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Technology-aided programs to support leisure engagement and basic communication in people with extensive neuro-motor impairment and absence of speech

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Abstract

Objective: The present study was aimed at assessing two new technology-aided programs (one based on an adaptation of an experimental device ["Talking Hands"] and one based on commercial technology) to help individuals with severe neuro-motor and speech disabilities independently manage access to leisure events and basic forms of communication interaction. Methods: The two adult participants were exposed to an $AA^1BA^1B^1CC^1$ design in which A and A^1 represented baseline conditions, B intervention conditions based on the use of the "Talking Hands" technology, B^1 intervention conditions based on the use of tablet technology, C a condition in which B and B^1 were alternated,

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Ethical approval: The study was approved by an institutional ethics committee. All procedures performed during the study 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.

Informed consent: The participants' legal representatives provided written informed consent for the participants' involvement in the study.

and C^1 a condition in which the participants were allowed to choose whether they wanted the use the B or B^1 program conditions. Results: During the baseline conditions (i.e., without the technology-aided programs), the participants showed no independent access to leisure events or communication interactions. During the intervention B and B^1 conditions, they successfully managed to use the different technology-aided programs to access leisure events and start communication interactions. During the C^1 condition, they showed preference for the tablet-based program. Conclusions: The two programs may be effective in supporting basic leisure and communication in people with extensive neuro-motor and speech disabilities.

Keywords: Leisure; Communication; Technology; Neuro-motor impairment; Lack of speech.

1. Introduction

Individuals with extensive neuro-motor impairments and lack of speech due to traumatic brain injury, stroke or other causes can experience very serious limitations in their daily life, with very negative consequences for their occupation, social interaction and quality of life (Brown, Hatton, & Emerson, 2013; D'Amico, Lancioni, Buonocunto, Ricci, & Fiore, 2019; Lancioni, Singh, O'Reilly, Sigafoos, D'Amico, Vincenti *et al.*, 2019; Lancioni, Singh, O'Reilly, Sigafoos, D'Amico, Buonocunto *et al.*, 2020). Given their condition, in fact, they (a) are typically forced to use a wheelchair or stay in bed, (b) have limited skills/opportunities to reach objects and engage in any form of functional activity, and (c) may be unable to successfully call for the caregiver's attention and express needs or desires (Estraneo, Moretta, Loreto, Santoro, & Trojano, 2014; Dang, Chen, He, & Chen, 2017; Teng, Dong, Zhang, An, & Lv, 2017; Hassett, Wong, Sheaves, Daher, Grady, Egan *et al.*, 2018; Lancioni, O'Reilly, Sigafoos, D'Amico, Spica, Buonocunto *et al.*, 2021). They may also show signs of detachment and apparent unhappiness often reported as forms of depression (Unglik, Bungener, Delgadillo, Salachas, Pradat, Bruneteau *et al.*, 2018; Ferro & Santos, 2019; Kapoor, Lanctot, Bayley, Hermann, Murray, & Swartz, 2019).

While there is consensus about the need for intervention to improve the individuals' situation, common intervention strategies available in daily contexts (e.g., physiotherapy and speech and language therapy) may have marginal effects on the aforementioned problems (Carvalho, Azevedo, Marques, Dias, & Cerqueira, 2018; Palmer, Witts, & Chater, 2018; Palmer, Dimairo, Cooper, Enderby, Brady, Bowen *et al.*, 2019; Wilson, Martins, Efrosman, DiSabatino, Benbrahim, & Patterson, 2019). During recent years, efforts have been made to develop technology-aided programs aimed at offering individuals the opportunity to independently access preferred leisure events (e.g., music) and also to start interaction/communication events (e.g., call the caregiver or send messages to relevant people not present in the immediate context) (Brunner, Hemsley, Togher, & Palmer, 2017; D'Amico *et al.*, 2019; Fager, Fried-Oken, Jakobs, & Beukelman, 2019; Lancioni *et al.*, 2019; 2020; Stasolla, Caffò, Bottiroli, & Ciarmoli, 2022). For example, Lancioni and colleagues (2019) used a smartphone and cards representing leisure and communication options, which were fitted with frequency-coded identification tags legible by the smartphone (Irani, Gunasekaran, & Dwivedi, 2010). Holding those cards against the back of the smartphone allowed the individuals to independently (a) access leisure

events (e.g., music and comedy sketches) and (b) send text messages to communication partners (e.g., family members) or call the caregiver. Lancioni and colleagues (2020) assessed a more advanced program that relied on a smartphone and a tablet, which worked in combination. The smartphone presented verbally the main options (i.e., music/videos, messages, and caregiver) or the alternatives available within the option chosen in groups of three, and the participants could select the first, second or third option/alternative by activating the proximity sensor of the smartphone once, twice or three times. The smartphone would verbalize the participant's choices and these verbalizations triggered the tablet to present music and videos, to send messages or to call the caregiver (i.e., in accordance with the verbalizations).

