reasonably practical approach that might suit daily contexts).

2.2 Ethical Approval and Informed Consent

The general view of staff and caregivers was that the participants would find their involvement in the study a positive experience, having the opportunity to practice beneficial responses and enjoy preferred stimulation. Notwithstanding this view, the participants' opinion about and consent to the study could not be obtained, given their general condition. For this reason, their legal representatives were involved in reading and signing formal consent documents on their behalf. The study complied with the 1964 Helsinki Declaration and its later amendments and was approved by an institutional Ethics Committee.

2.3 Setting, Sessions, Material, Responses, Stimuli, and Research Assistants

The study was conducted in the rehabilitation and care centers the participants attended (i.e., in quiet areas/rooms of those centers). Baseline and intervention sessions lasted 10 min and were typically scheduled once or twice a day, 3 to 5 days a week. The material for the sessions included a desk and a chair where the participants sat, several sets of objects, and three large containers. At each session, one set of objects and one container were available. The objects were on the desk, while the container could be to the participants' left, to the participants' right, or high up in front of them. The responses consisted of placing the objects displayed on the desk into the container available. Depending on the container's position, a response involved left arm and shoulder stretching, right arm and shoulder stretching, or one or both arms and shoulders forward and upward stretching (with torso straightening). Specifically, the responses involved movement schemes that physiotherapists had recommended for the participants to exercise (see the Participants section).

The stimuli used contingent on the occurrence of the responses during the intervention sessions were selected based on staff recommendation and a stimulus preference screening procedure. This procedure consisted of selecting three segments of each of the stimuli recommended by staff (e.g., three segments of a song) and presenting each segment about 10 non-consecutive times over successive screening periods. The stimuli kept for the study were those that, according to the research assistants carrying out the screening, produced positive reactions (e.g., alerting and smiling) in at least 50% of the presentations. The research assistants were three females with a Master's degree in psychology who had experience in working with people with intellectual and multiple disabilities and in implementing technology-aided intervention programs.

2.4 Technology System

The technology system was similar to that of Lancioni et al. [40] and entailed a portable computer, a webcam, and a mini speaker. The computer was fitted with the Windows 11 operating system and specific software. It included a variety of music (song) stimuli considered to be preferred by the participants based on the aforementioned stimulus preference screening, as well as verbal encouragements/prompts to place an object in the container available (see below). The webcam, linked to the computer, was fixed on a camera tripod to monitor the participants' responses from a distance. The mini speaker was located next to the container available in the session and delivered music stimuli contingent on the responses and verbal encouragements/prompts after preset intervals of no responding. The software employed, which is available to the reader (https://osf.io/vsqf5/?view_only=eba15e5bfb6646ed8d443fa403924958), was developed with Python programming language and based on open-source libraries: OpenCV for image processing and MediaPipe Pose for identifying human body landmarks in 3D space.

Based on the software, the system managed several functions. First, via the webcam, it monitored the position of the participants' arms/hands in relation to the top edge of the container where they were to place the objects available on their desks. When the participants' hands were seen in that area, the system assumed that the participants were performing a response. Second, via the mini speaker, it delivered a 12-s period of preferred stimulation (i.e., music and songs, which could also be combined with recorded verbal praise from staff) contingent on each response. If a new response occurred while the stimulation for the previous response was still on, the system automatically reset, thus starting a new 12-s stimulation period. Third, it gave the participants verbal encouragement/prompts to put an object in the container after a specific period had elapsed without a response (see below). Fourth, it assisted in data recording (see below). All those functions were operative during the intervention sessions. Only the first and the last functions were operative during the baseline sessions.

2.5 Data Recording

Data recording concerned (a) the number of responses performed in total (i.e., the number of times the system spotted the participants' hand(s) on the top edge of the container where they had to place the objects), and (b) the number of those responses that were performed after system's encouragements/prompts. Both measures were recorded automatically via the technology system, and a simple correction was made at the end of the sessions. The correction consisted of subtracting one response from the total (i.e., the response guided by the research assistant at the start of the sessions).

2.6 Experimental Conditions and Data Analysis

The participants were exposed to the intervention (with the technology system) following a non-concurrent multiple baseline across participants designs [44, 45]. In line with the design, the participants had different numbers of baseline sessions before they started the intervention phase. During the intervention phase, the technology system ensured that the participants received preferred stimulation contingent on each response and verbal encouragements/prompts in case of no response. A study supervisor with direct access to the sessions or video recordings of them provided regular feedback to the research assistants about their performance during the sessions. Such feedback was to ensure a high level of procedural fidelity during the study [46]).

The difference between the baseline and the intervention frequencies of responses was assessed through the percentage of non-overlapping data method (PND [47]). This method determined the percentage of intervention data points presenting a response frequency higher than the baseline highest value for each participant.

2.7 Baseline

During the baseline phase, the system was only used to monitor the participants' responses and record their frequency of occurrence. The participants sat at a desk with about 40 objects (e.g., halfa-litre water bottles, or soap and pasta packages) and were to place those objects in the container available. The container could be to the participants' left, to their right, or high up in front of them. Its position changed across sessions (see the Setting, Sessions, Material, Responses, Stimuli, and Research Assistants section). At the start of a session, the participants were guided to place one of the objects in the container available and instructed to place the other objects in the container. The research assistants would (a) repeat the instruction to put objects in the container after intervals of about 2 min of no responding and (b) provide extra objects (i.e., putting them on the desk) if the participants had used all those available before the end of the 10-min session. At the end of the session, the participants were provided with about 30 s of preferred music stimulation.

2.8 Intervention

During the intervention phase, which was preceded by four to six practice sessions, the technology system monitored the participants' responses, delivered 12 s of preferred stimulation contingent on the single responses, recorded their frequency, and provided verbal encouragements/prompts to put objects in the container in case of no responding (see the Technology System section). During the practice sessions, the participants were made to familiarize themselves with the technology system's stimulation for the responses and the technology system's encouragements/prompts to respond. Together with the system's encouragements/prompts, they could also receive verbal or verbal and physical prompts from the research assistants. No research assistants' prompts were available during the intervention sessions that followed. A technology system's encouragement/prompt was delivered 22-24 s after the end of the previous response and was automatically repeated at intervals of 10 s until a new response occurred (see Lancioni et al. [40]). At the start of each session, the research assistants instructed the participants to put objects in the container and guided them to put one object in the container available, as in the baseline. Then, the participants were to perform the responses independently. The container was located to their left, right, or high up in front of them on different sessions. The research assistants would place extra objects on the participants' desk if all those initially available were used before the end of the session.

3. Results

The six graphs in Figure 1 report the baseline and intervention data for the six participants. The black squares represent the mean frequency of responses performed per session over blocks of baseline and intervention sessions. The blocks, which are used to simplify the graphic presentation of the data, include two sessions during the baseline and three sessions during the intervention. Blocks with different numbers of sessions are marked with a numeral specifying the sessions included. The figure does not report the practice sessions used at the start of the intervention phase.