Both programs were reported to be largely successful in helping the participants engage in leisure and basic forms of communication interaction. Notwithstanding their positive impact, the aforementioned programs might not represent a satisfactory or suitable solution for individuals with relatively limited hand movements/control, relatively low level of functioning, and/or limited social connections. In fact, individuals with limited hand movements/control may have serious problems in manipulating cards and/or operating their choices through specific numbers of sensor activations (e.g., of smartphone' proximity sensor activations). Individuals with limited functioning skills or reduced social connections outside their immediate context might have limited interest in interacting with (e.g., sending messages to) possibly relevant people living outside that context. In light of these considerations, it might be argued that new types of programs may be required to support individuals with reduced abilities or interests like the ones just mentioned.

The present study was aimed at assessing two new programs (one based on an adapted experimental device previously developed for other populations ["Talking Hands"; Pezzuoli, Tafaro, Pane, Corona, & Corradini, 2020] and one based on commercial technology) to help those individuals manage access to leisure events and basic forms of communication interaction. Two participants were involved in the study. Each participant was asked to use both programs so as to determine the effectiveness of those programs and the participants' preference between programs.

2. Method

2.1. Participants

The participants were a man and a woman (Jimmy and Ellen, pseudonyms) of 62 and 48 years of age. Jimmy had suffered post-anoxia damage of the left fronto-temporal-parietal area of the brain and this damage was aggravated by subsequent hemorrhage. Ellen had suffered extended brain damage following a traumatic event. The aforementioned types of brain damage had occurred about 10 and 15 years prior to the beginning of this study. Both participants presented with extensive motor impairment. They were in a wheelchair and their hand and arm movements were also reduced, curtailing any chances to manipulate objects. They did not possess speech skills. Jimmy tried to express himself with general sounds accompanied by general hand gestures that mainly signaled agreement/disagreement or happiness/unhappiness. Ellen could produce some basic vocalizations and could also use general gestures and finger movements to signal specific meanings. Both participants were able to understand and respond appropriately (e.g., with eye, hand or head movements) to simple questions concerning them, their family, or daily events. Their general condition was considered to be between the sixth and seventh level (Ellen) or upper end of the seventh level (Jimmy) of cognitive functioning as described on the Levels of Cognitive Functioning scale revised (Hagen, 1998). Both participants attended a rehabilitation and care center, in which they were provided with conventional treatments, such as physiotherapy, speech and language therapy, and occupational therapy.

The participants (a) were known to enjoy leisure events such as those available in the program (e.g., watching music, sport, and recipe/cooking videos) and were dependent on others to access those events, (b) were interested in starting some basic form of communication interaction with caregivers (occasionally calling distant partners), and (c) seemed willing to use the technology systems at the basis of the programs (i.e., after demonstrations of the technology systems' functioning). Given the participants' inability to sign a consent form for the study, their legal representatives were provided with details about the study and asked to sign that form on their behalf. The study complied with the 1964 Helsinki declaration and its later amendments and had been approved by an institutional ethics committee.

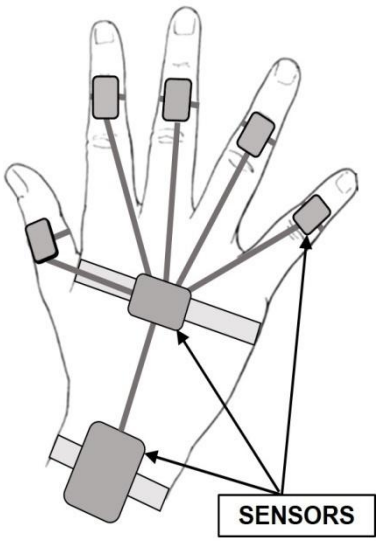
2.2. Setting, sessions, and research assistant

Quiet areas of the center that the participants attended served as setting for the study. The participants were sitting in their wheelchair, which was fitted with a tray. Sessions were conducted on an individual basis, typically once or twice a day, 2 to 4 days a week. Baseline and intervention sessions were scheduled to last 20 min except during the baseline (A^1) phases (see below). Any leisure or communication event started within the 20-min limit was to be completed with an extension of the session length. The research assistant, who was responsible for implementing the sessions and recording part of the data, had experience in the treatment of individuals with intellectual and multiple disabilities (including motor and communication disabilities) and in the use of technology-aided interventions.