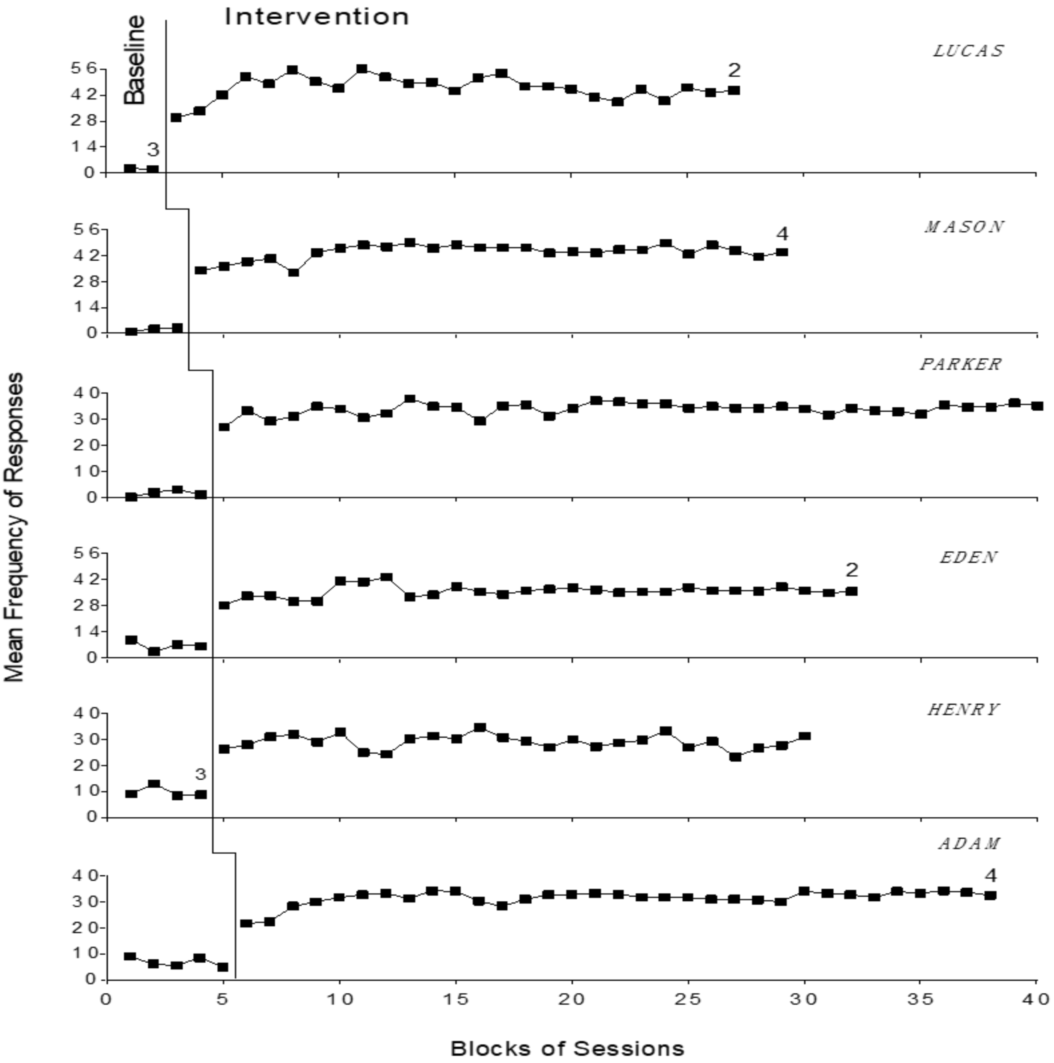

Figure 1 The six graphs report the baseline and intervention data for the six participants. The black squares represent the mean frequency of responses performed per session over blocks of baseline and intervention sessions. The blocks include two sessions during the baseline and three sessions during the intervention. Blocks with different numbers of sessions are marked with a numeral specifying the sessions included. The values on the ordinate axes of the graphs vary across participants.

During the baseline, which included 5 to 10 sessions, the participants' mean frequency of responses varied between near zero (Lucas, Mason, and Parker) and about 10 (Henry) per session. The participants with near-zero responses tended to alternate passivity with manipulation of the objects on the desk and had minimal hand movements outside the desk's boundaries.

During the intervention, which included 74 to 108 sessions, the participants' mean frequency of responses increased to between about 29 (Henry) and 46 (Lucas) per session. The differences in response frequencies were due to the participants' motor/response conditions and stimulation-seeking strategies. Some participants (notably Lucas and Mason) initiated a new response immediately after a stimulation period and, on occasions, produced a new response even before the stimulation ended, thus making the stimulation almost continuous during the session. Other participants (notably Henry and Adam) started to organize a new response a few seconds after the end of the stimulation period. With some initial exceptions, the responses of Lucas, Mason, Parker, and Eden were virtually all independent of system's encouragements/prompts.

On the other hand, Henry and Adam had a mean of nearly 5.5 and 3 responses per session (i.e., about 18.5% and 9% of all the responses) occurring with system's encouragement/prompts. Irrespective of an apparent similarity, the data of these two latter participants reflected different performance patterns. Henry tended to receive encouragement/prompts because he could require extra time executing the responses, and thus, encouragements/prompts typically accompanied and reassured his response performance. Adam tended to receive system's encouragements/prompts because he could get distracted in manipulating and playing with the objects and thus delayed the start of new responses.

The percentage of non-overlapping data method (PND) showed indices of 1 for all participants except Henry, whose index was 0.96. These indices, which indicate that all or all but three of the intervention data points exceeded the highest baseline data point, confirm the strong impact of the intervention with the technology system across all participants.

4. Discussion

4.1 Findings and Implications

The results suggest that all participants managed to increase their physical activity (i.e., their response frequency) during the intervention sessions with the support of the technology system. These results confirm the suitability of interactive technologies to deliver preferred stimulation contingent on functional responses for people with severe intellectual and multiple disabilities [28-33]. The same results also underline the applicability of (a) a non-invasive technology system (i.e., a system that does not require sensors tied to the participants' body or the material they use for their responses) and (b) meaningful tasks as the basis for fostering exercise of relevant movement schemes with non-ambulatory participants, thus extending the recent research evidence obtained with ambulatory participants [40]. In light of the above, several considerations may be made.