2.3. Technology for the first program

The technology system used for this program was a simplified version of the Talking Hands (Pezzuoli *et al.*, 2020). The system involves series/combinations of sensors linked via Bluetooth to a smartphone. The sensors (including an accelerometer, a gyroscope and a magnetometer) were fixed on the fingers, the back and the wrist of one hand (see Fig. 1). The smartphone (i.e., a Samsung Galaxy with Android operating system) was (a) provided with Google account and Google assistant, and (b) fitted with specific software, WhatsApp Messenger, and the MacroDroid application. MacroDroid allowed programming of the smartphone's functioning. The sensors allowed the smartphone to determine the position and orientation of the fingers, hand and arm. Based on such position and orientation, the smartphone recognized the participants' requests/choices included in the program and responded to them appropriately. The intervention sessions, which started with the participants wearing the system's sensors, were set up in different ways for the two participants (i.e. in line with their response style and motor skills).

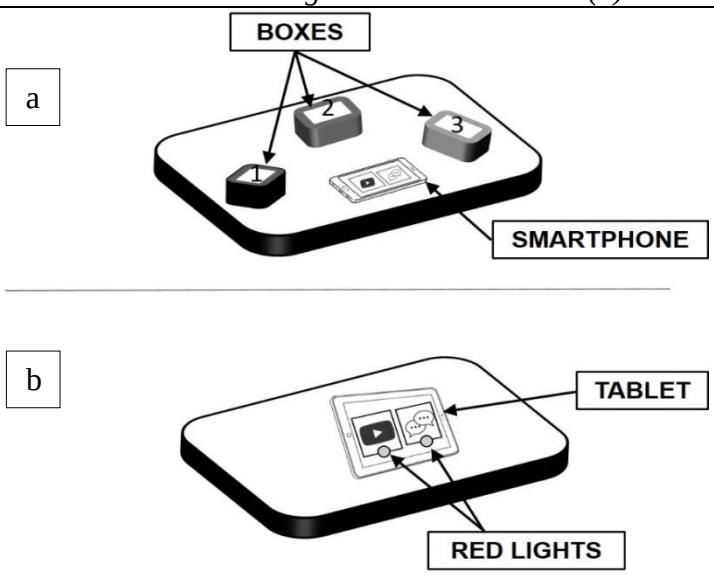
Figure 1 – *Talking Hands technology with sensors fixed on the fingers, the back of the hand, and the wrist*



Jimmy had the smartphone and three little boxes on the wheelchair's tray, one to the left [box 1], one just in front [box 2], and one to the right [box 3] (see the upper section of Figure 2). At the start of a session, the smartphone verbalized: "If you want to see videos touch box 1, if you want to talk to staff or make a call touch box 2". Icons for the two offers also appeared on the smartphone's screen. If Jimmy touched box 1, the smartphone presented three options (e.g., "You can watch BOLLE [box 1], BOCELLI [box 2], QUEEN [box 3]"). Depending on the box touched, Jimmy would see on the smartphone's screen a video with BOLLE dancing or BOCELLI or QUEEN singing. If Jimmy chose to talk to staff or make a call [box 2], the smartphone would present options such as "You can call your sister/friend [box 1], you can ask to hear a joke [box 2], or you can ask something else [box 3]". Depending on the choice, a video call was made to his sister/friend, or a staff/caregiver (informed by the system) intervened to present a joke or investigate what Jimmy wanted to ask and provide an answer to that. The smartphone would verbalize a new offer of seeing videos and talking with staff or making a video call immediately after a previous leisure event or video call had ended or after about 1.5 min from the choice of one of the staff talking options. The offers were regularly repeated until Jimmy made a new choice. The leisure videos available for choice changed

across different choice occasions. The same occurred for the person to call (i.e., sister and friend).

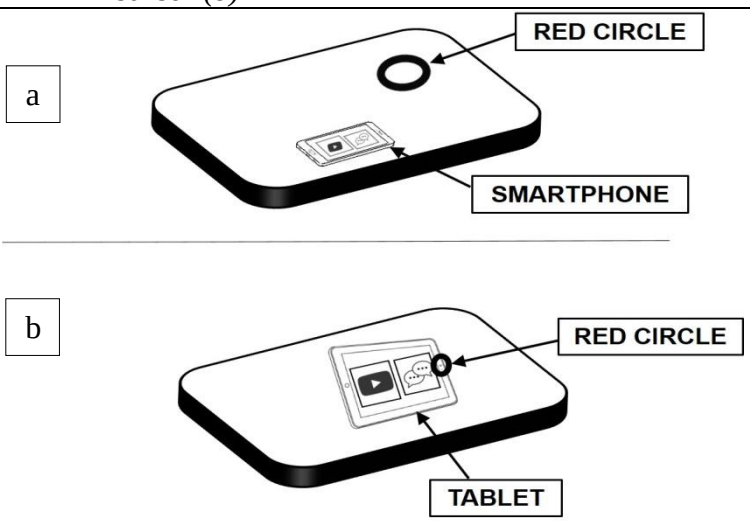
Figure 2 (a-b) – *Jimmy's wheelchair tray with the three boxes and smartphone with icons for leisure videos and communication on its screen (a). Tablet with the same icons and red lights under those icons (b)*



For Ellen, there were no boxes. Instead a red circle was placed on her wheelchair's tray, in front of her. Starting a session led the smartphone to verbalize: "If you want to see videos touch the red circle" and (after 5 s) "If you want to talk to staff touch the red circle." Icons for the two choice areas/offers also appeared on the smartphone's screen (see the upper section of Fig. 3). If Ellen touched the red circle in relation to the first offer, the smartphone would verbalize (using the same phraseology as above), at intervals of about 5 s from one another, the three options available (e.g., kitchen recipes, a preferred singer, and a preferred music festival). If Ellen touched the red circle in relation to one of these three options, the smartphone showed a video of one of the various alternatives available for such option (e.g., of one of the recipes or one of the preferred songs of the preferred singer). If Ellen touched the red circle in relation to the second offer, the smartphone verbalized (and showed icons for) the different options, which could be: "What time is it?", "What is the plan for the day?" or "I want to know something else." No video calls were planned for Ellen,

as she did not have an interest for them. All other conditions were as for Jimmy. The leisure videos used for the two participants typically lasted between about 2 and 4 min.

Figure 3 (a-b) – *Ellen's wheelchair's tray with the red circle and the smartphone with icons for leisure videos and communication on its screen (a). Tablet with the same icons and a red circle surrounding the tablet's proximity sensor (b)*



2.4. Technology for the second program

The technology for this program involved a Samsung Galaxy tablet with Android operating system, WhatsApp Messenger and the MacroDroid application, which allowed programming of the tablet's functioning. For Jimmy, the tablet presented the first two choice areas (i.e., videos and talking with staff or making a call) using the same phraseology and icons as in the previous program with a red light underneath the icons. In this case, Jimmy was asked to select one area or the other by touching the related red light (see lower section of Figure 2). Once the choice was made, the tablet presented the three options available for that area. Again, Jimmy was to make his choice by touching the red light below the option he wanted. Choices led to the same consequences as in the previous program. For Ellen, conditions were as in the previous program, except that the choice response consisted of touching a red circle on the tablet (i.e., a red circle surrounding

the tablet's proximity sensor; see lower section of Figure 3) rather than the red circle on the tray.

2.5. Experimental conditions

The study was divided into seven phases according to an $AA^1BA^1B^1CC^1$ sequence. The A (baseline) phase was aimed at determining how many leisure events were independently accessed and communication interactions started by the participants during sessions mirroring their typical daily conditions. The A^1 (baseline) phases were aimed at determining whether the participants could use a smartphone and a tablet to independently access leisure events and start forms of communication interaction. The B was an intervention phase focused on the introduction and use of the program based on the Talking Hands technology. The B^1 was an intervention phase focused on the introduction and use of the program based on the tablet technology. The C phase served to alternate the use of the two programs. The C^1 phase served to make the participants choose which program they wanted to use at the start of each session. The end of the C^1 phase was followed by three weekly follow-up checks. The A phase was longer for Ellen than for Jimmy, according to a multiple baseline across participants design (Barlow, Nock, & Hersen, 2009). During all sessions, the participants sat in their wheelchair fitted with a tray (see *Setting, Sessions, and Research Assistant*). To ensure procedural fidelity (Ledford & Gast, 2014), a study coordinator with access to video recordings of the sessions provided the research assistant with regular feedback on her performance.

2.5.1. Baseline (A) phase

The A phase included three and five 20-min sessions for Jimmy and Ellen, respectively. During those sessions, no technology was available, so they illustrated the typical participants' condition.

2.5.2. Baseline (A^1) phases

The two A^1 phases included two sessions and one session, respectively. Each session included four trials. At each trial, the research assistant told the participants that they could use the smartphone or the tablet on their wheelchair's tray to access videos with music and other preferred options (e.g., dance and food recipes) and call the caregiver. The smartphone and tablet's screen showed the YouTube and WhatsApp icons. If the participants did not manage to operate either device within 10-20 s, the research assistant

did it for them, so they could access a preferred event (e.g., a song) and avoid frustration and failure.