First, helping participants increase their physical activity, despite their apparent lack of interest in it (i.e., by using an intervention strategy that fosters their motivation to engage in it), may be viewed as a relevant achievement. The intervention strategy apparently brings the participants to perceive the engagement as a positive experience/event in which their enjoyment of the stimulation available for physical activity prevails over the effort required by the activity [28, 32, 39, 48, 49]. Such perception is probably instrumental to (a) guarantee that the participants will continue to engage in physical activity independent of staff prompts if the stimulation they receive for it is attractive/motivating, (b) improve the participants' physical condition and social appearance, and presumably their quality of life, and (c) help them avoid stress and anxiety (i.e., conditions that could emerge in situations of strict staff supervision/prompts) [9, 39, 40, 48-52].

Second, the participant's ability to engage in physical activity independent of direct staff supervision can have significant implications. Indeed, such ability would modify the general view that physical activity does not attract the attention and interest of participants with severe intellectual and multiple disabilities and also change the public perception that any intervention in the area will be expensive in terms of staff time. Concerning this latter point, one could argue that an intervention approach relying on technology-regulated positive stimulation contingent on relevant physical responses might have clear, practical advantages over an approach relying on staff supervision and thus might be more suitable (affordable) for daily contexts [1, 2, 5, 40, 53].

Third, making the participants exercise relevant movement schemes as part of a meaningful occupational task can benefit the participants and their context. Indeed, the participants would probably find the practice of different stretching movements involving their arms and shoulders outside of a meaningful occupational task difficult to understand and carry out consistently and accurately [2, 54]. Similarly, staff and caregivers (a) could find it more difficult to ask the participants to practice those movements in an abstract context (i.e., outside of a meaningful/familiar occupational frame), and (b) could also consider such practice artificial and thus raise doubts as to its applicability/suitability [6, 55].

Fourth, the use of a technology system that is largely unobtrusive, that works without any physical link with the participants' body or the material they manipulate for their physical activity, may be considered relatively practical (i.e., more fitting than the use of systems relying on sensors fixed on the participants' body or the activity material) [8, 50, 56]. A system that is more practical (more easily applicable) across participants and contexts might have a greater chance of being accepted and used within daily contexts [40, 57]. This would likely offer new opportunities for relevant and independent physical activity to people with multiple disabilities, whose levels of physical engagement and personal initiative are typically low [2, 5, 12, 20].

4.2 Limitations and Future Research

The first limitation of this study concerns the relatively small number of participants included in the evaluation of the technology-aided intervention. This limitation does not allow one to make general statements about the results obtained and their overall implications. New research will need to involve direct and systematic replications of the present study with new participants to determine the robustness of the current findings and their level of generality [58-60]. A second limitation concerns the lack of a specific assessment of the participant's perception of the intervention sessions. Their consistent responding may suggest that (a) they enjoyed the stimulation contingent on such responding and (b) the fairly large amount of stimulation available during those sessions characterized the sessions as a positive context/experience. To test these views, one could record the participants' indices of happiness during those sessions and other daily situations and verify whether the sessions represent a happier, more satisfactory event than the other situations [29, 61].

A third limitation concerns the lack of maintenance and generalization assessment. To amend this limitation, future studies must assess the strength of the participants' responses over more extended periods and across contexts [48, 49]. A fourth limitation concerns the lack of a check to determine the social validity of the technology and intervention in general. New studies may address this issue by interviewing staff working with people with severe intellectual and multiple disabilities (e.g., by showing them intervention sessions with the technology system and asking them to rate its suitability and impact) [62, 63].

5. Conclusions

The study has shown that the technology-aided intervention set up for participants with intellectual, visual, and motor disabilities effectively fostered their physical activity independent of any specific staff supervision. The participants succeeded in exercising relevant physical responses (arms and shoulders stretching instrumental for their performance of a simple occupational task), apparently motivated by the technology-regulated stimulation contingent on their responses. These findings (a) support the evidence obtained with previous technology-aided intervention strategies relying on the use of positive stimulation contingent on the responses to strengthen and (b) add to such evidence in that the technology used in the present study is non-intrusive for the participants (i.e., does not require sensors to be fitted on their body or their activity material). Despite this promising evidence and the potential suitability of this approach for daily contexts, more research would be necessary before any specific conclusion can be drawn. One objective of future research would be to address the limitations of this study. Other objectives would be to (a) find ways of identifying the most adequate forms of activity for people presenting with different types/combinations of disabilities, (b) determine the best dosage of such activity, and (c) define the means whereby the effects of such activity can be measured and quantified.

Author Contributions

GL was responsible for setting up the study, acquiring and analyzing the data, and writing the manuscript. GA, CF, AL and CS collaborated in setting up the study and the technology system, in acquiring and analyzing the data, and in editing the manuscript. NS, MO'R, and JS 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 software they set up for the study is freely available at (https://osf.io/vsqf5/?view_only=eba15e5bfb6646ed8d443fa403924958).

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