2.5.3. Intervention (B) phase

This phase was introduced by two practice sessions, in which the participants were helped by the research assistant to make leisure or communication choices and thus access leisure events or communication interactions through the use of the Talking Hands technology. Subsequently, the participants received 11 and 9 regular 20-min sessions, respectively. In these sessions, the participants did not receive any guidance. Yet, the research assistant could provide a general encouragement or approval.

2.5.4. Intervention (B^1) phase

This phase was identical to the B phase except that the participants were to use the tablet-based program.

2.5.5. Intervention (C) phase

This phase included four sessions with two of the sessions identical to those used in the B phase and the other two identical to those carried out in the B^1 phase. The B and B^1 sessions were alternated.

2.5.6. Choice (C^1) phase

Each session started with a research assistant showing the participants the two technology systems (i.e., the Talking Hands and the tablet) and asking them to choose (point out/indicate) the one they wanted to use for the session. Then, the system chosen was made available for the session, in which conditions were as in the B and B^1 phases.

2.5.7. Follow-up checks

Three follow-up checks were carried out 1, 2, and 3 weeks after the end of the C^1 phase. Each check included one or two sessions with the system that the participants had chosen more often during the C^1 phase. Conditions were as in the B and B^1 phases.

2.6. Measures

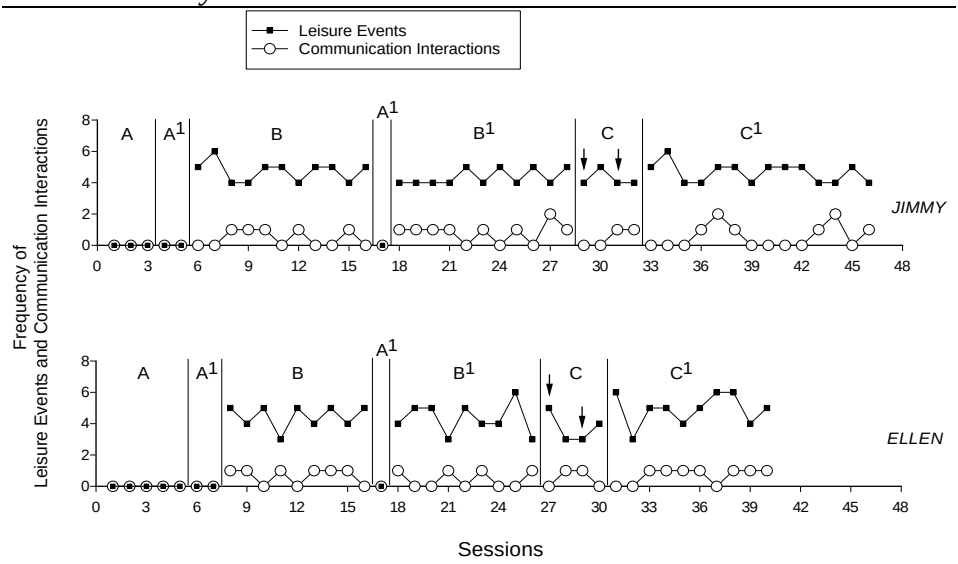
The measures recorded during the study were the number of leisure events accessed and communication interactions started independently (a) without any support during the baseline (A and A^1) phases, and (b) through

the use of the technology systems available during the other phases of the study and the follow-up checks. During the C^1 phase, the choice responses (i.e., selection of the system to use for the sessions) were also recorded. Recording of leisure and communication events was carried out (a) by the research assistant and a reliability observer watching videos of the sessions (i.e., during the A and A^1 phases) and (b) by the systems (i.e., the MacroDroid application, which allowed the recording of the sessions' data through the system log) during all other phases of the study including the follow-up checks. Recording of choice responses (i.e., during the C^1 phase) was conducted by the research assistant and a reliability observer using videos of the sessions). Interrater agreement for the recording of the leisure and communication events during the A and A^1 phases was computed by dividing the number of sessions in which the research assistant and the reliability observer reported the same events by the total number of sessions and multiplying by 100%. The same formula was used for the recording of the choice responses. Percentages of agreement of 100 were reported for the leisure and communication events as well as the choice responses of each participant.

3. Results

The participants' data across the different phases of the study are reported in the two graphs of Figure 4. The black squares and circles represent the frequency of leisure events independently accessed and the number of communication interactions independently started per session, respectively. The arrows appearing in the C phase mark the sessions carried out with the Talking Hands technology, thus discriminating those sessions from those carried out with the use of the tablet. During the first baseline (A) phase, Jimmy and Ellen did not manage to independently access any leisure events and did not start communication interactions. Similarly, during the A^1 phases (i.e., one following the A phase and one following the B phase), neither participant was able to use the smartphone or tablet. So, neither participant managed to independently access leisure events or start communication interactions.

Figure 4 – *Data across the different phases of the study ($AA^1BA^1B^1CC^1$) for Jimmy and Ellen*



The black squares and circles represent the frequency of leisure events independently accessed and the number of communication interactions independently started per session, respectively. The arrows appearing in the C phase mark the sessions carried out with the Talking Hands technology, thus discriminating those sessions from those carried out with the use of the tablet.

During the B phase, both participants were able to use the program based on the Talking Hands technology. Jimmy managed to independently access a mean of about 4.5 leisure events per session and to start a mean of about one communication interaction every two sessions. Ellen independently accessed a mean of about 4.5 leisure events per session and a mean of two communication interactions every three sessions. During the B^1 phase, both participants were able to use the tablet-based program effectively and managed leisure and communication interaction frequencies on the whole comparable to those of the B phase. During the C phase, the participants showed similar performance with the two programs. During the C^1 phase, both participants consistently chose the tablet-based program so all the sessions appearing in the figure during that phase were carried out with the tablet-based program. The participants continued to independently manage leisure and communication events. The participants' performance remained stable during the follow-up checks (not reported in the figure), which were carried out with the tablet-based program.

4. Discussion

The results suggest that the two technology-aided programs were effective in supporting participants with extensive neuro-motor impairment and lack of speech to independently access leisure events and start communication interactions. These findings (a) confirm previous data with participants showing similar types of disabilities (Stasolla, Caffò, Damiani, Perilli, Di Leone, & Albano, 2015; D'Amico *et al.*, 2019; Lancioni *et al.*, 2019; 2020; 2021; Stasolla *et al.*, 2022) and also (b) provide evidence about new technology-aided intervention strategies that might be satisfactorily applied in rehabilitation contexts. In light of the findings, a few considerations may be put forward.

First, the programs used in this study may be seen as complementary to those reported by D'Amico and colleagues (2019) and Lancioni and colleagues (2019; 2020). Some of those programs were apparently broader in scope than the present ones. In fact, those programs included a wider range of leisure options and a wider range of people that the participants could reach for communication purposes. Notwithstanding this apparent difference, it is noteworthy that the programs used in this study could be easily extended in terms of leisure and communication options whenever participants with more extensive interests and abilities were involved.

Second, the participants were equally successful in using the two programs and their performance seemed to be consistent across programs. In spite of this similarity in terms of impact, the two programs were perceived as different in terms of preference. Indeed, when the participants were allowed to choose the program they wanted to use for the session (i.e., during the C^1 phase), the choice/preference was for the program based on the use of the tablet. Informal reports suggest that the participants seemed to prefer the tablet-based program because this did not require them to wear any prosthetic element. With regard to this point, one consideration may be relevant. That is, using the Talking Hands technology in a relatively restricted way (i.e., for a small number of position discriminations), as it was done in this study, would not necessarily require the participants to wear the finger sensors. A less invasive version of the Talking Hands technology (i.e., without finger sensors) could make the program based on such technology more friendly and thus more easily acceptable to the users.

Third, in addition to the participants' preference, another issue that at present might make the tablet-based program favorite is the fact that it relies on fairly inexpensive and easily accessible commercial technology (Federici

& Scherer, 2017; Boot, Owuor, Dinsmore, & MacLachlan, 2018; da Silva, Bulle Oliveira, Pinheiro Bezerra, Pedrozo Campos Antunes, Guerrero Daboin, Raimundo *et al.*, 2018; Borg, 2019). Indeed, the tablet may be acquired for probably less than US$300 and the MacroDroid application has a negligible cost. While the accessibility and cost aspects and the participants' preference are important variables that make the tablet-based program positive and advantageous, it must be noted that such program is not a ready-made tool that rehabilitation and care staff can acquire and just use without any preparatory work. In fact, the tablet needs to be programmed through the MacroDroid so as to ensure that its functioning is in line with the aims of the study and the response repertoire of the participant (i.e., the form of response that is considered more suitable for the participant).

4.1. Limitations and future research

The study presents three main limitations, that is, a small number of participants, a lack of assessment of whether the participants enjoyed the sessions, and an absence of a social validation of the programs. The fact that only two participants were involved in the study asks for future research to extend the evaluation of the programs with new participants to determine the programs' overall effectiveness and adaptability to users with different needs and response skills (Kazdin, 2011; Freese & Peterson, 2017). Future research may also assess whether the participants enjoy the sessions. This assessment may be carried out by interviewing the participants and by possibly observing their behaviors (e.g., smiles, body movements, and vocalizations) during the sessions (Flores, Moret-Tatay, Gutierrez-Bermejo, Vasquez, & Jenaro, 2021; Stasolla *et al.*, 2022). Social validations of the programs could be carried out with staff personnel (a) watching videos of the two programs and (b) rating the programs in terms of efficacy, friendliness, and applicability (Plackett, Thomas, & Thomas, 2017; Worthen & Luiselli, 2019).

In conclusion, the study has provided some new evidence as to the possibility of helping people with extensive neuro-motor impairment and lack of speech engage in leisure and basic communication. New studies are however needed to extend the assessment of the programs (in the present or updated forms) with additional participants and thus determine the overall reliability and applicability of those programs.

References

Barlow, D. H., Nock, M., & Hersen, M. (2009). *Single-case experimental designs* (3rd ed.). New York: Allyn & Bacon.

Boot, F. H., Owuor, J., Dinsmore, J., & MacLachlan, M. (2018). Access to assistive technology for people with intellectual disabilities: A systematic review to identify barriers and facilitators. *Journal of Intellectual Disability Research, 62* (10), 900-921.

Borg, J. (2019). Commentary on selection of assistive technology in a context with limited resources. *Disability and Rehabilitation: Assistive Technology, 14* (8), 753-754.

Brown, I., Hatton, C., & Emerson, E. (2013). Quality of life indicators for individuals with intellectual disabilities: Extending current practice. *Intellectual and Developmental Disabilities, 51* (5), 316-332.

Brunner, M., Hemsley, B., Togher, L., & Palmer, S. (2017). Technology and its role in rehabilitation for people with cognitive-communication disability following a traumatic brain injury (TBI). *Brain Injury, 31* (8), 1028-1043.

Carvalho, R., Azevedo, E., Marques, P., Dias, N., & Cerqueira, J. J. (2018). Physiotherapy based on problem-solving in upper limb function and neuroplasticity in chronic stroke patients: A case series. *Journal of Evaluation in Clinical Practice, 24* (3), 552-560.

D'Amico, F., Lancioni, G. E., Buonocunto, F., Ricci, C., & Fiore, P. (2019). Technology-aided leisure and communication support in extensive neuro-motor and communication impairments. *European Journal of Physical and Rehabilitation Medicine, 55* (5), 682-686.

Dang, B., Chen, W., He, W., & Chen, G. (2017). Rehabilitation treatment and progress of traumatic brain injury dysfunction. *Neural Plasticity*: 1582182. doi.org/10.1155/2017/1582182.

da Silva, A. P., Bulle Oliveira, A. S., Pinheiro Bezerra, I. M., Pedrozo Campos Antunes, T., Guerrero Daboin, B. E., Raimundo, R. D., Dos Santos, V. R., & de Abreu, L. C. (2018). Low cost assistive technology to support educational activities for adolescents with cerebral palsy. *Disability and Rehabilitation: Assistive Technology, 13* (7), 676-682.

Estraneo, A., Moretta, P., Loreto, V., Santoro, L., & Trojano, L. (2014). Clinical and neuropsychological long-term outcomes after late recovery of responsiveness: A case series. *Archives of Physical Medicine and Rehabilitation, 95* (4), 711-716.

Fager, S. K., Fried-Oken, M., Jakobs, T., & Beukelman, D. R. (2019). New and emerging access technologies for adults with complex communication needs and severe motor impairments: State of the science. *Augmentative and Alternative Communication, 35* (1), 13-25.

Federici, S., & Scherer, M. (2017). *Assistive Technology Assessment Handbook* (2nd ed.). Boca Raton, FL: CRC Press.

Ferro, J. M., & Santos, A. C. (2019). Emotions after stroke: A narrative review. *International Journal of Stroke, 15* (3), 256-267.

Flores, N., Moret-Tatay, C., Gutierrez-Bermejo, B., Vasquez, A., & Jenaro, C. (2021). Assessment of occupational health and job satisfaction in workers with intellectual disability: A job demands-resources perspective. *International Journal of Environmental Research and Public Health, 18* (4): 2072. doi.org/10.3390/ijerph18042072.

Freese, J., & Peterson, D. (2017). Replication in social science. *Annual Review of Sociology, 43* (1), 147-165.

Hagen, C. (1998). *Levels of cognitive functioning scale. Rehabilitation of the head injured adult: Comprehensive physical management* (3rd ed.). Downey (CA): Professional Staff Association of the Rancho Los Amigos Hospital, Inc.

Hassett, L., Wong, S., Sheaves, E., Daher, M., Grady, A., Egan, C., Seeto, C., Hosking, T., & Moseley, A. (2018). Time use and physical activity in a specialised brain injury rehabilitation unit: An observational study. *Brain Injury, 32* (7), 850-857.

Irani, Z., Gunasekaran, A., & Dwivedi, Y. K. (2010). Radio frequency identification (RFID): Research trends and framework. *International Journal of Production Research, 48* (9), 2485-2511.

Kapoor, A., Lanctot, K. L., Bayley, M., Hermann, N., Murray, B. J., & Swartz, R. H. (2019). Screening for post-stroke depression and cognitive impairment at baseline predicts long-term patient-centered outcomes after stroke. *Journal of Geriatric Psychiatry and Neurology, 32* (1), 40-48.

Kazdin, A. E. (2011). *Single-case research designs: Methods for clinical and applied settings (2nd ed.)*. London: Oxford University Press.

Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Sigafoos, J., D'Amico, F., Vincenti, A., Buonocunto, F., Susco, V., Lanzilotti, C., & Navarro, J. (2019). Basic smartphone-aided communication and leisure for people with extensive neuro-motor impairment and absence of speech. *NeuroRehabilitation, 45* (3), 311-322.

Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Sigafoos, J., D'Amico, F., Buonocunto, F., Lanzilotti, C., Alberti, G., & Navarro, J. (2020). Mainstream technology to support basic communication and leisure in people with neurological disorders, motor impairment and lack of speech. *Brain Injury, 34* (7), 921-927.

Lancioni, G. E., O'Reilly, M. F., Sigafoos, J., D'Amico, F., Spica, A., Buonocunto, F., Del Gaudio, V., Lanzilotti, C., & Navarro, J. (2021). Mainstream technology as basic support for individuals with extensive neuro-motor impairments and absence of verbal skills. *Advances in Nurodevelopmental Disorders, 5* (1), 85-92.

Ledford, J. R., & Gast, D. L. (2014). Measuring procedural fidelity in behavioural research. *Neuropsychological Rehabilitation, 24* (3-4), 332-348.

Palmer, R., Witts, H., & Chater, T. (2018). What speech and language therapy do community dwelling stroke survivors with aphasia receive in the UK? *PLoS One, 13* (7): e0200096. doi.org/10. 1371/journal.pone.0200096.

Palmer, R., Dimairo, M., Cooper, C., Enderby, P., Brady, M., Bowen, A., Latimer, N., Julious, S., Cross, E., Alshreef, A., Harrison, M., Bradley, E., Witts, H., & Chater, T. (2019). Self-managed, computerised speech and language therapy for patients with chronic aphasia post-stroke compared with usual care or attention control (big CACTUS): A multicentre, single-blinded, randomised controlled trial. *The Lancet. Neurology, 18* (9), 821-833.

Pezzuoli, F., Tafaro, D., Pane, M., Corona, D., & Corradini, M. L. (2020). Development of a new sign language translation system for people with autism spectrum disorder. *Advances in Neurodevelopmental Disorders, 4* (4), 439-446.

Plackett, R., Thomas, S., & Thomas, S. (2017). Professionals' views on the use of smartphone technology to support children and adolescents with memory impairment due to acquired brain injury. *Disability and Rehabilitation: Assistive Technology, 12* (3), 236-243.

Stasolla, F., Caffò, A. O., Damiani, R., Perilli, V., Di Leone, A., & Albano, V. (2015). Assistive technology-based programs to promote communication and leisure activities by three children emerged from a minimally conscious state. *Cognitive Processing, 16* (1), 69-78.

Stasolla, F., Caffò, A. O., Bottiroli, S., & Ciarmoli, D. (2022). An assistive technology program for enabling five adolescents emerging from a minimally conscious state to engage in communication, occupation, and leisure opportunities. *Developmental Neurorehabilitation, 25* (3), 193-204.

Teng, Z., Dong, Y., Zhang, D., An, J., & Lv, P. (2017). Cerebral small vessel disease and post-stroke cognitive impairment. *International Journal of Neuroscience, 127,* 824-830.

Unglik, J., Bungener, C., Delgadillo, D., Salachas, F., Pradat, P. F., Bruneteau, G., Lenglet, T., Le Forestier, N., Couratier, P., Vacher, Y., & Lacomblez, L. (2018). Emotional feeling in patients suffering from amyotrophic lateral sclerosis. *Geriatrie et Psychologie Neuropsychiatrie du Viellissement, 16* (4), 414-422.

Wilson, T., Martins, O., Efrosman, M., DiSabatino, V., Benbrahim, B. M., & Patterson, K. K. (2019). Physiotherapy practice patterns in gait rehabilitation for adults with acquired brain injury. *Brain Injury, 33* (3), 333-348.

Worthen, D., & Luiselli, J. K. (2019). Comparative effects and social validation of support strategies to promote mindfulness practices among high school students. *Child & Family Behavior Therapy, 41* (4), 221-236.